The status of sea cucumbers at Pohnpei Island and Ant Atoll, Federated States of Micronesia, in 2017

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Summary

Sea cucumbers have long been harvested in Pohnpei, Federated States of Micronesia. These resources have been targeted for subsistence use and commercial export to Asian markets. However, since 1991, a moratorium on commercial exploitation of sea cucumbers for the export market has been implemented to remedy the significant drop in stocks following, largely, unregulated commercial harvests after World War II. While subsistence fishing for sea cucumbers has always been legal (only valid for a handful of species that are excluded from commercial export: curryfish, sandfish, brown curryfish, dragonfish, red and grey impatient sea cucumbers), the moratorium was officially only interrupted once, in 2016, due to increasing pressure from a local exporter to capitalise on the sea cucumber resource. However, the lack of scientific evidence of recovered stocks and lack of a management plan was highly criticised and led to the re-closure of the fishery until these issues were addressed. This report presents information regarding the status of sea cucumber stocks in 2017, and examines the capacity of the resource to undergo commercial harvesting.

Information on the 2016 harvest was provided by Pohnpei State's Office of Fisheries and Aquaculture to examine the catches from this fishery and the income earned from exporting sea cucumbers to China. While the fishery was initially planned to be open for six days to allow fishers to collect up to 67 metric tons (mt) of sea cucumber (wet weight), the court ordered the fishery to be closed after the first day of harvest, during which 13,511 individual sea cucumbers were caught, corresponding to 15.8 mt (wet weight, or 0.9 mt of dried product). Catch composition was dominated by – surf redfish, tigerfish and black teatfish – with these three species accounting for 98% of the overall estimated income of USD 16,854 to the fishing communities. Estimated local export sales and Chinese store sales were, respectively, three (USD 35,898) and seven (USD 123,631) times higher than the overall income to fishers.

An in-water survey was conducted around Pohnpei Island and in the lagoon of Ant Atoll in May 2017 to assess the status of sea cucumber stocks. In total, 209 stations, covering approximately 25 ha, were surveyed during the 2017 assessment. Four Pacific Community (SPC) standardised methods (i.e. manta tow, reef benthos transect, soft benthos transect and reef front transect) were used both in areas open to fishing and within marine protected areas (MPAs).

This in-water assessment revealed Pohnpei's sea cucumber stocks to be in a poor state. Sea cucumber assemblages were largely dominated by lollyfish (*Holothuria atra*) and to a lesser extent pinkfish (*H. edulis*), snakefish (*H. coluber*), greenfish (*Stichopus chloronotus*), tiger fish (*Bohadschia argus*) and surf redfish (*Actinopyga mauritiana*). Species densities were below regional reference densities in most cases, with the exception of surf redfish on the reef crest, and pinkfish on the coastal fringe and on the reef flat for open areas for which harvestable stocks were calculated. The density of high-value species, such as white teatfish and sandfish, were critically low. Results from this survey and another recent survey (2016–2017 College of Micronesia survey) have shown declining mean densities of several species (black teatfish, tigerfish, chalkfish and surf redfish) since a 2013 assessment. Length-frequency data of four commonly observed species (lollyfish, pinkfish, surf redfish and greenfish), and comparisons of mean live length against regional common lengths for most species, revealed that most sea cucumbers measured in 2017 consisted of small- to medium-sized individuals. The effectiveness of MPAs in conserving sea cucumber populations in Pohnpei was not demonstrated from this survey.

At the end of the in-water assessment on 26 May 2017, a stakeholder workshop was held to discuss the results of the 2017 assessment and the management arrangements for the fishery. After presentations on preliminary results of the 2017 assessment and the 2016 harvest, participants divided into small working groups to discuss management issues and possible ways to sustainably manage this fishery. The key issues raised during the meeting regarding the 2016 harvest included: 1) lack of transparency in quota calculations and targeted sea cucumber species; 2) excessive numbers of fishing permits awarded; 3) lack of monitoring and enforcement; 4) irregularities linked to the registration process; 5) absence of a management plan; and 6) lack of stakeholder consultations in the development of management strategies.

Results of the 2017 assessment tend to suggest that sea cucumber stocks have not recovered from a long history of harvesting prior to the 1991 moratorium, and may have been impacted by others factors such as the 2016 harvest, the subsistence harvest, a disruption to the ecosystem, and detrimental fishing practices. A preliminary cost–benefit analysis, based on calculated harvestable stocks of pinkfish and surf redfish, indicates that there would be little benefit from proceeding with such a small harvest (representing slightly over 10 mt of wet weight for each species, which corresponds to 1 mt of processed beche-de-mer product for the two species combined), and that it may even encourage illegal fishing to generate more profits. Maintaining the moratorium on commercial harvesting is, therefore, recommended. In case the Pohnpei State Government decides to proceed with a commercial harvest of sea cucumbers, a number of management suggestions are made to implement a sea cucumber management plan prior to a harvest. The implementation of a management plan for the local fishery is also recommended in order to address the impact on species targeted for subsistence.

Introduction

The Federated States of Micronesia (FSM) consists of more than 600 islands and atolls. Situated in the western Pacific, these islands lie between the equator and 14°N latitude and between 135°E and 166°E longitude. FSM consists of four states: Pohnpei, Kosrae, Chuuk and Yap. FSM's 200-mile exclusive economic zone covers approximately 3 million km^2 (1.3 million mi^2), while the total land area amounts to approximately 700 km^2 (270 mi^2) (Bell et al. 2011).

Pohnpei State occupies 133.4 mi^2 of land, of which Pohnpei Island constitutes 130 mi^2. Pohnpei State consists of eight atolls (Mwoakiloa, Ngatik, Nukuoro, Oroluk, Pingelap, Kapingamarangi, Sapwuafik and Ant) and the large island of Pohnpei (typically termed Pohnpei Island or Pohnpei proper). The eight atolls form six municipalities: Kapingamarangi, Mokil, Ngatik, Nukuoro, Oroluk and Pingelap. Pohnpei Island is also divided into six municipalities: Kitti, Kolonia, Madolenihmw, Nett, Sokehs and Uh. At the 2010 census, approximately 35% of FSM's population lived in Pohnpei (36,196 out of 102,843 people) (FSM Statistics 2010). Pohnpei Island is considered to be one of the wettest places on earth, with annual rainfall exceeding 7600 millimeters (300 inches) per year in certain mountains of the interior. Pohnpei Island has a narrow littoral zone where most people live), mangrove fringes around most of the island, a large lagoon and an extensive barrier reef.

Fishing is a key source of sustenance and livelihood for the people of Pohnpei. Coastal fisheries resources are largely 'open access', and include a variety of finfish and invertebrates, such as lobsters, mud crabs, giant clams and sea cucumbers.

Sea cucumber resources

Sea cucumbers belong to the phylum Echinodermata and are closely related to starfishes and sea urchins. More than 1600 species (Appeltans et al. 2012) are recognised globally in a range of habitats, from intertidal waters to deep oceans, and extending from the tropics to the polar regions. More than 70 species have been recorded in Micronesia (Kerr et al. 2007, 2008, 2014; Kerr 2013; Michonneau et al. 2013), with many of these harvested for commercial purposes, and specifically for the beche-de-mer trade (Pakoa et al. 2014). Most species of sea cucumbers found in the Pacific Islands region reproduce sexually and have separate sexes. Elsewhere, some species are protandric hermaphrodites, changing from males to females in the course of their life history (Sewell 1994). A few species found in the Pacific, including *Holothuria atra, H. edulis, H. leucospilota, Stichopus chloronotus, S. horrens* and *Bohadschia marmorata*, are known to reproduce asexually (Harriot 1980; Conand et al. 1997; Laxminarayana 2006). Sea cucumbers in the Pacific Islands region usually spawn during summer, although some species (e.g. *Holothuria whitmaei*) spawn in the cooler months of the year (Shiell and Uthicke 2006).

The average life span of sea cucumbers is between 5 and 10 years although some species may live for up to 15 years (Rahman 2014; Plagányi et al. 2015). Most species attain sexual maturity at two to six years (Rahman 2014). The majority of tropical sea cucumbers are deposit-feeders, processing large volumes of benthic sediments from which they absorb and digest organic bacterial, fungal and detrital matter, and in doing so, play a key role in turning over sediment and recycling nutrients (Kitano et al. 2003; MacTavish et al. 2012). Many species also play a key role in bioturbation and oxygenation of sediments through burrowing (MacTavish et al. 2012).

Sea cucumber fisheries in Pohnpei

Of the 1600 or more species of sea cucumber described globally, 28 species have been recorded in Pohnpei (Table 1). Many of these species represent important commodities for both subsistence fisheries for local consumption and commercial fisheries for export in the beche-de-mer trade.

Table 1. Sea cucumber species reported from Pohnpei State waters (SPC unpublished data).

Common name	Scientific name	Local name
Black teatfish	*Holothuria whitmaei*	
Brown curryfish	*Stichopus vastus**	Werer
Brown sandfish	*Bohadschia vitiensis*[1]	Moatop
Chalkfish	*Bohadschia similis*	Kemed
Brown sandfish	*Bohadschia marmorata*	
Curryfish	*Stichopus herrmanni**	Kapwelo
Deepwater blackfish	*Actinopyga palauensis*	
Deepwater redfish	*Actinopyga echinites*	
Dragonfish	*Stichopus horrens**	Koid
Elephant trunkfish	*Holothuria fuscopunctata*	
Flowerfish	*Holothuria graeffei*	
Greenfish	*Stichopus chloronotus*	Sapwarong
Grey impatient sea cucumber	*Holothuria arenicola**	
Hairy blackfish	*Actinopyga miliaris*	
Hairy greyfish	*Actinopyga* sp.	
Red impatient sea cucumber	*Holothuria impatiens**	
Leopardfish	*Bohadschia argus*	Penpen
Lollyfish	*Holothuria atra*	Katop
Pinkfish	*Holothuria edulis*	Katop weitahta
Prickly redfish	*Thelenota ananas*	
Red snakefish	*Holothuria roseomaculata*[2]	
Sandfish	*Holothuria scabra**	Loangon
Snakefish	*Holothuria coluber*	
Spotted-worm sea cucumber	*Synapta maculata*	
Stonefish	*Actinopyga lecanora*	
Surf redfish	*Actinopyga mauritiana*	
Tiger tail sea cucumber	*Holothuria hilla*	
White teatfish	*Holothuria fuscogilva*	
White threadfish	*Holothuria leucospilota*	

* Species of importance for the local market

Subsistence fisheries

Sea cucumbers are an important resource to the people of Pohnpei and other FSM states for food security and income through sales at local markets. Curryfish (*Stichopus herrmanni*), brown curryfish (*S. vastus*), dragonfish (*S. horrens*), sandfish (*Holothuria scabra*), grey impatient sea cucumber (*H. arenicola*) and red impatient sea cucumber (*H. impatiens*) are consumed locally in Pohnpei. These species can be gleaned from intertidal and shallow subtidal areas of the fringing reefs around Pohnpei, making them an important source of livelihood for fishers without a boat, particularly women (Lambeth 2000). Lollyfish are also used for their medicinal properties and their ability to stun or kill fish and invertebrates that are trapped in reef pools or hide in reef crevices. The body wall of lollyfish is rubbed on rocks or on other hard substrates to produce a reddish-pink dye that is toxic to some marine organisms. Lollyfish are also harvested for use as fertiliser in gardens or farms in coastal communities around Pohnpei (Ryan Ladore, Office of Fisheries and Aquaculture, Pohnpei State, pers. comm., May 2017). Under state law, exports of wild-caught individuals of the six sea cucumber species important to local consumption (i.e. curryfish, sandfish, brown curryfish, dragonfish, grey impatient sea cucumber, red impatient sea cucumber) are prohibited (Itaia Fred, Acting Administrator, Office of Fisheries and Aquaculture, Pohnpei State Government, pers. comm., May 2017).

[1] Species recognised to be a synonym of *Bohadschia vitiensis* with a slightly different colour pattern (Kim et al. 2013) but kept as *B. similis* in this report.
[2] Species closely related to *Holothuria flavomaculata* (Kerr 2013).

Commercial (export) fisheries

Sea cucumbers have long been commercially exploited in Pohnpei, and the FSM in general. According to reports, sea cucumbers were harvested extensively in Micronesia in the late 1800s, and during the Japanese mandate in the first half of the 1900s (Smith 1992). During the Japanese administration prior to World War II, an estimated one million pounds of beche-de-mer were exported annually from Chuuk (Beardsley 1971). In 1941, approximately 1,414,515 pounds (wet weight) of sea cucumbers were exported from FSM, with 201,784 pounds (14%) of this from Pohnpei (Smith 1992). Sea cucumber populations were also heavily impacted during World War II, when large numbers of Japanese soldiers were left without food and subsequently harvested significant amounts of sea cucumbers to supplement their diets (Kinch et al. 2008).

Few data are available on sea cucumber harvests in Pohnpei from World War II until the late 20th century. In the early 1990s, the Pohnpei State Government realised that the largely unregulated harvesting of sea cucumbers over two decades had depleted stocks, and in 1991 the senate declared a moratorium on the export of sea cucumbers – 'a prohibition of trade for sea cucumber and trochus' – until a management framework had been developed and endorsed through state law. The policy stands to this day, and a formal sea cucumber management framework has yet to be established. In many ways, this history follows that observed across the Pacific: since the 1980s, there has been a marked increase in demand from Asian markets for beche-de-mer. Coupled with unregulated harvests and a lack of effective management, this has led to significant overfishing of stocks and subsequent population declines and closures of sea cucumber fisheries in numerous Pacific Island countries and territories (Pakoa and Bertram 2013).

In recent years, there has been a renewed interest in re-opening the sea cucumber fishery in Pohnpei. In 2012, the Director of the Office of Fisheries and Aquaculture (OFA) proposed to the senate that new sea cucumber regulation be enacted prior to re-opening the fishery. A sea cucumber bill was developed in 2012, but OFA further proposed that the bill be put on hold until further assessment of sea cucumber stocks and a management framework for the fishery be finalised.

In 2013, an assessment of sea cucumber resources in Pohnpei proper was conducted by OFA, FSM Department of Resources and Development (FSM DRD), the Conservation Society of Pohnpei (CSP) and the Pacific Community (SPC, then known as the Secretariat of the Pacific Community). While no report from this survey was finalised, data stored at SPC (SPC, unpublished data) on behalf of OFA suggest that a limited number of species were found at relatively healthy population densities (i.e. densities over regional reference densities prescribed in Pakoa et al. 2014), and could, thus, only sustain a small harvest. In February 2015, regulations involving sea cucumbers were modified in the state legislature (S.L.NO 8L-58-14) in favour of the commercialisation of the sea cucumber fishery. And, in the spring of 2016, an export company was awarded a licence to export up to 67,500 kg wet weight of sea cucumbers (excluding species consumed locally) from Pohnpei Island's territorial waters (Bourgoin and Pelep 2017). During the 2016 harvest a number of rules were established to manage the fishery, including:

- issuing only a single export licence;
- a requirement that all sea cucumber fishers had to be registered with OFA;
- excluding the harvest of subsistence species;
- limiting collection methods to collecting by hand by either gleaning or free-diving;
- limiting the number of harvest days for prescribed species;
- limiting the sites where sea cucumbers could be landed to specific monitoring points; and
- imposing a total quota and individual fisher species-specific quotas.

Harvests were planned over a six-day-fishing period, with harvests of different species limited to specific days (Table 2). Information regarding the harvest in 2016 is conflicting. According to Bourgoin and Pelep (2017), the fishery was open for two days. According to OFA, the fishery was open for a single day before a court-issued mandate to cease the harvest until such time that a formal management plan had been established.

Table 2. Proposed harvest days for sea cucumber species in the 2016 harvest.

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Surf redfish	Black teatfish	Golden sandfish	Prickly redfish	White teatfish	Deepwater blackfish
Chalkfish	Curryfish	Hairy fish[3]	Tigerfish	Deepwater redfish	Elephant trunkfish
Stonefish	Lollyfish	Red snakefish	Snakefish	Pinkfish	Greenfish

[3] Includes both hairy blackfish and hairy greyfish.

In 2016, a team from the University of Guam Marine Laboratory undertook a survey to estimate current sea cucumber population levels. It was concluded that commercial harvesting of sea cucumbers was not recommended because of the low numbers of both large- and small-bodied species (CSP 2016). Similarly, a team from the College of Micronesia (COM) surveyed sea cucumber resources in shallow (< 3 m in depth) lagoonal areas of Pohnpei, spanning from May 2016 to April 2017 (Bourgoin and Pelep 2017). The authors cautioned against allowing commercial harvests of sea cucumbers for export, due to the relatively low densities and small body sizes of observed individuals (Bourgoin and Pelep 2017).

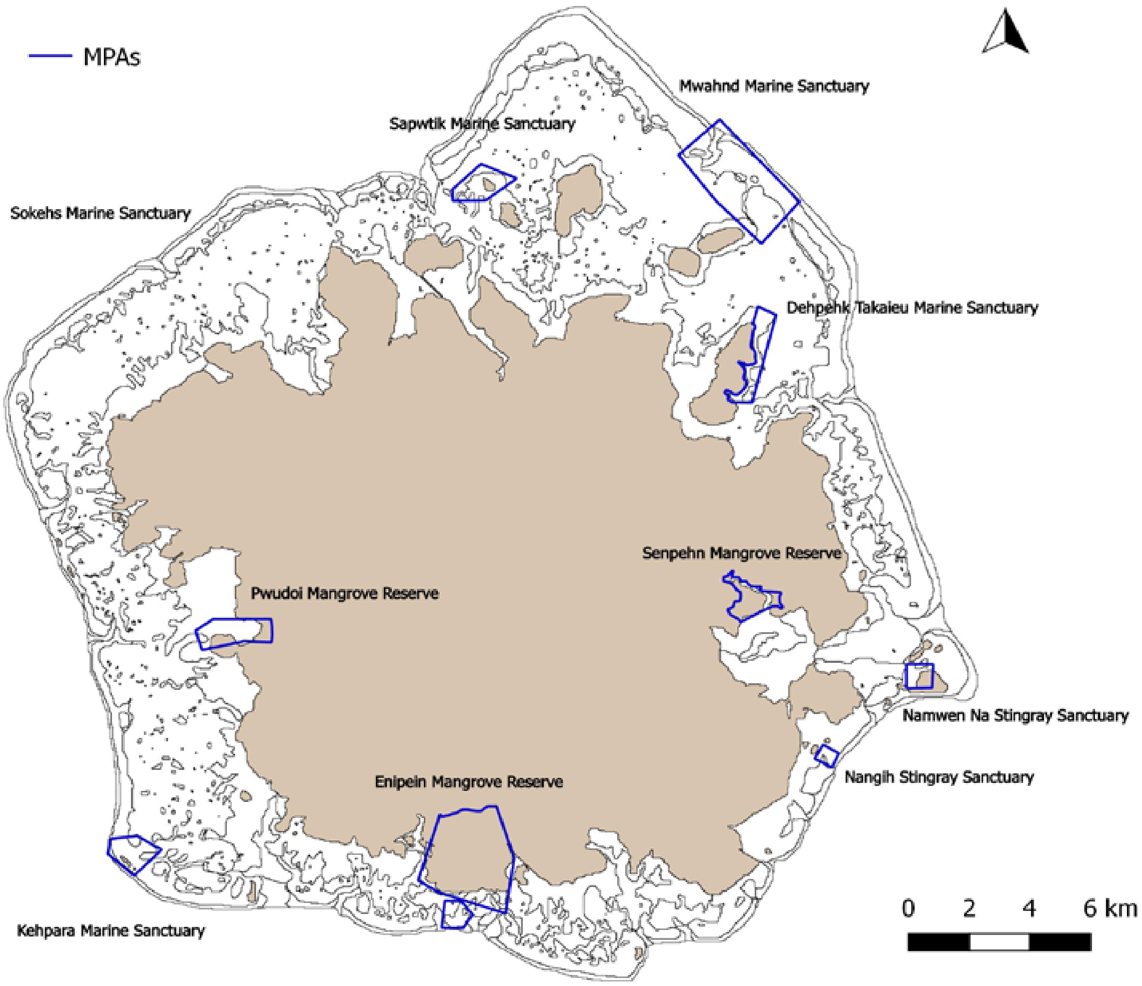


Figure 1. Marine protected areas (MPAs) in Pohnpei based on files available at the Pacific Community and from the Conservation Society of Pohnpei. This map does not include[4] Nanwap Marine Sanctuary located on the east coast (North of Namwen Na Stingray Sanctuary).

This report

In this report, we provide a re-assessment of the status of sea cucumber stocks in Pohnpei, based on in-water surveys conducted in May 2017, using methodologies and survey locations used in the 2013 survey. We also provide an assessment of stocks at neighbouring Ant Atoll. In addition, an estimation of total and harvestable stock sizes for species observed in relatively high densities is presented, along with information on the quantity of sea cucumbers harvested in 2016, prices paid to fishers and income generated, based on data held by OFA. Finally, options for management and monitoring are discussed.

[4] This sanctuary is not included due to unavailability of coordinates.

Methodology

2016 harvest

Data on the number of individual sea cucumbers harvested and prices paid to fishers (on an individual species basis) during the 2016 commercial harvest were collected by OFA. This information was examined graphically and used to calculate income to fishing communities. Numbers of harvested individuals were converted to wet weights using average weight of prescribed sea cucumber lengths (Pakoa et al. 2014). Wet weights were converted to dry weights using conversion ratios provided in Pakoa et al. (2014). A comparison of the monetary value of sea cucumbers from local fisher incomes through the commercial market chain were performed using information provided in Carleton et al (2013) for regional export values, and Purcell (2014a) for average selling prices in Chinese stores.

In-water resource assessments

In-water surveys were conducted at Pohnpei Island and Ant Atoll from 2 to 25 May 2017 to provide an indication of the current status of sea cucumber stocks. The survey used standardised SPC methodologies (see Pakoa et al. 2014), and generally matched the methodology and locations of the 2013 survey (SPC unpublished data), where appropriate. In addition, survey stations were established in both areas of open access to fishing ('open' sites) and marine protected areas (MPAs) to determine whether MPAs affected sea cucumber stocks. The survey involved both broad- and fine-scale assessment techniques that covered different habitats and provided different degrees of precision and information.

Manta tows

Manta tows were used to provide a broad-scale assessment of sea cucumber stocks over relatively large areas within a short time frame. In this assessment, a snorkeler was towed behind a boat on a manta board at an average speed of approximately 4 km/hour. A single manta tow station consisted of six 300 m x 2 m replicate transects (Figure 2, Figure 3). The length of each tow replicate was calibrated using the odometer function within the trip computer option of a Garmin 64s Map GPS. The start and end GPS positions of each replicate were recorded to an accuracy of < 5 m. All large, sedentary invertebrates observed within each transect were identified to the species level and enumerated.

Reef benthos transects and soft benthos transects

Reef benthos transects and soft benthos transects were conducted to provide information on presence, abundance, density and length of invertebrate species living on coral reef and soft-bottom habitats at fine spatial scales. Each station consisted of six parallel 40 m x 1 m replicate transects (Figure 2, Figure 3). Stations were surveyed by two snorkelers swimming parallel to one another and who identified, enumerated and measured all macro-invertebrate species encountered.

Reef front transects

Reef front transects were conducted to provide information on presence, abundance, densityand size (length) of specific invertebrate species on the reef crest, and carried out at fine spatial scales. This methodology was adapted from the mother of pearl transect approach (see Pakoa et al. 2014). Each station consisted of six 40 m x 1 m replicate transects. Stations were surveyed by two surveyors who snorkelled or walked (depending on the water depth) parallel to one another along the reef crest, along with a navigator who determined the length of each transect using a GPS (Figure 2, Figure 3).

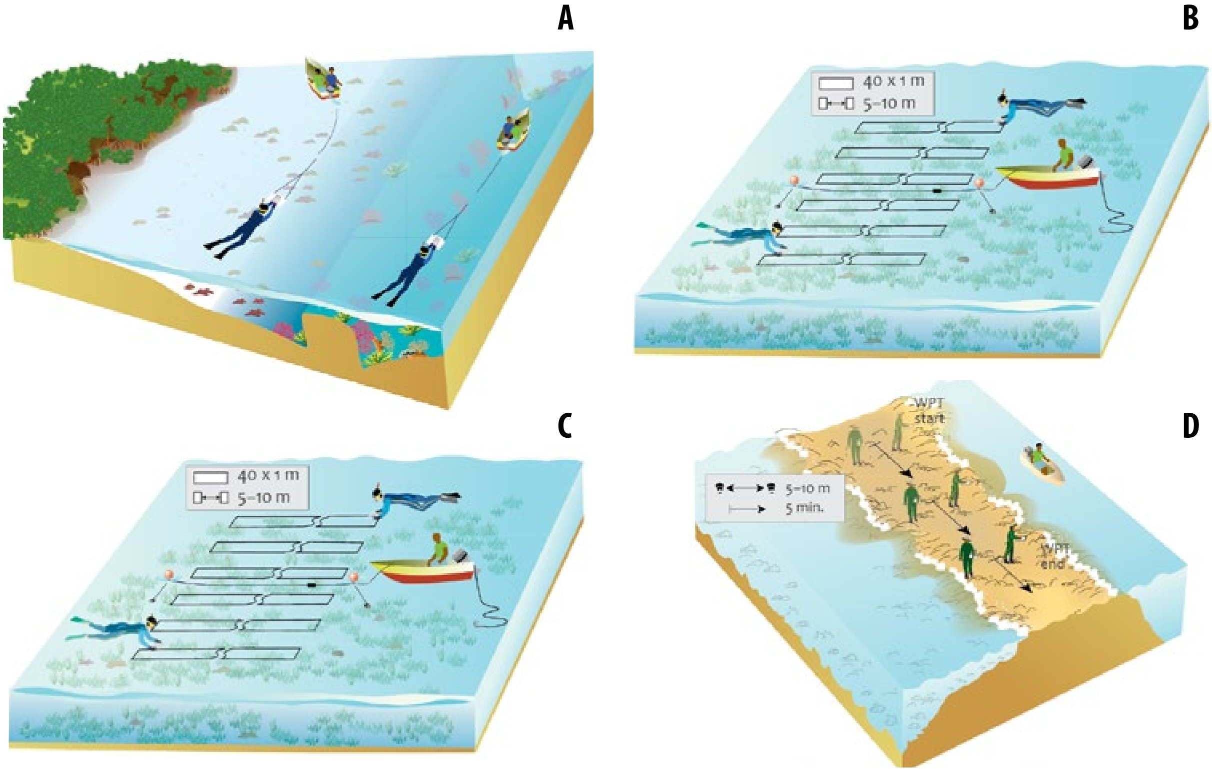


Figure 2. Diagrammatic representation of the four invertebrate survey methods used during in-water assessments in Pohnpei (adapted from Pakoa et al. 2014). A: manta tow; B: reef benthos transect; C: soft benthos transect; D: reef front transect.

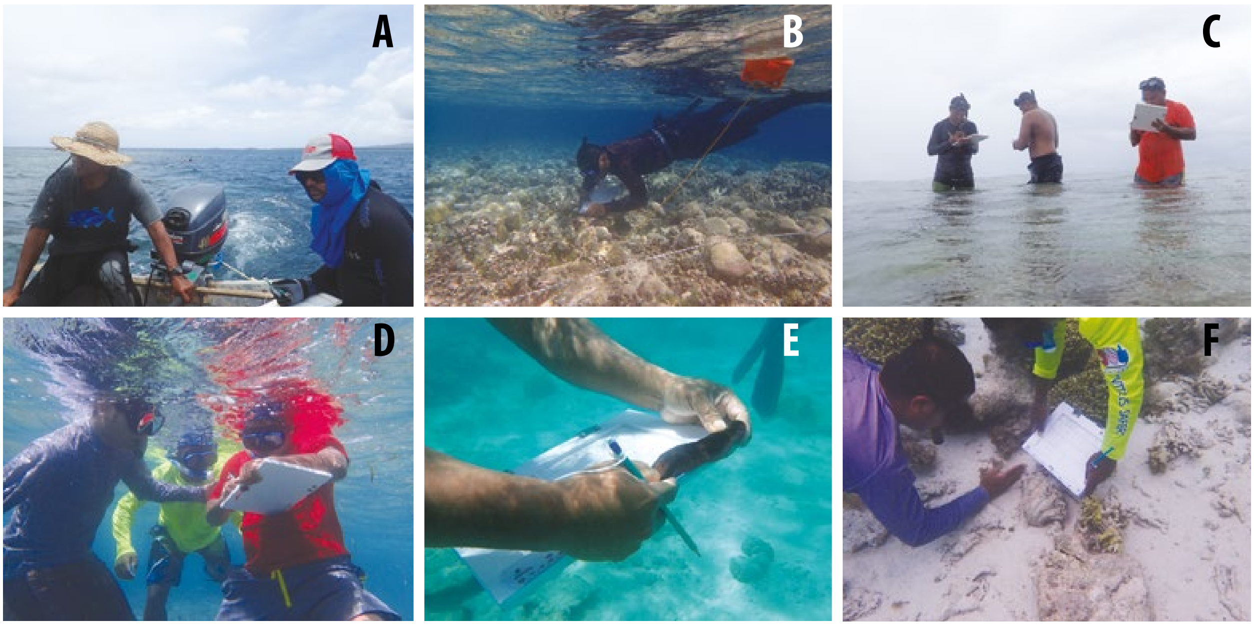


Figure 3. Field activities: A) manta tow; B) reef benthos transect; C) reef front transect; D) habitat recording; E and F) measuring sea cucumber and other macroinvertebrates.

Data analysis and reporting

In-water assessment data were entered into and analysed using SPC's Reef Fisheries Integrated Database.

In this report, assessments of the status of sea cucumber resources have been based on fishery status indicators described in Friedman et al. (2008) and Pakoa et al. (2014), which include:

- species richness (the number of species observed at each location, Pohnpei and Ant);
- relative abundance (how abundant a species is relative to other species);
- cumulative density (the sum of all sea cucumbers observed at stations, irrespective of species);
- mean density of individual species per station (individuals/ha ± standard error, SE);
- mean length (±SE);
- length frequency of key species; and
- standing stocks and quotas for species of high densities.

Where possible, data were compared between areas open to fishing ('open areas') and MPAs, and against data from the previous island-wide assessments in 2013 (SPC unpublished data) and 2016 (Bourgoin and Pelep 2017). Density data were additionally compared with reference densities for healthy sea cucumber stocks developed by SPC (Pakoa et al. 2014). These reference densities were calculated from the upper 25% of mean densities from survey work by SPC at 90 sites across the Pacific Islands region (Pakoa et al. 2014). The small areas of individual MPAs limited the number of stations that could be established in each MPA, and therefore, data for MPAs were generally pooled. Sea cucumber densities for reef benthos transect stations at Mwahnd and Kehpara MPAs, however, were examined individually for the 2017 survey and compared with nearby open stations, to assess the performance of these MPAs on protecting sea cucumber stocks. Data for sea cucumbers within the Kehpara Marine Sanctuary were compared against that of Moore et al. (2012) and Moore et al. (2015) in order to provide an assessment of the performance of this MPA over time.

Mean length (mm) was determined for each species in the 2017 assessment by pooling length information across all sites for Pohnpei Island. Mean lengths were compared against those obtained in previous surveys (SPC unpublished data; Bourgoin and Pelep 2017) and against regional common lengths (Purcell et al. 2008). Length frequencies of key indicator species (species with densities above reference densities for at least one site and one approach or commonly encountered species with high numbers of measurements) were evaluated with respect to maturity lengths or prescribed lengths. Length frequencies of lollyfish, pinkfish, surf redfish and greenfish were compared between open areas and MPAs.

Stocks estimates and quotas were calculated using the approach described below (adapted from Pakoa et al. 2014):

- Species with mean densities above regional reference densities for defined habitat type in open areas were selected. In this case, these species were pinkfish on the reef flat and the coastal fringe, and surf redfish on the crest (see Results).
- Quantum Geographic Information System software (QGIS 2.18 version, Quantum GIS Development Team 2017) was used to estimate the area of preferred habitat in the open areas (by deducting the area of MPAs from the overall area of habitat type) for each species observed in densities exceeding regional reference densities. A conservative approach was adopted, in which only 80% of the habitat area selected was used for stock estimates.
- A 95% confidence interval (CI) around mean densities was calculated for each species of each selected habitat using the formula (in Excel) "= confidence(alpha, standard_dev, size)" (where alpha = the significance level used to calculate the confidence level, for 95% CI alpha = 0.05, standard_dev = standard deviation of individual station density estimates, size = number of stations surveyed). Only minimum densities (i.e. 95% CI deducted from mean density) were considered to ensure estimates were conservative.
- For each species, stock estimates were calculated by multiplying the lower 95% CI around mean density by 80% of area of suitable habitat in open areas.
- A proportion of 20–30% of the adult population is commonly used for quota calculation in various types of fisheries. In this report, quotas were calculated using 30% of the adult stock population, which was assessed for different species using respective size frequency data. For surf redfish, adult stocks were taken as the percentage of the population equal to or over 230 mm, the estimate of maturity length (Purcell et al. 2012). For pinkfish, adult stocks were taken as the percentage of the population equal to or over the prescribed harvest length of 200 mm using length frequency data (cf. size frequency section). The number of individuals was converted into wet (live) weights and dry (processed) weights using conversion ratios of average length to average live weight and wet weight to dry weight (Pakoa et. 2014). Quotas presented in this report are calculated for a single harvest for the specified species. New quotas will need to be assessed prior to any other harvest based on updated stocks.

A cost–benefit analysis was performed to determine whether the proposed quotas would provide substantial benefits or, on the contrary, cost money and/or return little benefit. To design the cost–benefit model, estimates of overall purchases from fishers and total exports incomes were calculated. Overall purchases from fishers were calculated using an estimated selling price at the landing site (i.e. USD 0.1 per piece of pinkfish and USD 0.4 per piece of surf redfish) multiplied by adult stock for both pinkfish and surf redfish. The overall income from fishers equalled overall purchase from fishers, this value was then divided into different numbers of permits in order to provide income to individual fishers for different case scenarios. Total export incomes were calculated using export prices in the region from Carleton et al. 2013 (i.e. USD 6/kg of dried pinkfish and USD 39/kg of dried surf redfish). Other information regarding staff organisational planning was provided by OFA staff based on the 2016 single monitoring day to complete estimates.

Stakeholder workshop

A stakeholder workshop was held on 26 May 2017, bringing together stakeholders to discuss the current status of sea cucumber stocks, management strategies for the 2016 harvest, and potential ways forward for the fishery. The meeting was attended by 33 stakeholders, including representatives from the national and state fisheries offices, state government representatives, non-governmental organisations (including CSP and the Micronesia Conservation Trust), community leaders and regional agencies. The workshop was divided into two principle parts: 1) oral presentations and 2) working group discussions. Two presentations were provided to participants, with time for questions provided after the presentations. The first presentation focused on the preliminary results of the 2017 assessment. The second focused on the 2016 harvest and the management arrangements that were in place. Participants then broke up into smaller working groups to discuss the methodology and results of the 2017 assessment, the management issues regarding the 2016 harvest, and possible ways forward for the fishery.

Results

2016 harvest

Species composition

While only 3 species were open for harvest, 10 species were collected from 3 municipalities (Kitti, Kolonia and Sokehs) of Pohnpei proper during the 2016 harvest. Landings were dominated by three species: surf redfish (representing 48% of all sea cucumbers landed), tigerfish (32%) and black teatfish (16%) (Figure 4).

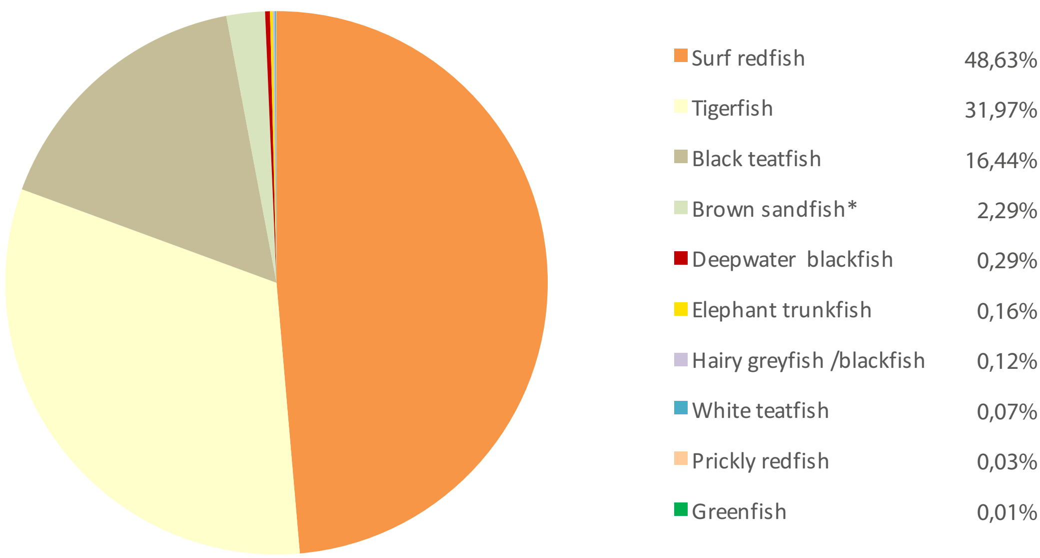


Figure 4. Sea cucumber species composition (% of total catch by number) during the 2016 harvest.
*Brown sandfish is an unconfirmed species[5].

[5] Unconfirmed species. Extrapolation from catch data, where golden sandfish was recorded but not included in the harvest plan, and not recorded from past surveys, while the relatively common brown sandfish was not recorded but proposed in the harvest plan.

Production

Pre-defined quotas were established by OFA prior to harvest, and the number of sea cucumber individuals collected were far below the proposed quotas although as many as 13,511 individuals were collected within one day (Figure 5). There were important differences in the number of sea cucumbers collected with regard to species and the number harvested ranged from 1 for greenfish to 6570 for surf redfish. In addition to surf redfish, only two species had over 500 individuals collected – black teatfish and tigerfish — totalling 2221 and 4319 individuals, respectively.

The total estimated wet weight of harvested individuals was 15.8 mt, roughly well divided between the three most collected species. Using a wet-to-dry conversion ratio (Table 3), the overall amount of beche-de-mer product exported was below 1 mt.

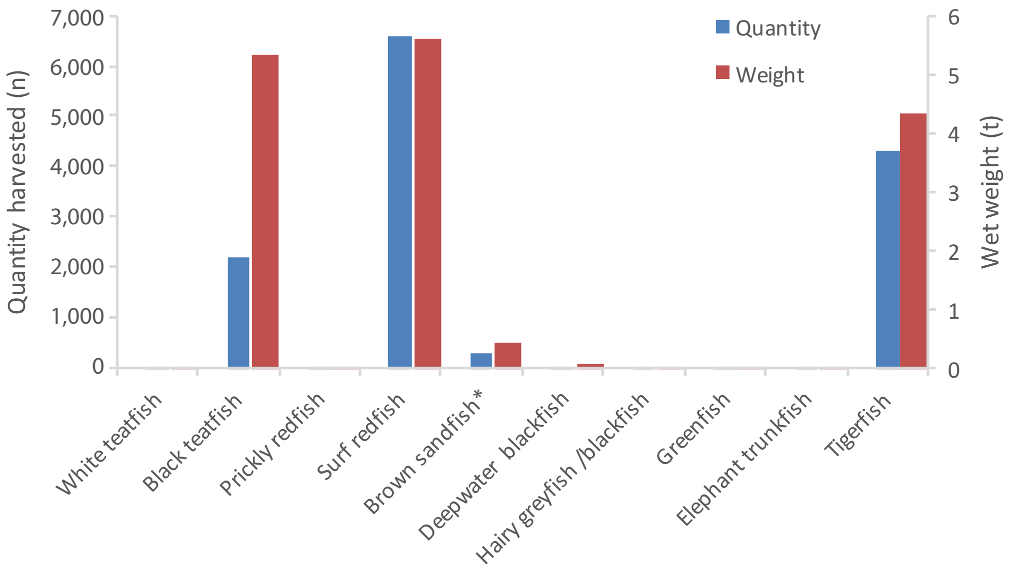


Figure 5. Number and corresponding estimated wet weights of sea cucumbers harvested during the 2016 harvest. *Brown sandfish is an unconfirmed species.

Prices paid to fishers and income to fishing communities

Prices per individual sea cucumber were set by OFA prior to the 2016 harvest. Three species fetched prices above USD 5 per live specimen: white teatfish, black teatfish and prickly redfish. The remaining species were bought at prices below USD 1 per live specimen (Table 3).

Table 3. Value group for export, wet weight to dry weight conversion ratio, and prices paid to fishers for all species harvested in 2016.

Species	Value	Conversion ratio	Prices paid to fishers (USD)
White teatfish	VH	0.08	$10.50
Black teatfish	H	0.07	$5.50
Prickly redfish	H	0.05	$6.50
Elephant trunkfish	M	0.1	$0.80
Surf redfish	L	0.055	$0.40
Brown sandfish*	L	0.05	$0.40
Deepwater blackfish	L	0.055	$0.40
Hairy greyfish/blackfish	L	0.05	$0.30
Greenfish	L	0.03	$0.40
Tigerfish	L	0.04	$0.40

*Brown sandfish is an unconfirmed species.

The overall income to fishers during the 2016 harvest was USD 16,854. The species that most contributed to this income (72%) was black teatfish, followed by surf redfish (16%) and tigerfish (10%) (Figure 6).

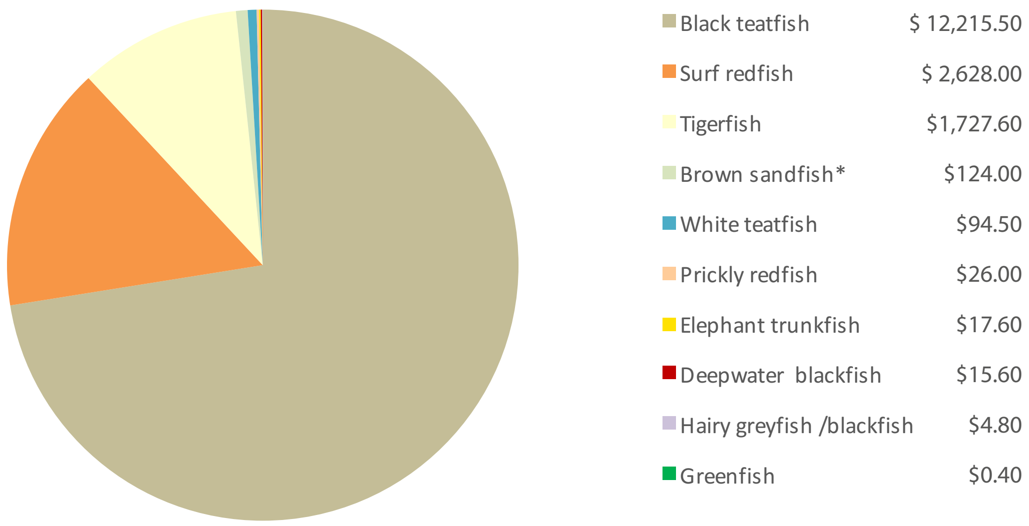


Figure 6. Breakdown of income to fishing communities for individual species harvested during the 2016 harvest day. *Brown sandfish is an unconfirmed species.

Market values of the 2016 harvest

Overall income to fishers is at the bottom of the market value chain, and the selling price at Chinese stores is at the top of this market value chain, while the Pohnpei State Government and exporter sit in the middle of this chain (Figure 7). Estimation of selling prices on the Chinese market for the 2016 harvest was USD 123,631, a value that is more than seven times higher than fisher incomes and over three times higher than the estimated local exporting price (Figure 7). Overall, 70% of the Chinese market value of the 2016 harvest has not been profiting Pohnpei, but rather middlemen and buyers for the Chinese market, while fishers only received 13.6% of the estimated final selling price. These estimates demonstrate that local exporters would have not generated a profit from the 2016 one-day harvest because of the additional price paid to fishers (USD 16,854) and to licensing fees (USD 25,000) paid to Pohnpei State Government exceeded the local export value (USD 35,898).

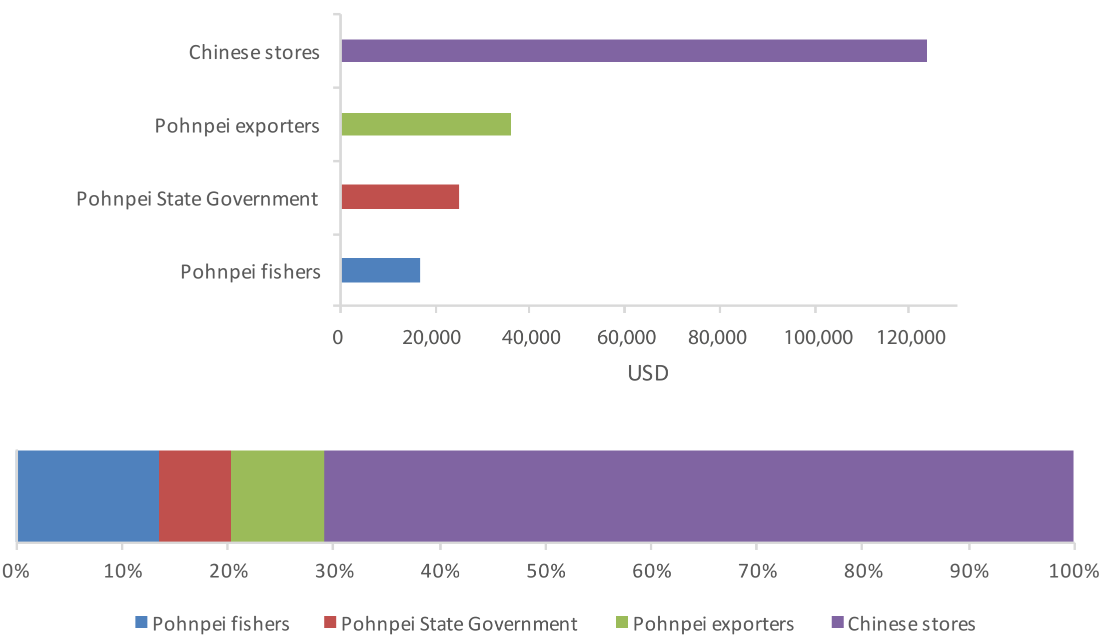


Figure 7. Estimated market value chain of sea cucumber product for the 2016 harvest excluding monitoring and transformation (e.g. processing, transporting) costs. Top graph in USD per party; bottom graph in percentage (%) of the total market value for each party.

In-water resource assessments

Survey coverage

In total, 209 stations were surveyed during the 2017 assessment, including 171 stations around Pohnpei and 38 stations in Ant Atoll (Figure 8, Figure 9), with approximately 20 ha of intertidal and subtidal habitats surveyed around Pohnpei and 5 ha surveyed around Ant Atoll (all methods combined). In total, 65 manta tow transects were covered during the course of the survey, with 45 situated in Pohnpei open areas, 7 in Pohnpei's MPAs and 13 in Ant Atoll. A total of 90 reef benthos transect stations were surveyed: 52 in Pohnpei open areas, 16 in Pohnpei MPAs, and 22 stations at Ant Atoll. In total, 39 soft benthos transect stations were surveyed around Pohnpei, including 27 stations in open areas and 12 stations in MPAs. Due to a lack of soft-bottom habitat, no soft benthos transect stations were established at Ant Atoll. Fifteen reef front transect stations were surveyed during the 2017 survey, including eight in the open areas of Pohnpei, four stations in Pohnpei's MPAs, and 3 stations at Ant Atoll.

For Pohnpei, the overall number of stations and survey coverage (i.e. 20 ha) was slightly higher than in the 2013 Pohnpei-wide assessment based on data held at SPC (SPC unpublished data), which covered 13 ha (excluding Pingelap Atoll), and considerably greater than the 1 ha surveyed by COM (Bourgoin and Pelep 2017) over the course of 2016–2017.

Table 4. The number of survey stations and area surveyed for each method of the 2017 Pohnpei assessement.

Method	Pohnpei		Ant Atoll
	Open	MPA	Combined (Open + MPA)
Manta tow			
No. stations	45	7	13
Area surveyed	153,000 m^2	17,400 m^2	46,860 m^2
Reef benthos transect			
No. stations	52	16	22
Area surveyed	12,480 m^2	3, 840 m^2	5,280 m^2
Soft benthos transect			
No. stations	27	12	0
Area surveyed	6,480 m^2	2,880 m^2	0 m^2
Reef front transect			
No. stations	8	4	3
Area surveyed	1,920 m^2	960 m^2	720 m^2
Total area surveyed per site	**173,880 m^2**	**25,080 m^2**	**52,860 m^2**
Total area surveyed per Island	**198,960 m^2**		**52,860 m^2**

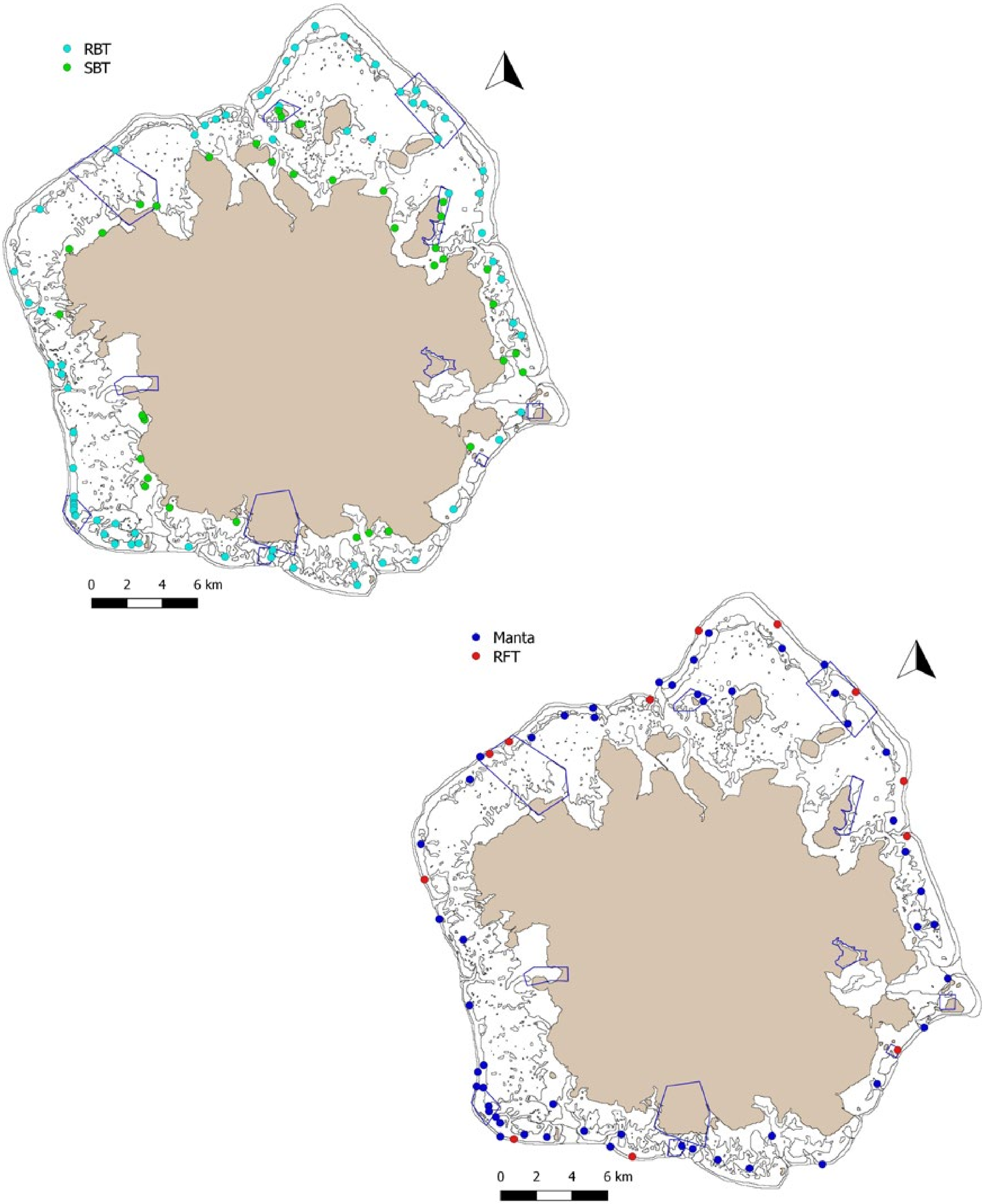


Figure 8. Location of survey stations for all survey methods around Pohnpei, 2017.

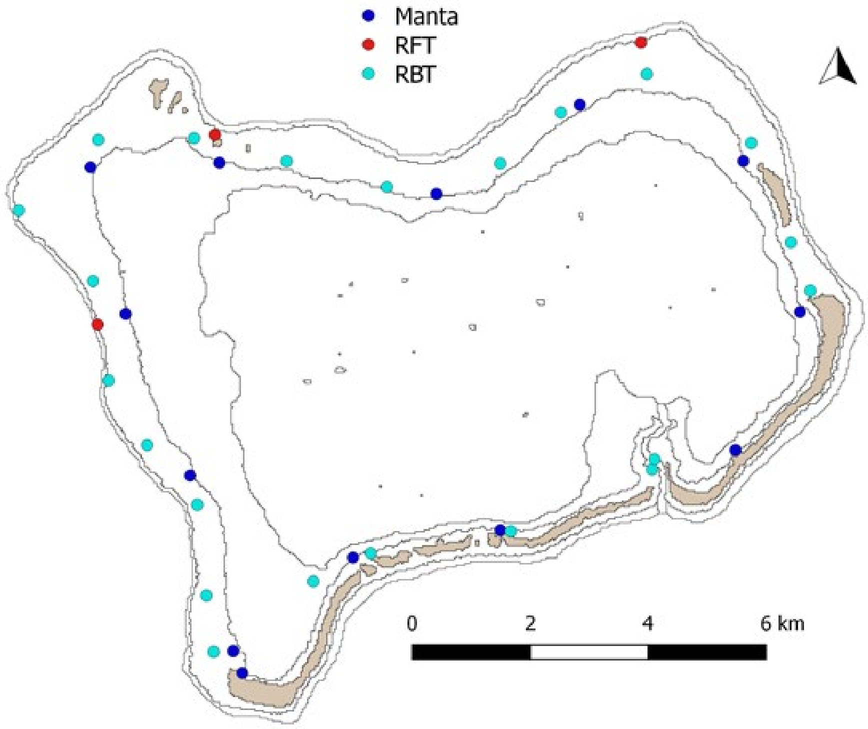


Figure 9. Location of survey stations for all survey methods at Ant Atoll, 2017.

Species presence

2017 assessment

In total, 24 species from seven genera were recorded from Pohnpei Island and Ant Atoll combined during the 2017 survey (Table 5). Of these, 23 species were recorded from Pohnpei, while only 10 species were recorded from Ant Atoll. In Pohnpei, 17 species were recorded in MPAs and 23 species were recorded from the open areas. Of the 24 species recorded, 23 are of commercial importance. The only non-commercially important species recorded was *Synapta maculata*.

Comparison with previous assessments

Several differences were observed with respect to species presence among the 2017 and previous Pohnpei Island-wide surveys (SPC unpublished data; Bourgoin and Pelep 2017). The main differences among the surveys were:

- the absence of three species during the 2017 assessment that were recorded during the 2013 assessment: grey impatient sea cucumber (*Holothuria arenicola*), red impatient sea cucumber (*H. impatiens*) and undescribed hairy greyfish (*Actinopyga* sp.);
- the presence of four species during the 2017 assessment that were not recorded in 2013: stonefish (*Actinopyga lecanora*), tiger tail sea cucumber (*Holothuria hilla*), spotted-worm sea cucumber (*Synapta maculata*) and amberfish (*Thelenota anax*);
- the absence of two species during the 2017 assessment that were recorded during the 2016–2017 COM survey: white threadfish (*Holothuria leucospilota*) and dragonfish (*Stichopus horrens*); and
- the presence of species during the 2017 assessment that were not recorded during the 2016–2017 COM survey: surf redfish (*Actinopyga mauritiana*), white teatfish (*Holothuria fuscogilva*), elephant trunkfish (*H. fuscopunctata*), sandfish (*H. scabra*), spotted-worm sea cucumber (*Synapta maculata*), prickly redfish (*Thelenota ananas*), and amberfish (*T. anax*).

These differences may be related to habitat differences (e.g. amberfish was only recorded from the sandy-bottom slope of Ant Atoll's lagoon), to sampling effort (e.g. lower numbers of stations were surveyed in the 2016–2017 COM survey and no stations were surveyed on the reef crest and outer reef), to local distribution of species where some species such as hairy greyfish may be restricted to small aggregations (Clayton Hedson, Fisheries Specialist, Office of Fisheries and Aquaculture, Pohnpei State Government, pers. comm., May 2017), and to potential confusion between species (grey and red impatient sea cucumbers and tiger tail sea cucumber).

Table 5. List of species encountered and recorded at Pohnpei Island and Ant Atoll.[6]

Common name	Scientific name	Pohnpei (2017)		Pohnpei	Ant (2017)
		Open	MPAs	2013	Open + MPAs
Deepwater redfish	*Actinopyga echinites*	+	+	+	
Stonefish	*Actinopyga lecanora*	+			
Surf redfish	*Actinopyga mauritiana*	+	+	+	
Hairy blackfish	*Actinopyga miliaris*	+	+	+	
Hairy greyfish	*Actinopyga sp*			+	
Deepwater blackfish	*Actinopyga palauensis*	+		+	
Tigerfish	*Bohadschia argus*	+	+	+	+
Chalkfish	*Bohadschia similis*[6]	+		+	
Brown sandfish	*Bohadschia vitiensis*	+	+	+	+
Lollyfish	*Holothuria atra*	+	+	+	+
Grey impatient	*Holothuria arenicola*			+	
Snakefish	*Holothuria coluber*	+	+	+	
Pinkfish	*Holothuria edulis*	+	+	+	
Red snakefish	*Holothuria roseomaculata*	+	+	+	
White teatfish	*Holothuria fuscogilva*	+	+	+	+
Elephant trunkfish	*Holothuria fuscopunctata*	+	+	+	+
Tiger tail	*Holothuria hilla*	+	+		
Red impatient	*Holothuria impatiens*			+	
Sandfish	*Holothuria scabra*	+		+	
Black teatfish	*Holothuria whitmaei*	+		+	+
Flowerfish	*Pearsonothuria graeffei*	+	+	+	
Greenfish	*Stichopus chloronotus*	+	+	+	+
Curryfish	*Stichopus herrmanni*	+	+	+	+
Brown curryfish	*Stichopus vastus*	+	+	+	
Spotted-worm sea cucumber	*Synapta maculata*	+			
Prickly redfish	*Thelenota ananas*	+	+	+	+
Amberfish	*Thelenota anax*				+
Total number of verified species		**23**	**17**	**23**	**10**

Species of conservation significance

Most of the species encountered are listed under the International Union for Conservation of Nature (IUCN) 'Red List':

- *Holothuria scabra*, *H. whitmaei* and *Thelenota ananas* are classified as endangered;
- *Actinopyga echinites*, *A. mauritiana*, *A. miliaris*, *Holothuria fuscogilva* and *Stichopus herrmanni* are classified as vulnerable;
- *Actinopyga palauensis*, *Bohadschia argus, H. atra*, *H. coluber*, *H. edulis*, *H. fuscopunctata*, *H. hilla*, *Pearsonothuria graeffei*, *Stichopus chloronotus* and *S. vastus* are classified as least concern;
- *Actinopyga lecanora*, *Bohadschia similis*, *B.vitiensis* and *Thelenota anax* are classified as data deficient;
- *Holothuria roseomaculata* and *Synapta maculata* have not yet been evaluated.

Species abundance

A total of 23,222 individual sea cucumbers were counted during the 2017 assessment. Lollyfish was the most abundant species, representing 69% of all sea cucumbers observed, followed by pinkfish (12%) and greenfish (5%). Pie charts of each species' relative abundance (i.e. how abundant a species is compared with other species during a survey) by survey method (manta tow, soft benthos transect, reef benthos transect and reef front transect) are presented in Figure 10 for Pohnpei open area and Pohnpei MPAs, and in Figure 11 for Ant Atoll.

[6] Species recognised to be a synonym of Bohadschia vitiensis with a slightly different colour pattern (Kim et al. 2013) but recorded as B. similis in this report.

Manta tow

Manta tow is the method for which a greater diversity in abundance was observed.

Lollyfish were the most commonly observed species at manta stations at each site. At Pohnpei, lollyfish constituted 56% of all sea cucumbers observed at manta stations in open areas, and 48% of all sea cucumbers observed at manta stations in MPAs (Figure 10). The next most commonly observed species in the open areas were pinkfish, tigerfish, greenfish, curryfish and, to a lesser extent, elephant trunkfish, prickly redfish and flowerfish; for MPAs, the next most commonly observed species were pinkfish, greenfish, curryfish, tigerfish and, to a lesser extent, elephant trunkfish and flowerfish.

At Ant Atoll, lollyfish constituted 35% of all sea cucumbers observed at manta stations (Figure 11). The next most common species were prickly redfish, tigerfish, amberfish, elephant trunkfish and, to a lesser extent, brown sandfish, greenfish, curryfish and white teatfish.

Reef benthos transect

Lollyfish were the most commonly observed species at reef benthos transect stations at each site. At Pohnpei, lollyfish constituted 68% of all sea cucumbers observed at reef benthos transect stations in open areas and 64% of all sea cucumbers species within MPAs. Pinkfish was the next most common species, constituting 16% and 26% of sea cucumbers observed in open areas and MPAs (Figure 10).

At Ant Atoll, lollyfish constituted 78% of all sea cucumbers observed at reef benthos transect stations. The next most common species were tigerfish and prickly redfish, representing 18% and 4% of all sea cucumbers recorded, respectively (Figure 11).

Soft benthos transect

Once again, lollyfish was the most commonly observed species at soft benthos transect stations in both Pohnpei Island open areas and Pohnpei Island MPAs, constituting 80% and 96% of all sea cucumbers species recorded at these sites, respectively. In Pohnpei open areas, the next most commonly observed species at soft benthos transect stations were brown curryfish, pinkfish, tiger tail and snakefish, while in Pohnpei MPAs, the next most commonly observed species was pinkfish (Figure 10).

The soft benthos transect method was not used at Ant Atoll.

Reef front transect

For this method, surf redfish was the most commonly observed species at both Pohnpei sites, constituting 60% and 77% of all sea cucumbers observed in open areas and MPAs, respectively. The next most commonly observed species was lollyfish (Figure 10).

No sea cucumbers were observed during the reef front transect on the reef crest at Ant Atoll.

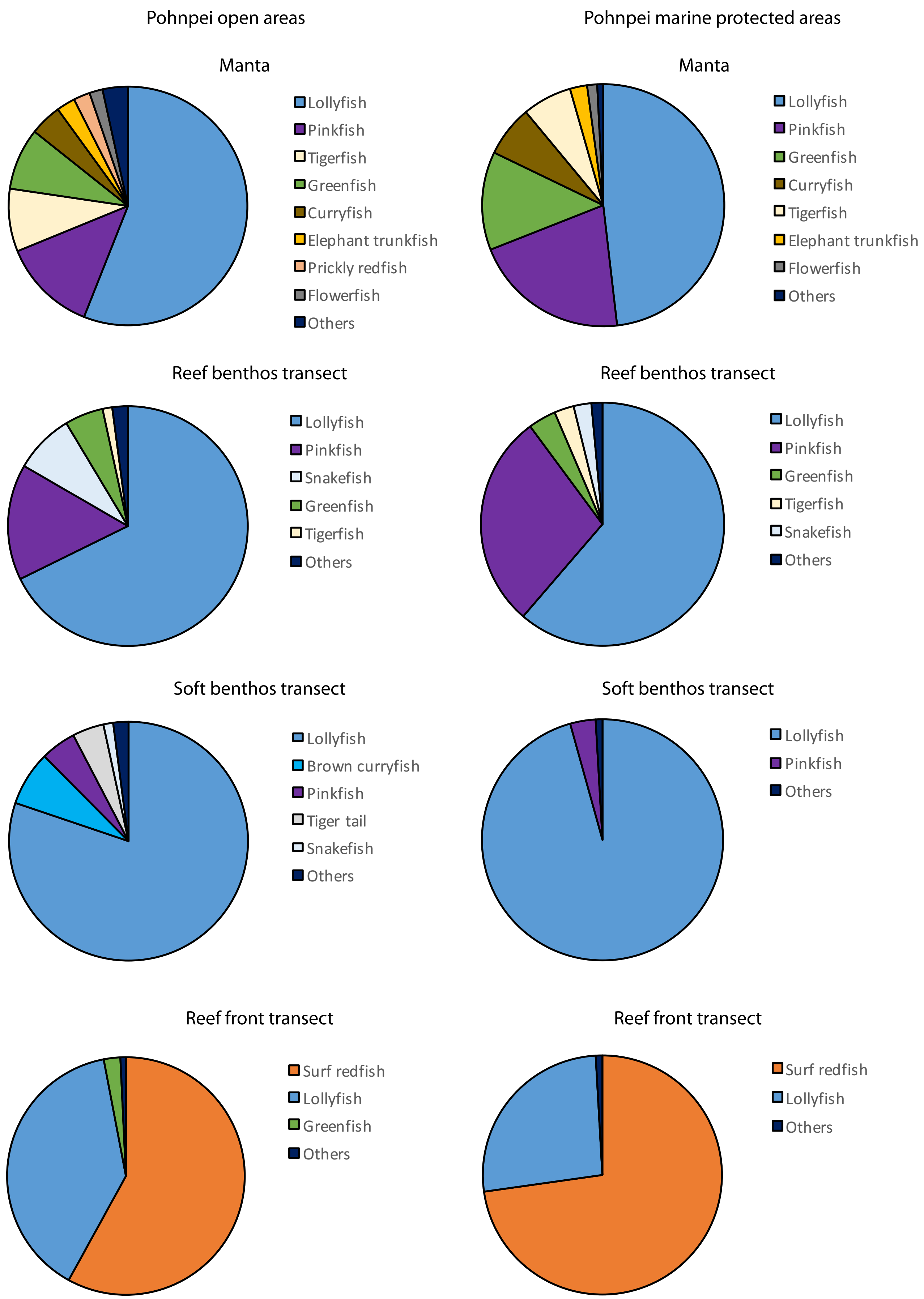


Figure 10. Relative abundance of sea cucumber species observed in Pohnpei open areas (left), and Pohnpei MPAs (right) for each method.

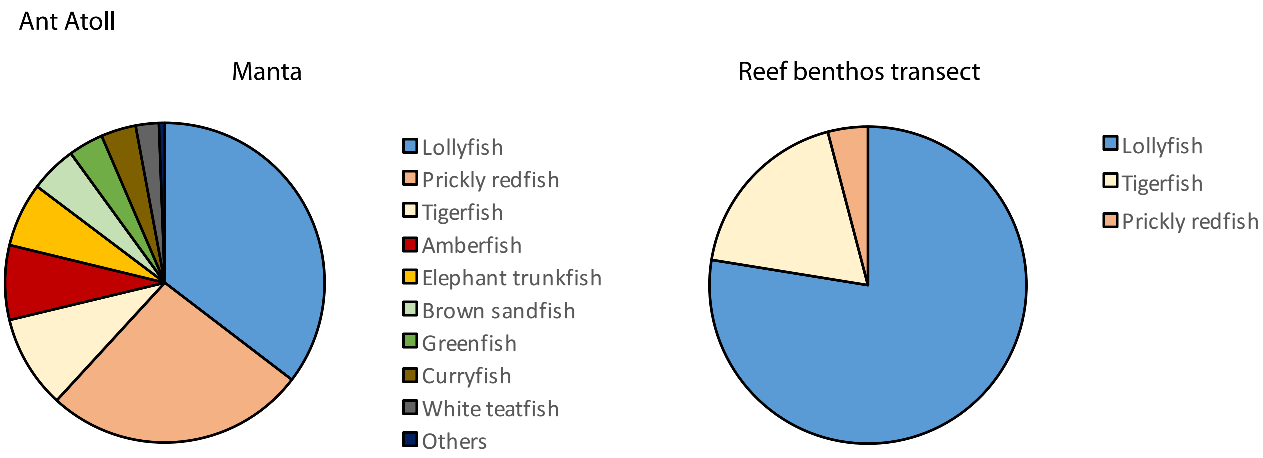


Figure 11. Relative abundance of sea cucumber species observed at Ant Atoll for manta tow and reef benthos transect methods.

Cumulative densities

Maps of cumulative densities (i.e. the sum of all individuals combined, regardless of species) observed for each survey method are presented in Figure 12 and Figure 13.

At Pohnpei, there was considerable variation among cumulative densities with respect to survey method and location (Figure 12). Cumulative densities (expressed as the number of individual sea cucumbers per hectare, ind/ha) observed at manta and reef front transect stations were relatively low, with densities reaching a maximum of 4,375 ind/ha and 4,333 ind/ha, respectively. Cumulative densities observed at reef benthos transect and soft benthos transect sites were higher. Mean cumulative density at reef benthos transect stations was 5474 ind/ha (6002 ind/ha in open areas vs 4086 ind/ha in MPAs), reaching up to 28,750 ind/ha at one station. Mean cumulative density at soft benthos transect stations was 7640 ind/ha (5608 ind/ha in open areas vs 12,212 ind/ha in MPAs), with a maximum of 37,167 ind/ha observed at one station. Cumulative densities at reef benthos transect stations varied markedly across the lagoon, with slightly higher densities observed on the eastern side of Pohnpei and in the vicinity of Nahlap and Kehpara islands, largely due to high densities of lollyfish. Densities at soft benthos transect stations also varied greatly, with the lowest cumulative densities recorded in the southwest of Pohnpei Island, and highest in the northeast (Figure 12).

At Ant Atoll, cumulative densities were very low at all stations (Figure 13). Reef benthos transect stations had the highest densities at the atoll, with a mean of 93 ind/ha and a maximum value of 625 ind/ha. Manta tow station densities were lower, with a mean of 36 ind/ha and a maximum value of 194 ind/ha. No sea cucumbers were recorded at the three reef front transect stations.

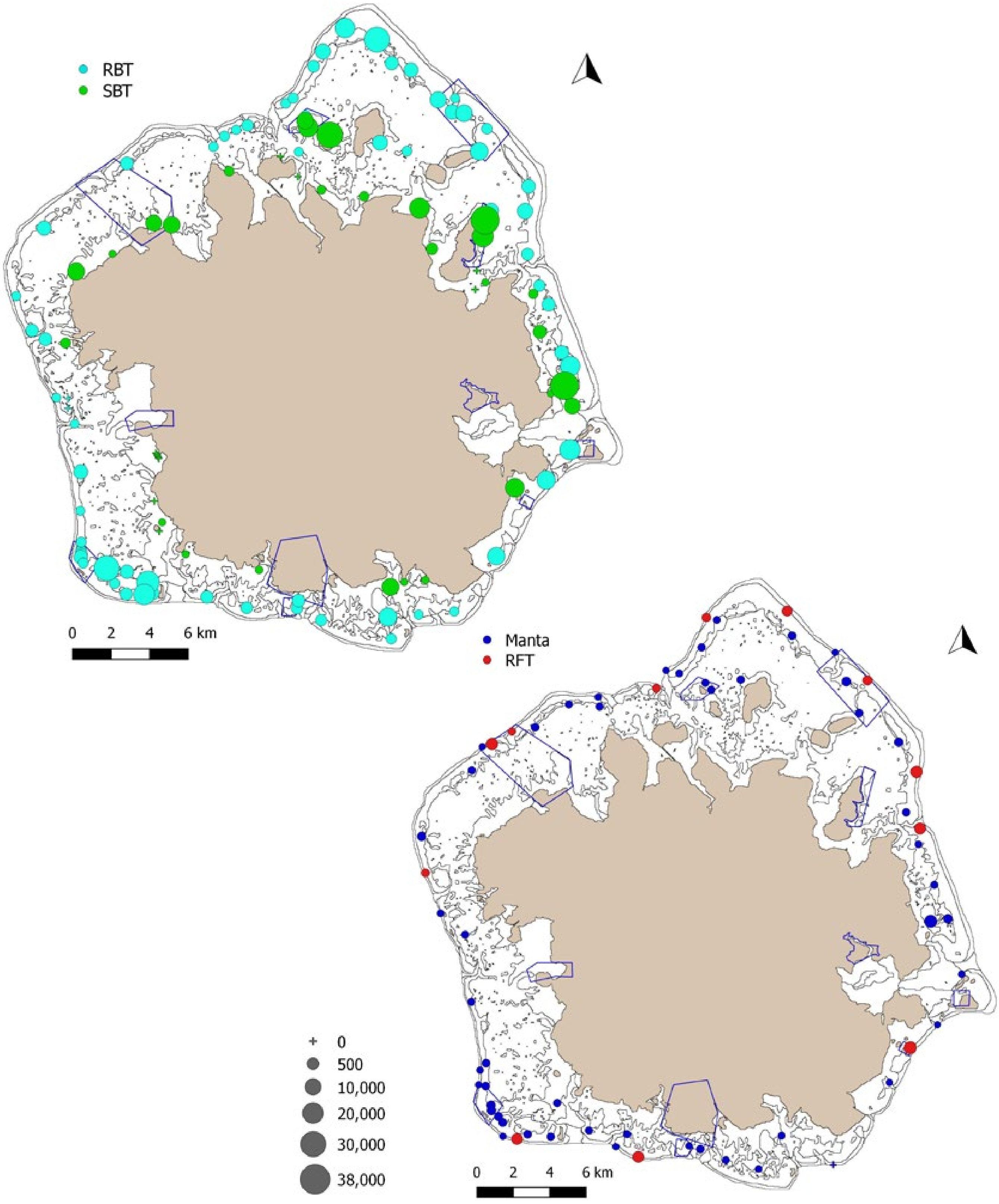


Figure 12. Overall sea cucumber densities (i.e. all species combined) at survey stations at Pohnpei during the 2017 assessment.

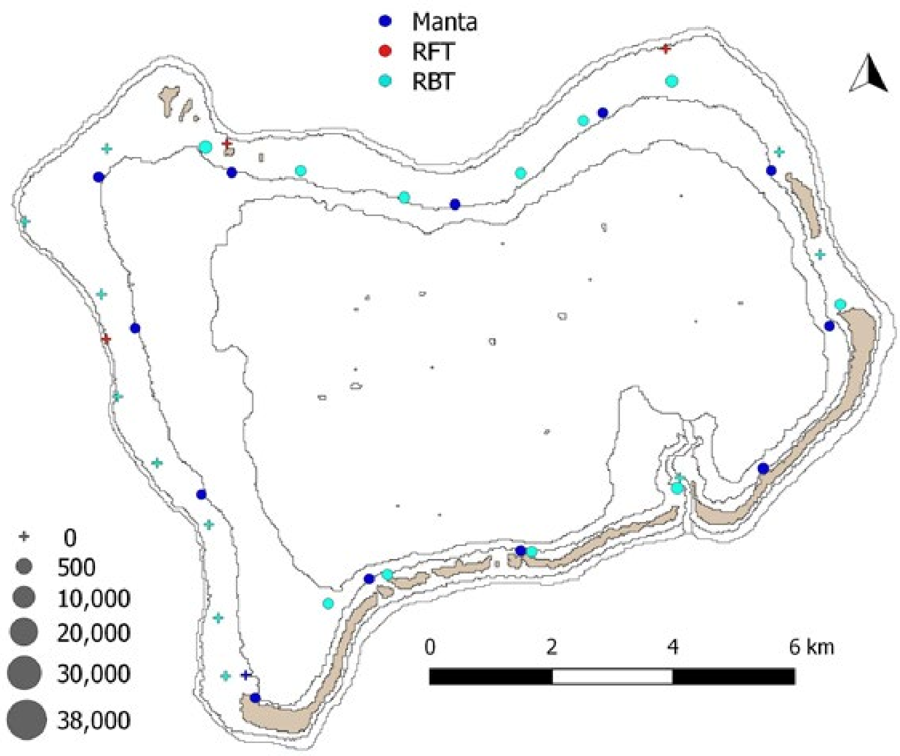


Figure 13. Overall sea cucumber densities (i.e. all species combined) at survey stations at Ant Atoll during the 2017 assessment.

Species densities

Mean densities (±SE) of individual sea cucumber species at manta tow, reef benthos transect, soft benthos transect and reef front transect stations for the 2017 survey are presented in Figure 14. Mean densities (±SE) of individual MPAs (Kehpara and Mwahnd) and surrounding open areas in 2017 are presented in Figure 15 and Figure 16. Comparisons of densities between the 2017 and 2013 assessments are presented in Figure 17 and Figure 18, and a comparison of Kehpara MPA densities through time is shown in Figure 19. Mean densities of sea cucumbers observed at manta tow, reef benthos transect, soft benthos transect and reef front transect stations are respectively presented in Appendices 1 to 4.

Pohnpei

- Present assessment, open areas and MPAs

At Pohnpei, densities for most sea cucumber species at manta stations within both open areas and MPAs were well below regional reference densities (Figure 14). The only exception was elephant trunkfish (*Holothuria fuscopunctata*), which was observed in mean densities (13 ± 8 ind/ha) that were slightly above reference densities (10 ind/ha) within MPAs.

Sea cucumber densities at reef benthos transect stations were generally below regional reference densities. The only exception was pinkfish (Holothuria edulis), which was observed in mean densities over three times greater than the regional reference density (260 ind/ha) in open areas (922 ± 292 ind/ha) and over four times greater than the regional reference density in MPAs (1167 ± 436 ind/ha).

At soft benthos transect stations, pinkfish was observed in mean densities slightly above the regional reference density (260 ind/ha), both for open areas and MPAs (269 ± 165 ind/ha and 417 ± 283 ind/ha), while lollyfish densities were higher than regional reference densities within MPAs only (11,684 ± 4497 ind/ha).

At reef front stations, the mean densities of surf redfish (Actinopyga mauritiana) were over eight times higher than regional reference densities (200 ind/ha) at MPAs (1698 ± 668 ind/ha) and six times higher than regional reference densities at open areas (1208 ± 339 ind/ha).

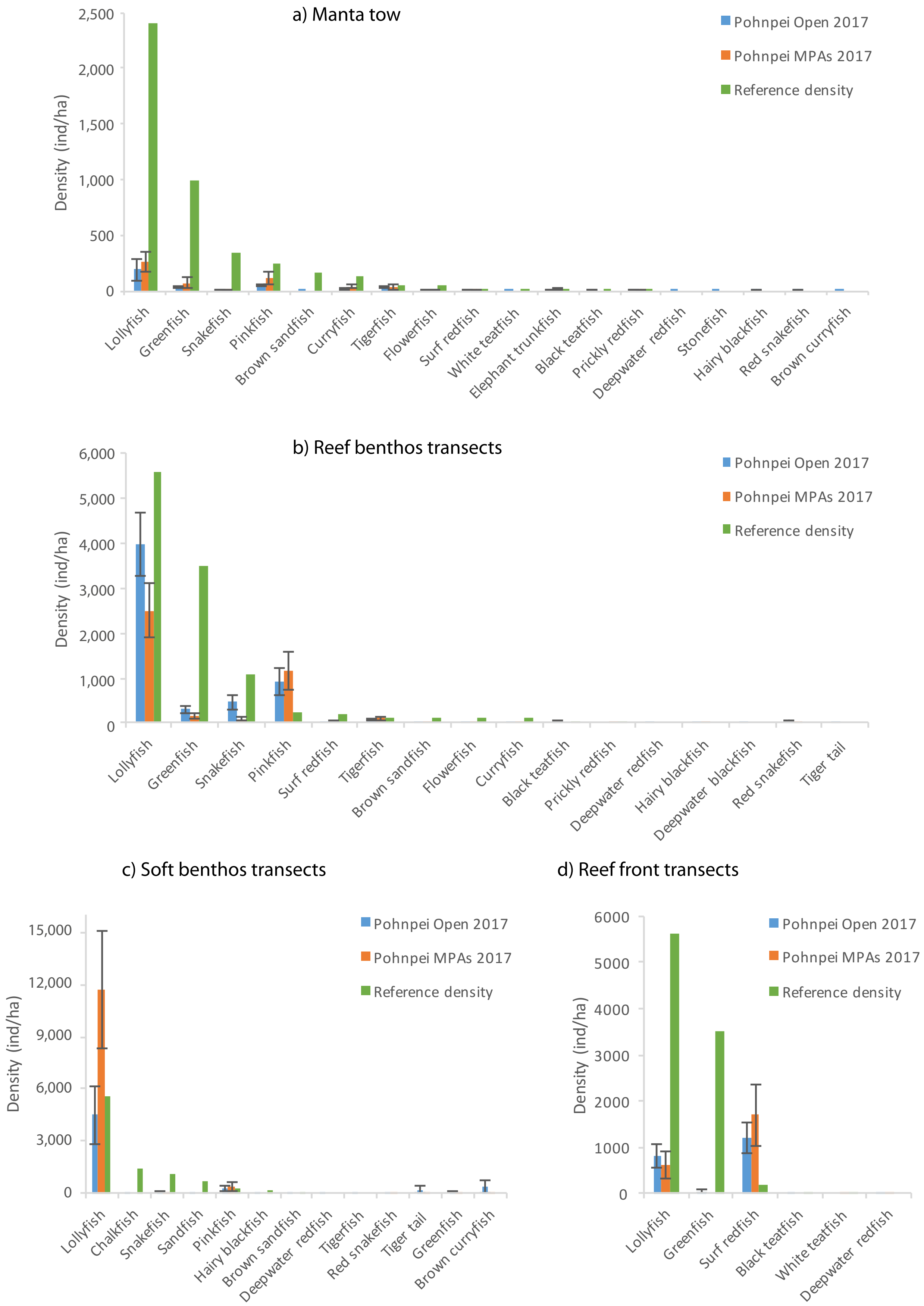


Figure 14. Mean densities (± SE) of sea cucumber species observed at a) manta tow, b) reef benthos transect, c) soft benthos transect and d) reef front transect stations at Pohnpei during the 2017 assessment, and corresponding regional reference densities (from Pakoa et al. 2014).

- Present assessment, individual MPAs (Kehpara and Mwahnd)

For Kehpara (Figure 15), mean densities showed great variations between open areas and MPAs. Most notably, mean densities of lollyfish, snakefish and pinkfish were three to over ten times higher in open areas than in MPAs.

In Mwahnd (Figure 16), few differences in mean densities were observed between MPA stations and open area stations. The only exception was snakefish, which was recorded at a mean higher density in the open area compared with the MPA (597 ± 213 ind/ha vs. 167 ± 89 ind/ha, respectively).

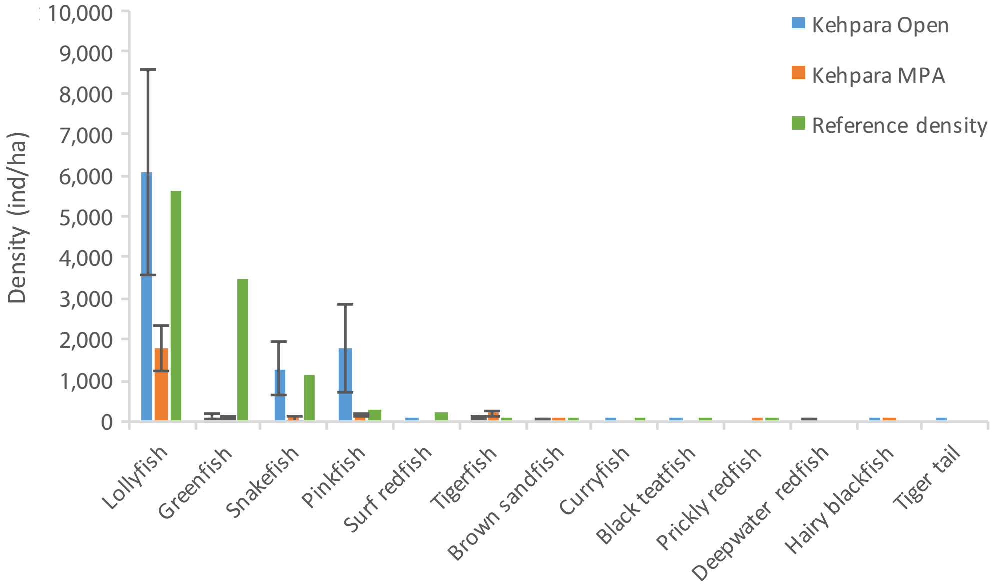


Figure 15. Mean densities (± SE) of sea cucumber species observed at reef benthos transects at Kehpara Marine Protected Area and open areas during the 2017 assessment, and corresponding regional densities.

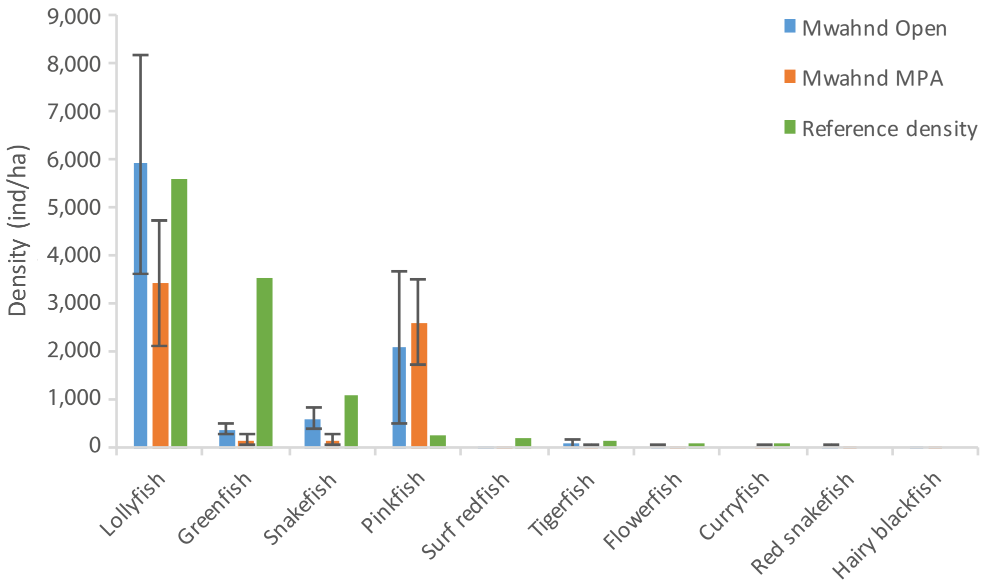


Figure 16. Mean densities (± SE) of sea cucumber species observed at reef benthos transects at Mwahnd Marine Protected Area and open areas during the 2017 assessment, and corresponding regional densities.

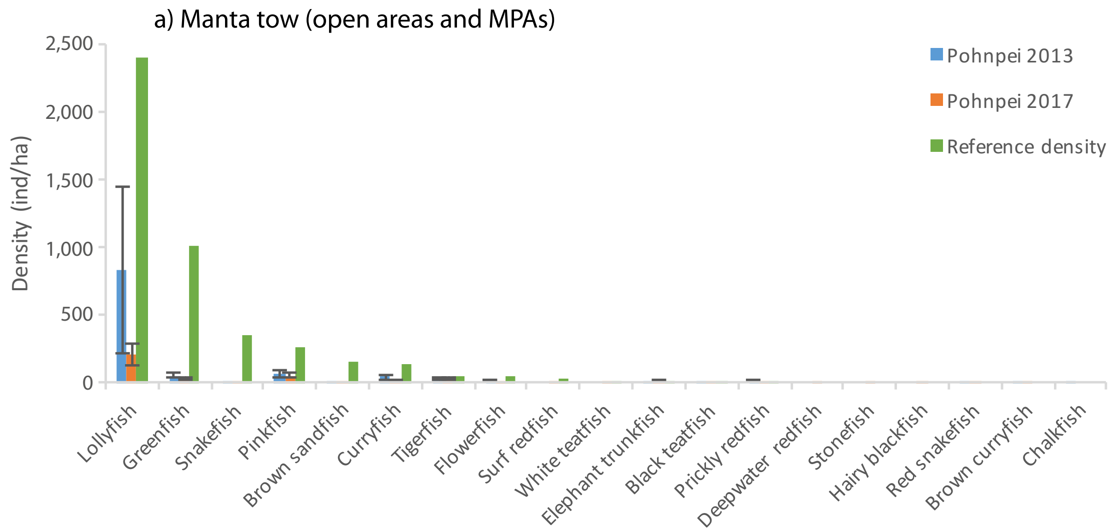
- Comparison with previous assessment, open areas and MPAs pooled

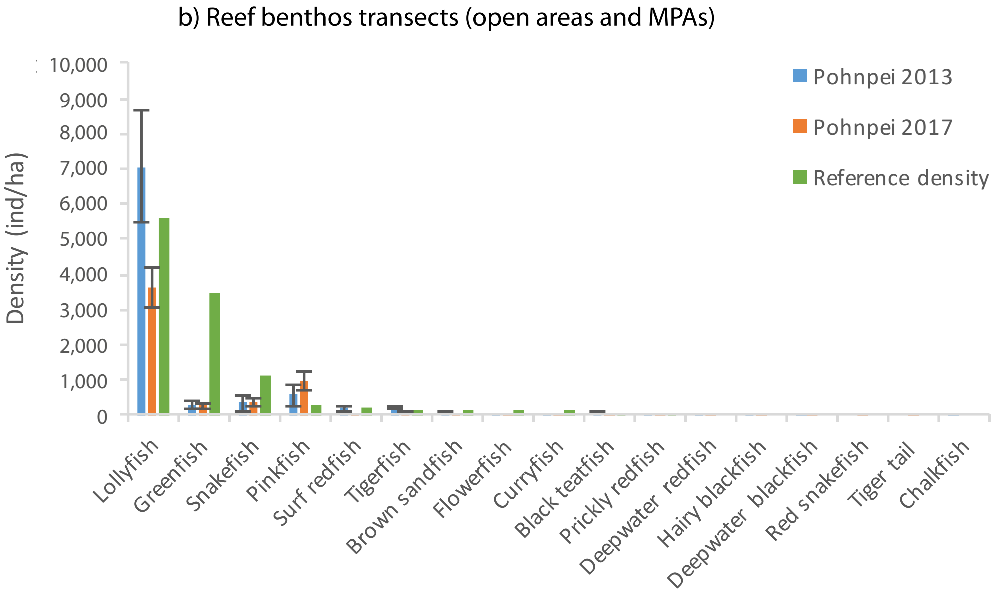
A comparison between mean densities of the 2013 assessment and the 2017 assessment at manta stations (open areas and MPAs pooled) did not reflect major changes (Figure 17). Curryfish and flowerfish mean densities were slightly lower in 2017

The major difference between the mean densities of the 2013 and 2017 surveys at reef benthos transect stations was recorded for lollyfish, which was two times lower in 2017 (Figure 17). Several species were recorded at slightly lower densities during the 2017 assessment, including surf redfish, tigerfish, brown sandfish and black teatfish, while pinkfish and flowerfish were recorded at slightly higher densities in 2017 relative to 2013 (Figure 17).

The comparison of mean densities at soft benthos transect stations between the 2013 and 2017 assessments revealed a similar trend as for reef benthos transect comparisons, with many species recorded at lower densities in 2017 (Figure 17). Lollyfish, chalkfish, sandfish, brown sandfish, surf redfish, hairy blackfish and greyfish were all recorded at much lower densities during the 2017 survey. In contrast, pinkfish, tiger tail sea cucumber and brown curryfish densities were slightly higher in 2017.

A comparison of the combined densities of soft benthos and reef benthos transects among the 2013 assessment, 2016–2017 COM survey and 2017 assessment (Figure 18) showed important variability. The densities of pinkfish, brown curryfish, tiger tail and red snakefish were higher in 2017 than in previous surveys, while densities of snakefish and greenfish were higher in 2017 relative to the 2016–2017 COM survey. The 2017 densities were, however, below both those of the 2013 and 2016–2017 surveys for brown sandfish and tigerfish, below the 2013 survey for curryfish, black teatfish, surf redfish, hairy blackfish, deepwater redfish, sandfish, chalkfish and prickly redfish, and below the 2016–2017 COM survey for stonefish.





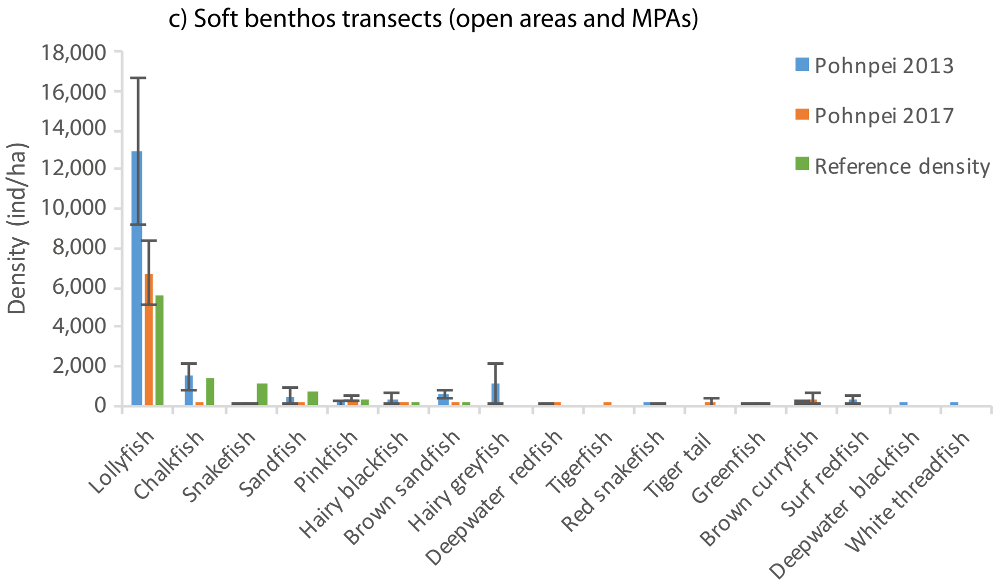


Figure 17. Comparison of densities of sea cucumber species (± SE) observed at a) manta tow, b) reef benthos transect and c) soft benthos transect stations at Pohnpei during the 2017 assessment and 2013 survey (SPC unpublished data), and corresponding reference densities.

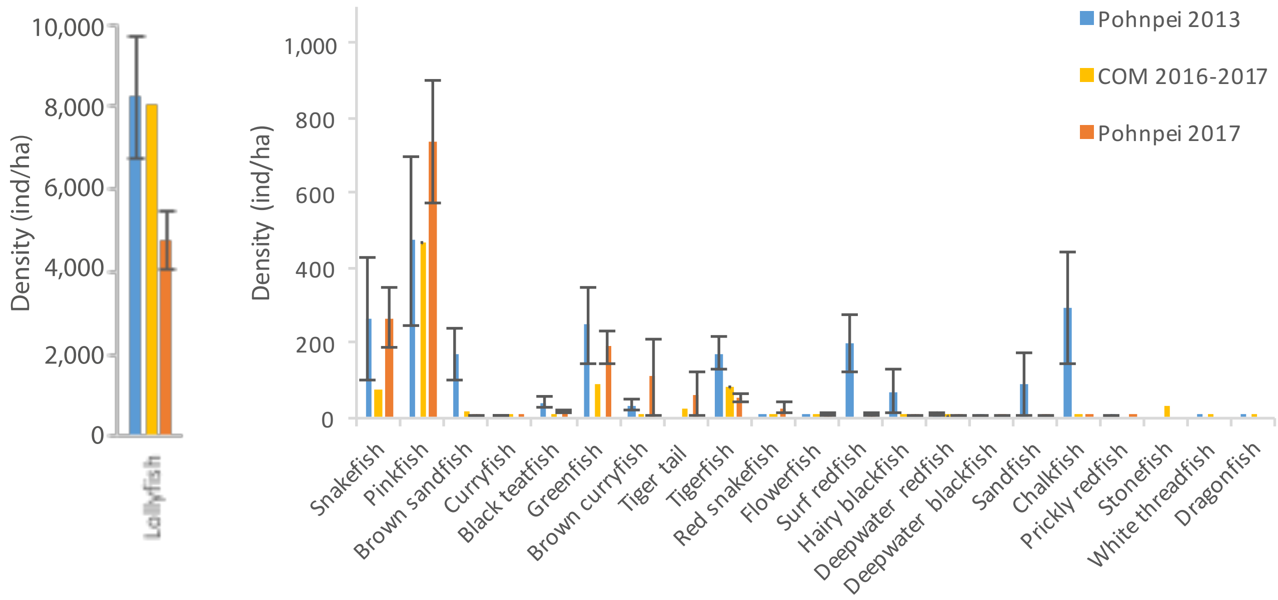


Figure 18. Comparison of mean densities of sea cucumber species (± SE) observed at reef benthos transect stations and soft benthos transects stations combined at Pohnpei for the 2013 assessment (based on data held at SPC), the 2016–2017 College of Micronesia survey (Bourgoin and Pelep 2017) and the 2017 assessment.

- Comparison with previous assessment, individual MPA (Kehpara)

Comparison of densities of Kehpara MPA between 2012, 2014 and the 2017 survey showed few significant differences (Figure 19). Lollyfish and pinkfish were recorded at much lower densities in 2017 than in the other two surveys.

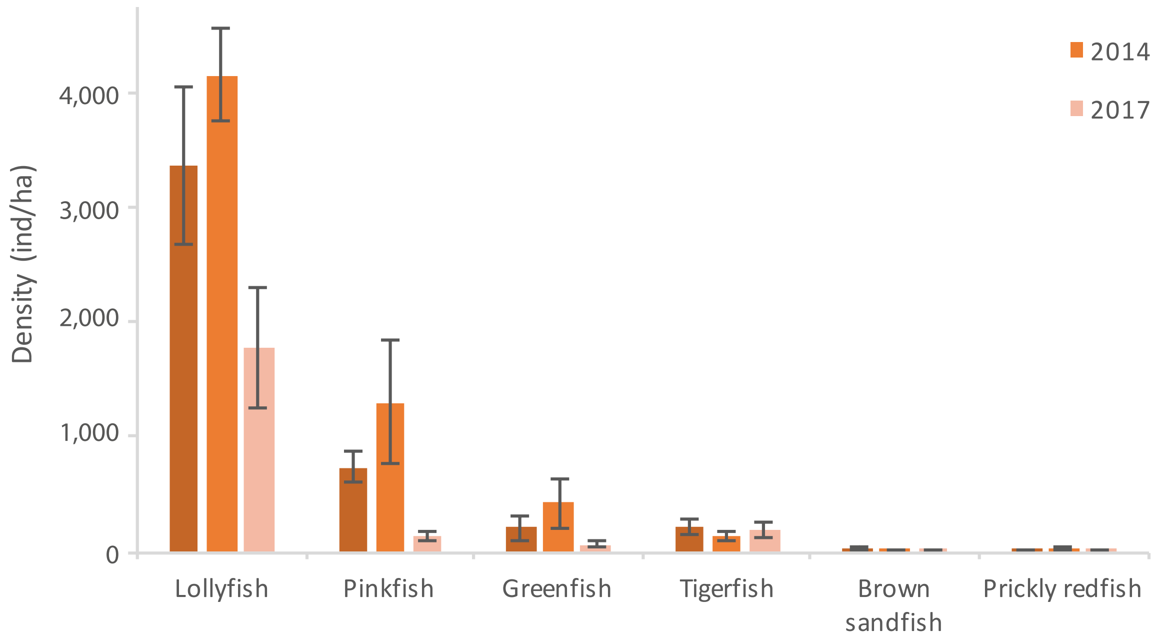


Figure 19. Comparison of sea cucumber species (± SE) observed at reef benthos transect stations at Kehpara Marine Protected Area during the climate change survey of 2012 and 2014 (Moore et al. 2012, 2015) and the 2017 assessment. Species presented in the graph were recorded in at least two of the three surveys.

Ant Atoll

At Ant Atoll, densities of all sea cucumber species were extremely low and well below reference densities (Table 6) for all survey methods. Lollyfish had the highest mean densities at manta tow and reef benthos transect stations, but densities were respectively 180 and 70 times lower than corresponding reference densities.

Table 6. Mean densities (± SE) of sea cucumber species observed at a) manta tow and b) reef benthos transect stations at Ant Atoll during the 2017 assessment, and corresponding regional densities.

a) Manta tow	Density ± SE	RRD
Lollyfish	12.8 ± 11.4	2,400
Greenfish	1.3 ± 1.3	1,000
Brown sandfish	1.7 ± 1.7	130
Curryfish	1.3 ± 1.1	130
Tigerfish	3.4 ± 1.3	50
Amberfish	2.7 ± 2.7	20
White teatfish	0.8 ± 0.6	10
Elephant trunkfish	2.4 ± 1.6	10
Black teatfish	0.2 ± 0.2	10
Prickly redfish	9.6 ± 3.4	10

b) Reef benthos transect	Density ± SE	RRD
Lollyfish	72.0 ± 72.0	5,600
Tigerfish	17.05 ± 8.5	120
Prickly redfish	3.8 ± 3.8	30

RRD = regional reference density

Population size structure

Length information can provide an indication of how well a species is sustaining its population, by indicating the presence of new recruits, juveniles and large breeding adults (Pakoa et al. 2014). Harvesting larger, more valuable individuals typically leads to declines in mean lengths. Length information, where samples sizes are sufficient, can also provide indications of natural mortality and the proportion of the population that is above minimum legal harvest lengths, or maturity, or prescribed harvest length.

Mean length and length frequencies

Mean lengths of the most commonly encountered species were below regional common lengths in most instances (Figure 20). The only exceptions were deepwater redfish (*Actinopyga echinites*) and hairy blackfish (*A. miliaris*), whose mean lengths were slightly above the regional common length (Figure 20). Mean lengths for all observed species, by site, is presented in Appendix 5.

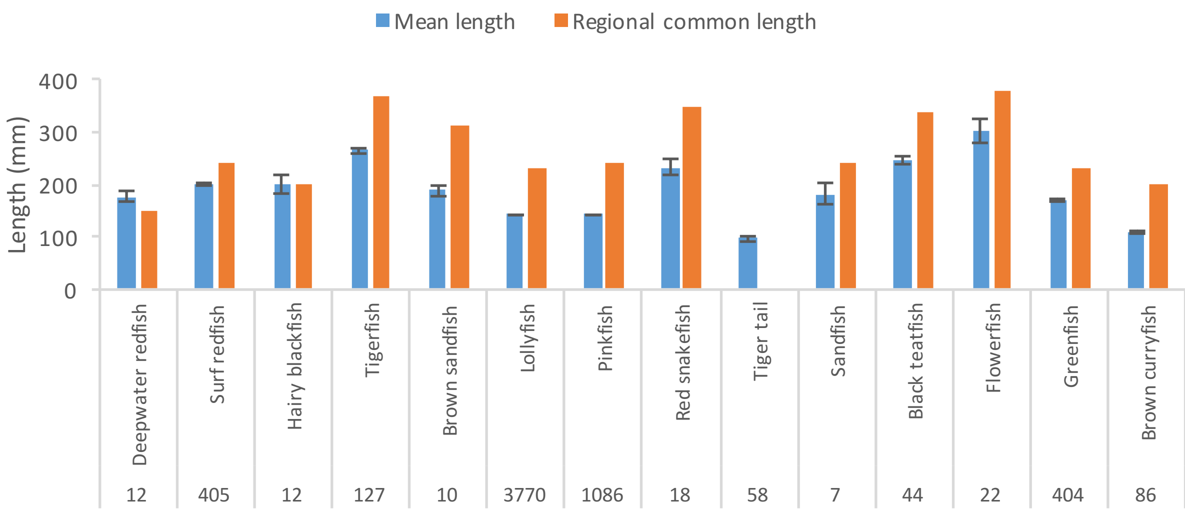


Figure 20. Mean lengths of measured sea cucumbers during the 2017 assessment (all sites of Pohnpei combined) relative to regional common lengths (Purcell et al. 2008). Only species with a minimum of seven measured individuals are displayed. Sample sizes of measured individuals are provided below species names. See Appendix 5 for mean lengths of all measured species by site.

Comparisons of sea cucumber mean lengths in Pohnpei among the 2013 assessment (SPC unpublished data), the 2016–2017 COM survey (Bourgoin and Pelep 2017) and the 2017 assessment showed few significant variations (Figure 21). The mean length of brown curryfish was much lower in 2017 compared with the other two surveys. Mean lengths of deepwater redfish, surf redfish, black teatfish and brown sandfish were lower in 2017 than in 2013. The mean length of hairy blackfish was higher in 2017 than in the other two surveys. The mean lengths of some of the most common species (i.e. lollyfish, pinkfish, greenfish and tigerfish) were relatively similar among the three surveys.

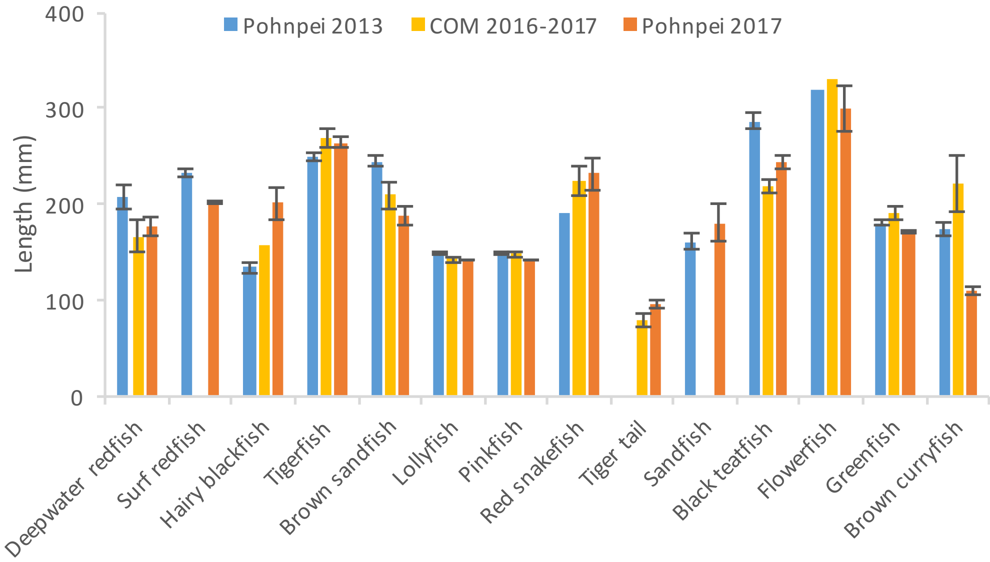
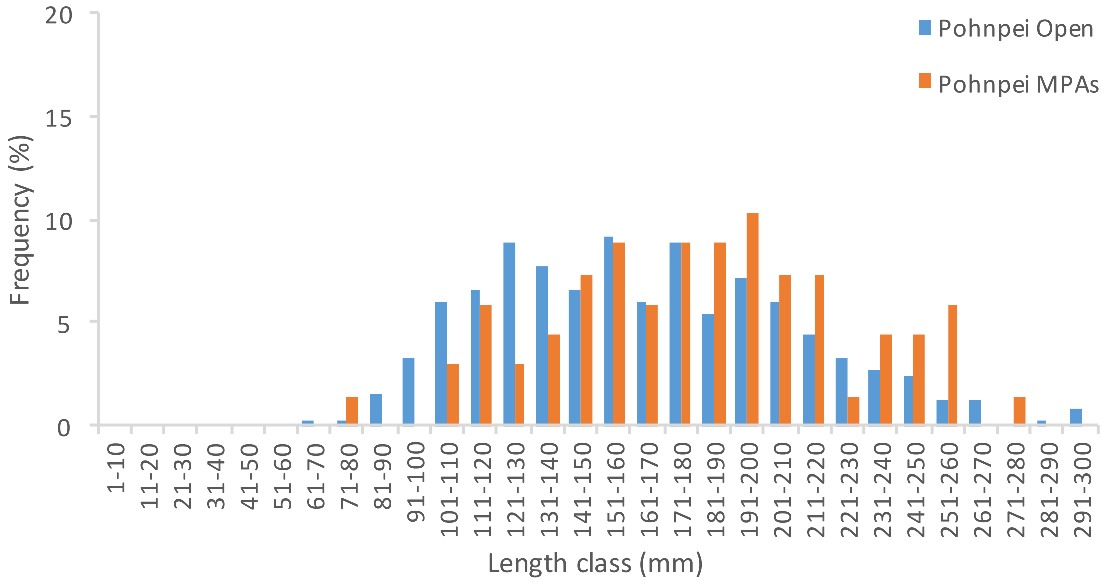


Figure 21. Comparison of mean lengths of sea cucumber species at Pohnpei for the 2013 assessment (SPC unpublished data), the COM 2016–2017 survey (Bourgoin and Pelep 2017) and the 2017 assessment. Only species with a minimum of seven individuals measured during the 2017 assessment are displayed.

- Lollyfish

Length frequency analysis revealed that the population of lollyfish in Pohnpei generally comprised small individuals, with few individuals greater than 250 mm (Figure 22). The modal (most common) length class of lollyfish in Pohnpei was 111–120 mm (Figure 22), while the mean length was 142.55 ± 1 mm (Figure 20). Of the 3770 individual lollyfish measured in Pohnpei, only 4.19% were above the common length (230 mm). Length frequency distributions were very similar between open areas and MPAs (Figure 22).



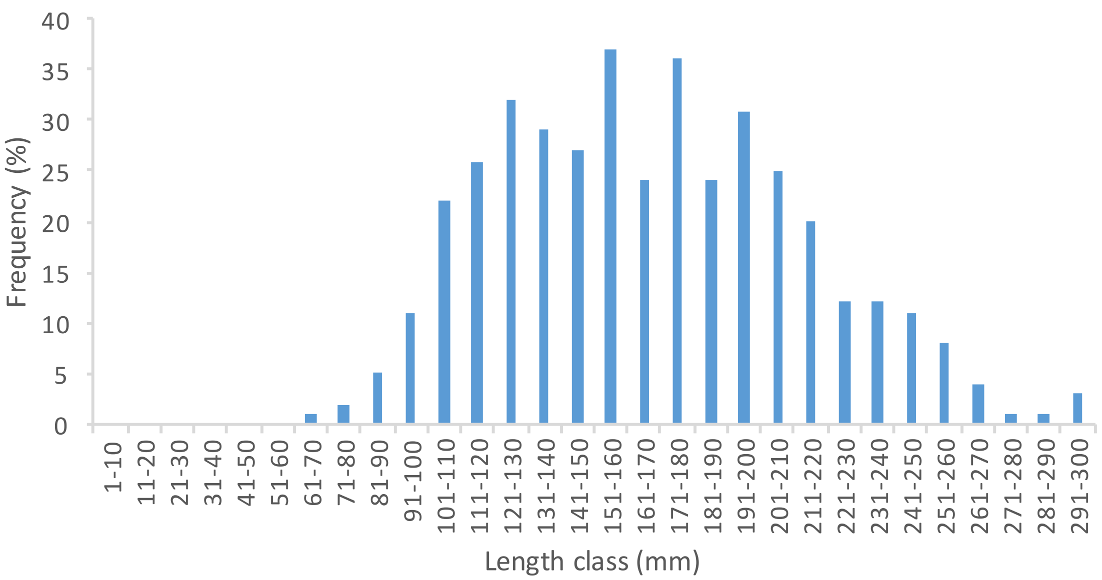
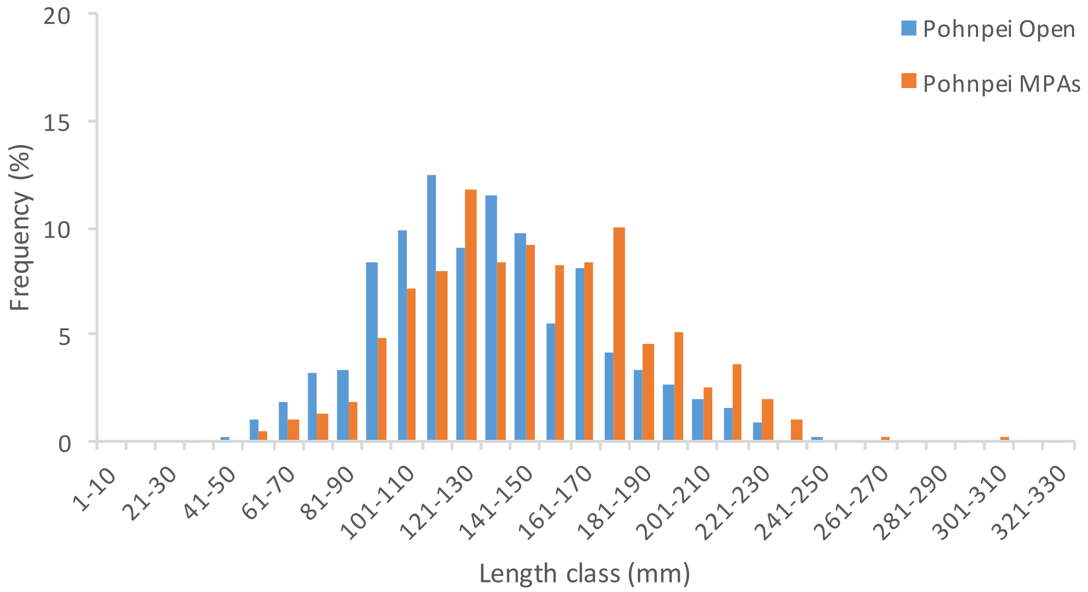


Figure 22. Length frequencies of lollyfish (*Holothuria atra*) at Pohnpei during the 2017 survey. Top graph: all sites combined; bottom graph: marine protected areas (MPAs) vs open areas.

- Pinkfish

Length frequency analysis revealed that the population of pinkfish in Pohnpei generally comprised small individuals, with few individuals greater than 250 mm (Figure 23). The modal length class of pinkfish in Pohnpei was 111–120 mm, while the mean length was 142.00 ± 1mm (Figure 20). Of the 1086 individual pinkfish measured in Pohnpei, only 9.39% were equal to and greater than the prescribed harvest length (200 mm) corresponding to only 7.48% in open areas (number used to calculate adult stock population, see below). Length frequency distributions were generally similar between open areas and MPAs of Pohnpei, although a slightly greater proportion of larger individuals was recorded within MPAs.



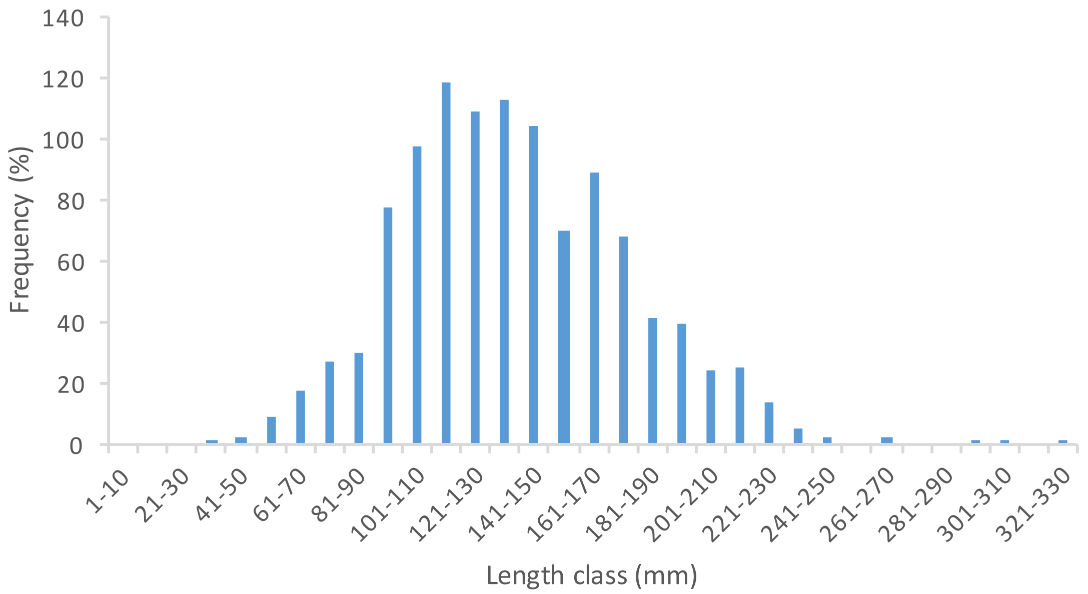


Figure 23. Length frequency of pinkfish (*Holothuria edulis*) at Pohnpei during the 2017 survey.
Top graph: all sites combined; bottom graph: marine protected areas (MPAs) vs open areas.

- Surf redfish

Length frequency analysis revealed that the population of surf redfish in Pohnpei generally comprised medium-sized individuals, with few individuals smaller than 120 mm and few larger than 260 mm (Figure 24). The modal length class of surf redfish in Pohnpei was 191–200 mm, while the mean length was 201.21 ± 2 mm (Figure 20). Of the 405 individual surf redfish measured in Pohnpei, 15.48% of individuals in open areas were equal to or above the estimated maturity length of 230 mm (Purcell et al. 2012) (number used to calculate adult stock population, see below). Examination of length frequencies revealed that MPAs supported a greater proportion of larger individuals than did open areas (Figure 24).

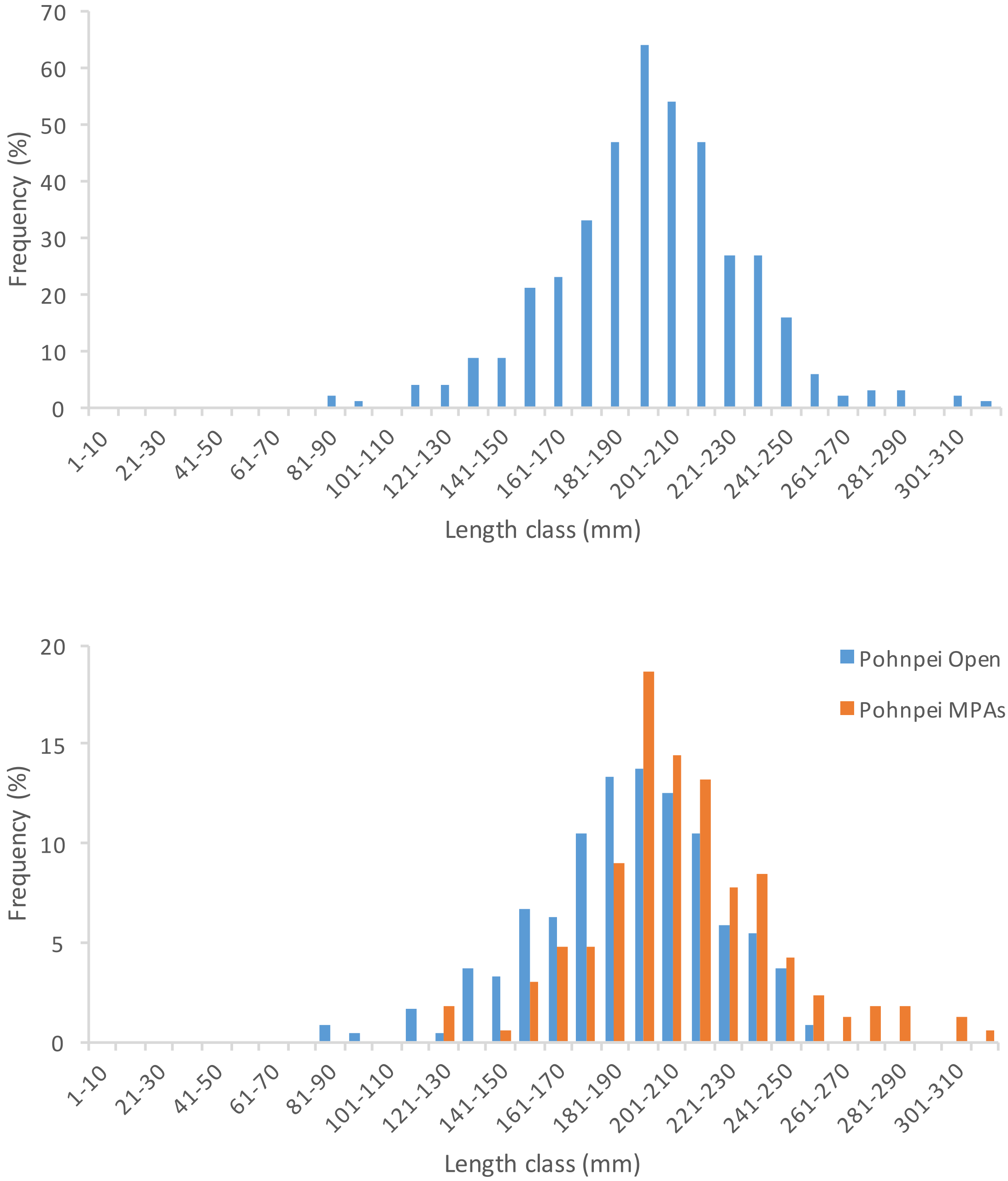


Figure 24. Length frequency of surf redfish (*Actinopyga mauritiana*) at Pohnpei during the 2017 survey.
Top graph: all sites combined; bottom graph: marine protected areas (MPAs) vs open areas.

- Greenfish

Length frequency analysis revealed that the population of greenfish in Pohnpei generally comprised small- to medium-sized individuals, with few individuals smaller than 100 mm and few larger than 260 mm (Figure 25). The modal length class of greenfish in Pohnpei was 151–160 mm, while the mean length was 170.90 ± 2 mm (Figure 20). Of the 404 individual greenfish measured in Pohnpei, only 17.57% were equal to and greater than the prescribed length (220 mm). Length frequency distributions were again similar between open areas and MPAs of Pohnpei, with a few larger individual recorded within MPAs.

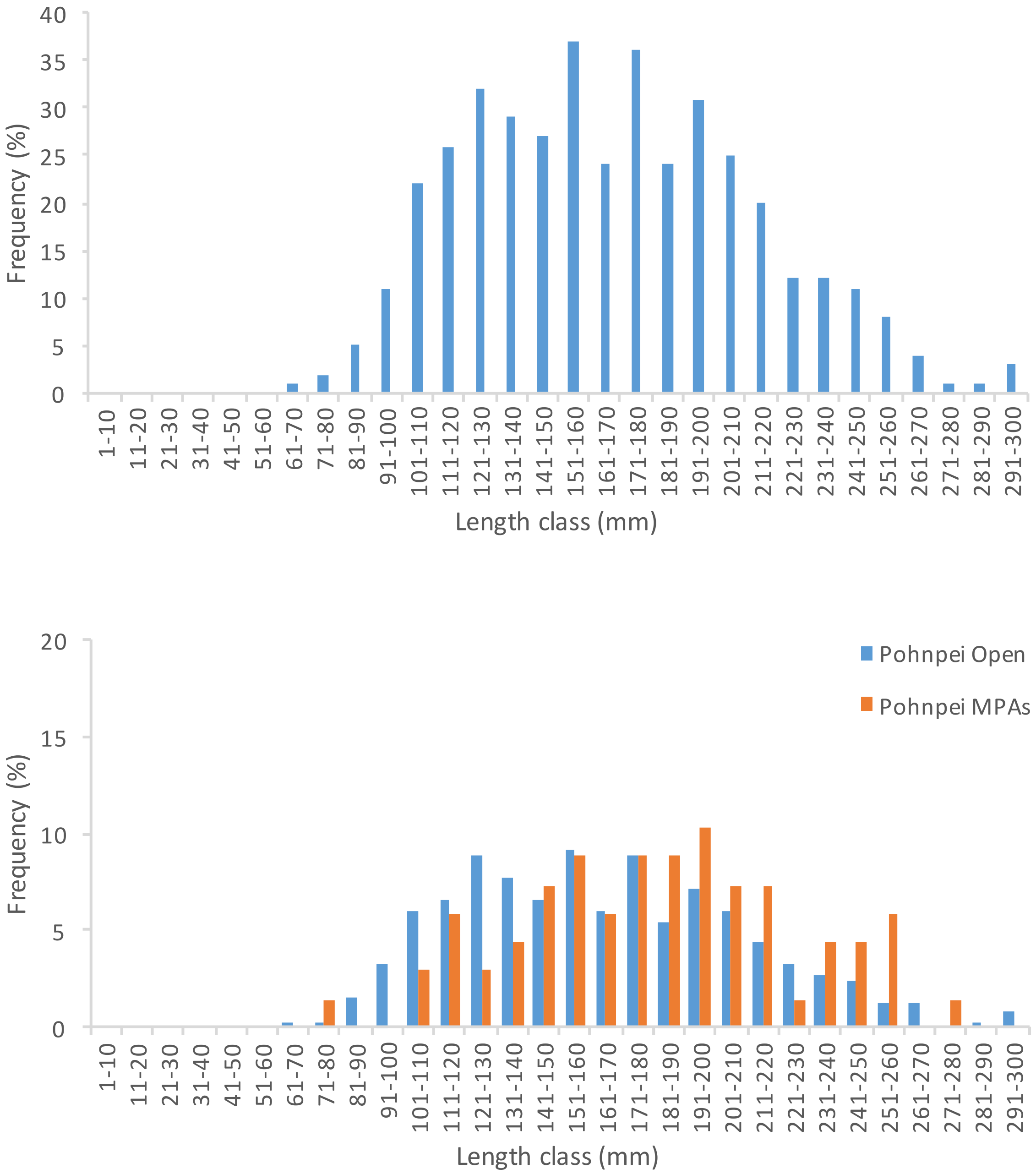


Figure 25. Length frequency of greenfish (*Stichopus chloronotus*) at Pohnpei during the 2017 survey.

Stock estimation

Stock estimations were calculated using the observed mean density of selected species and estimated area of habitat of this species based on survey results. Stock estimations were calculated only for those species that were observed in densities exceeding regional reference densities for at least one type of methodology: pinkfish (*Holothuria edulis*) and surf redfish (*Actinopyga mauritiana*). The estimated stocks were then used to calculate quotas of these selected species.

Area of habitat in Pohnpei

- Pinkfish

Pinkfish was observed in relatively high densities at both reef benthos and soft benthos transect stations and, therefore, the area considered for stock estimation comprises both reef flat and coastal fringe (Figure 26). The area of these habitats inside of MPAs was subtracted from the total area in order to estimate the stock for open areas only.

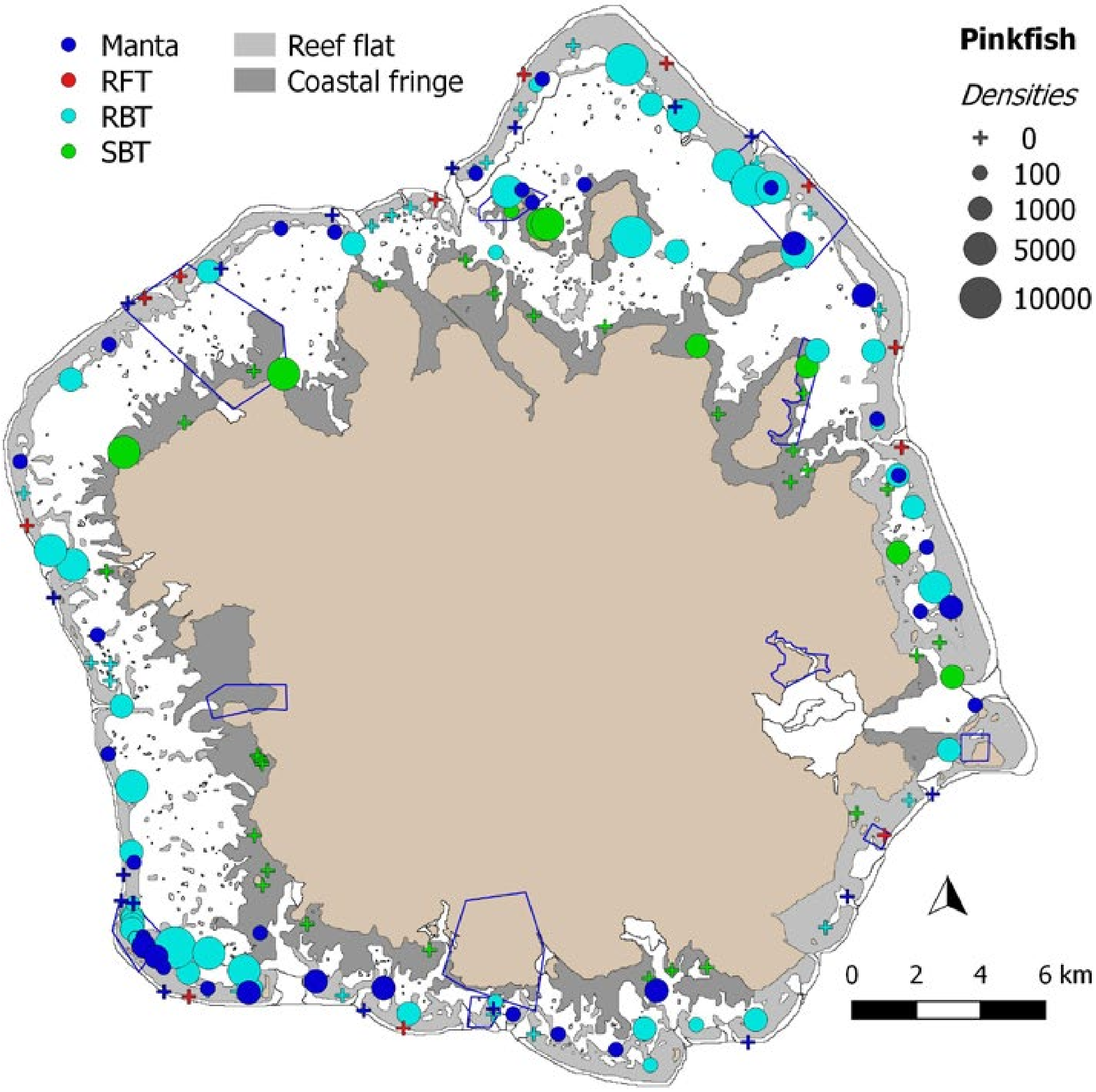


Figure 26. Pinkfish (*Holothuria edulis*) densities by station for each survey methodology and habitat (reef flat and coastal fringe) identified for stock estimates.

- Surf redfish

Surf redfish was observed in high densities at reef front transect stations along the reef crest and, therefore, only this area was considered for stock estimations (Figure 27). Based on field observations, the area of reef crest was calculated as a 50-m band around the reef. The area of the reef crest inside MPAs was subtracted from the total area of the reef crest in order to estimate the stock for open areas only.

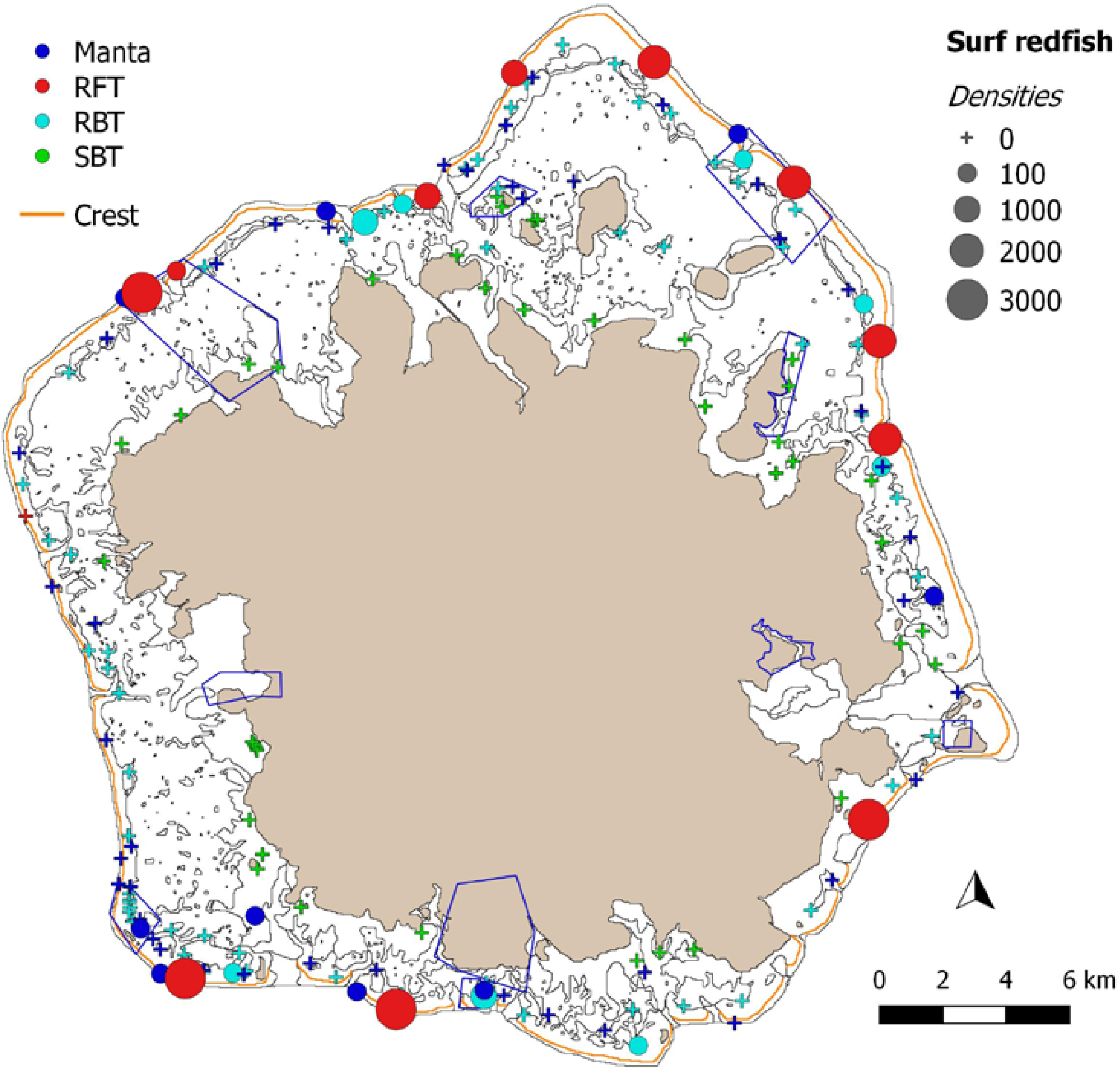


Figure 27. Surf redfish (*Actinopyga mauritiana*) densities by station for each survey methodology and habitat (reef crest) identified for stock estimates.

Surface area

Table 7 summarises the surface area of habitats gathered from QGIS software (Quantum GIS Development Team 2017) for pinkfish and surf redfish. This table includes a conservative approach whereby stock estimations are calculated using 80% of the surface area of each habitat.

Table 7. Area of representative habitats of selected species (pinkfish and surf redfish).

Species	Type area	Width* (m)	Total area (ha)	Marine protected areas (ha)	Open areas (ha)	Conservative approach (80% open)
Pinkfish	Reef flat	na	7,003	674	6,329	5,063
	Coastal fringe	na	6,856	660	6,196	4,956
	Combined	na	13,859	1,334	12,524	10,019
Surf redfish	Crest	50	642	55	587	470

*In the case of surf redfish, a band of 50 m is considered to represent the main habitat used by the species around the reef crest of Pohnpei. This width has been estimated by the authors and based on field observations.

Stock estimates

Table 8 presents the stock estimates for pinkfish and surf redfish. The minimum stock of pinkfish was estimated at 1,769,941 individuals on the reef flat. The 95% CI returned a negative value for pinkfish on the coastal fringe; accordingly, no quota has been calculated for this species in this habitat. For surf redfish, the minimum stock on the reef crest was estimated at 255,354 individuals.

Table 8. Stock estimates for pinkfish and surf redfish.

	Pinkfish		Surf redfish
Type of habitat	Reef flat	Coastal fringe	Crest
80% of habitat area (ha)	5,063	4,956	470
Mean density	922	269	1,208
95% CI	573	324	665
Stock estimates	1,769,941	-273,459	255,354

Quota calculation

The calculated quotas, based on 30% of the adult stock are very low (Table 9). The quotas were 39,717 individuals for pinkfish and 11,859 individuals for surf redfish, corresponding respectively to 2.26% and 4.64% of the entire stock of each species. The calculated quota for the sustainable harvest of pinkfish was 11.5 mt wet (live) weight, corresponding to just less than 0.5 mt of dried product. For surf redfish, the calculated quota was approximately 10 mt wet (live) weight, corresponding to just over 0.5 mt of dried surf redfish.

Table 9. Quota calculation for pinkfish and surf redfish for Pohnpei based on the 2017 assessment.

	Pinkfish	Surf redfish
Stock estimates	1,769,941	255,354
% Maturity size	7.48	15.48
Adult stock	132,392	39,529
30% Adult stock	39,717	11,859
% of overall stock (for harvest)	2.26	4.64
Conversion to wet weight	0.29	0.85
Wet weight (kg)	11,518	10,080
Conversion to dry weight	0.04	0.06
Dry weight (kg)	461	554
Dry weight (t)	0.46	0.55

Cost–benefit analysis

Calculations of the overall purchases from fishers and total export income based on the proposed quota for pinkfish and surf redfish are presented in Table 10.

Table 10. Estimates of purchases from fishers, and export values for the calculated quota.

	Pinkfish	Surf redfish
Harvestable adult stock (individuals)	39,717	11,859
Price paid to fishers (USD/piece)	0.1	0.4
Purchase from fishers (USD)	3,972	4,743
Overall purchase from fishers (USD)	8,715	
High quality export price (USD/dry kg)	6	39
Dry weight of harvestable stock (kg)	461	554
Export income (USD)	2,766	21,606
Total export income (USD)	24,372	

Further information is needed to fully assess the costs and benefits of a harvest based on the calculated quotas (summarised in Table 11). From an initial analysis, based on harvestable quotas, the fishing community could earn up to USD 8715 but when divided into permits, the analysis shows that it would require a well-defined permit selection process because it is only profitable for fishers to get involved if there is a limited number of them (100 or 200), considering that the use of a boat would be required (and would require fishers to buy fuel) for collecting the higher-value surf redfish.

Any company selected to export sea cucumbers from Pohnpei would spend more money paying the USD 25,000 licence fee than it would gain from the income generated from exporting high-quality beche-de-mer product. In addition to the licence fee, a company would have to pay fishers, processing equipment, workers (processing and packing) for about 50,000 sea cucumbers, and export transport costs.

Pohnpei State Government would be the party benefiting the most for this kind of harvest through the payment of licence fees from the exporter. However, the work needed to be done in preparation of the harvest, during the harvest and post-harvest (inspection of processing and exporting) is important and can prove to be costly even though it is quite hard to estimate. Realistically, the costs incurred to OFA would have been much higher than the costs displayed in Table 11 (which represent the minimum costs for a single harvest day based on the 2016 monitoring assessment, which was reported largely insufficient by many stakeholders) and considering that it does not include preparation time before the harvest and data collection and inspection time after the harvest.

Table 11. Costs and benefits (in USD) for involved parties during a single day of sea cucumber harvest based on calculated quotas of this survey.

Exporter		Fishing communities		Pohnpei State Government	
Export incomes	24,372	Incomes	8,715	Incomes (Licence)	25,000
Licence	25,000	100 permits	87	Permits incomes (100 at 3$)	300
Price paid to fishers	8,715	200 permits	44	Monitoring costs – Logistics**	160
Processing wages*	2,100	500 permits	17	Monitoring cost – Staffing***	529
Equipment (processing, packing)	TBA			Other administrative costs	TBA
Export costs (transport)	TBA				

* Based on minimum wages for five staff members working eight hours per day during one month;
** Minimum fuel costs for monitoring during a one-day harvest to cover for three vehicles and four boats based on the 2016 monitoring;
*** Minimum wages for OFA staff for a one day-harvest (23 staffs + overtime) based on the 2016 monitoring.

Stakeholder workshop

A synthesis of the key issues regarding the 2016 harvest, and potential ways to improve these, is provided below to help inform management.

1. **Lack of transparency in quota calculations and how species to be harvested were to be determined.** A major concern among many stakeholder groups revolved around the amount and species of sea cucumbers to be harvested in the 2016 harvest season. The Pohnpei State Government had proposed that 67 mt of wet product, comprising 18 species (or species groups in the case of hairy blackfish and hairy greyfish), could be harvested and exported from Pohnpei's inshore waters. Many stakeholders felt these numbers were excessive, and this sentiment was exacerbated by a lack of information on how these quotas and prescribed species were determined. Stakeholders agreed that quota calculations should be based on the approach provided in Pakoa et al. (2014), and that only species found in densities exceeding regional reference densities for healthy stocks proposed by SPC (Pakoa et al. 2014) should be considered for harvest.

2. **Number of fishing permits awarded.** Under OFA's harvest strategy, it was proposed that permits be awarded to 3500 individual fishers. Many stakeholders felt that this was excessive, citing that it would be beyond the capacity of monitoring agencies to handle so many fishers working over such large areas. Several stakeholder groups proposed that entry to the fishery be limited. Considerable thought would need to be given as to how many fishing licences are appropriate (this would be best determined from quota numbers and individual fisher cost–benefit calculations) and how to allocate individual fishing licences to ensure that benefits of the fishery are distributed equitably. Several stakeholders suggested that priority should be given to those fishers without additional sources of income or low-income households.

3. **Lack of monitoring and enforcement.** This point was largely related to the number of fishing permits that were awarded. Stakeholder groups felt that on-water monitoring and enforcement was insufficient to cope with the large number of fishers targeting sea cucumbers, and concerns were raised over the poaching of sea cucumbers from Pohnpei's many MPAs, with stakeholders stating that OFA lacked the necessary vessels and manpower to adequately enforce regulations. It was suggested that other groups could assist with the on-water monitoring, such as the police and conservation groups (e.g. CSP), and that harvests should be restricted to short time periods (e.g. a few days maximum). In such instances, adequate lead-in time would be required to enable the agencies involved in monitoring sufficient time to request funding of monitoring activities through their budgetary processes.

4. **Irregularities regarding the registration process for fishers and the transferability of quotas.** Several stakeholders questioned the current licence registration process, stating that there were loopholes in the process that allow fishers to register at multiple municipalities, or to register non-fishing family members such as children, or, as suggested by one stakeholder, their pets. Some stakeholders suggested that a single licence could be given per household, and that a single, centralised, and up-to-date registration system could be developed to prevent fishers from registering for multiple licences. It was discussed that a central registration facility may disadvantage fishers who lack the means to travel. In recognition of this, stakeholders proposed either a web-based system could be developed, or that OFA could establish a single registration system (database) and rotate around the municipalities on different days.

5. **Absence of a management plan, and lack of consultation in the development of management strategies.** A major concern of the 2016 harvest was the lack of a formal management plan and lack of communication and consultation when the management strategies for the 2016 harvest were formulated. Accordingly, the development of a management plan should be a high priority for OFA. Stakeholder engagement and consultation should be undertaken at all steps during the development of any new management plan, and should include all stakeholders in the fishery, including fishers, community groups, NGOs, processors, exporters, and local and national fisheries staff.

Conclusions

Results of the in-water survey indicate that sea cucumber populations in Pohnpei are in a poor state. Population densities of most species were below regional reference densities, with densities of high-value species such as white teatfish and sandfish being critically low. The low densities suggest that either the long history of largely unregulated harvests prior to 1991, the 2016 harvest, harvesting for local commerce and subsistence, a disruption of the ecosystem or a combination of factors have negatively impacted sea cucumber stocks around Pohnpei.

Noticeable decreases in density relative to 2013 were evident for several species of commercial (i.e. export) importance, in particular black teatfish, chalkfish, lollyfish, surf redfish and tigerfish. For black teatfish, surf redfish and tigerfish, it is likely that heavy harvesting during the 2016 harvest impacted stocks, resulting in the observed declines in abundance. In support of this suggestion, densities of these species during the 2016–2017 COM survey (Bourgoin and Pelep 2017), which took place after the 2016 harvest, were generally similar to those observed in 2017, indicating that declines had occurred prior to the two surveys, yet after the 2013 survey. In contrast, lollyfish were observed at densities much lower in 2017 than the 2016–2017 COM survey. While we are unable to rule out ecosystem effects or methodological differences, it is possible that the observed decline in lollyfish densities between the 2016–2017 COM survey and the 2017 assessment is due to recent harvests of this species for use as soil fertiliser.

In addition to declines of commercial species, densities of several species important to local consumption were also observed during the survey, in particular curryfish and sandfish. Again, while broad-scale ecosystem effects and methodological differences among surveys cannot be ruled out, these results suggest that local harvests for subsistence purposes are impacting these stocks. Historical data on the local subsistence fishery is lacking, and given the observed declines, greater efforts to quantify local harvests are warranted.

Length frequency data of four commonly observed species, lollyfish, pinkfish, surf redfish and greenfish, and comparisons of mean live length against regional common lengths for most species, revealed that most sea cucumbers measured consisted of small- to medium-sized individuals (below regional common lengths), providing further corroboration that stocks have not yet fully recovered from the long history of harvest prior to 1991. This supports the fact that minimum legal sizes should be imposed for species harvested for both commercial (i.e. export) and local subsistence purposes.

Few differences were observed in sea cucumber densities among MPAs and open areas, either across all MPAs combined or at the level of individual MPAs (Kehpara and Mwahnd), indicating that MPAs do not seem to be effective for conserving sea cucumber populations, despite the fact MPAs were closed during 2016 harvest, and given that some of the MPAs have been in place for many years. However, poaching may have been occurring in the MPAs in 2016, which would have been difficult to control because according to reports, there was limited on-water monitoring during the harvest. In addition, due to the small size of the MPAs and their limited number, fewer stations were surveyed in the MPAs, and surveys may have missed aggregations of sea cucumbers in these areas.

Estimated harvestable quotas of the two species (pinkfish and surf redfish) above reference densities in open areas totalled around 1 mt of dried beche-de-mer product. The cost–benefit analysis undertaken suggests that opening the fishery for such a limited amount would be of little economic benefit to any stakeholder, and proceeding with such a harvest may encourage illegal fishing and exports as a means of increasing profits.

Recommendations for management and monitoring

Considering the poor state of sea cucumber in Pohnpei, we strongly recommend that the Pohnpei State Government keep the commercial fishery closed for at least another five years and to implement a management plan for the sea cucumber subsistence fishery.

However, if the Pohnpei State Government decides to proceed with opening the commercial sea cucumber fishery for export, another detailed sea cucumber management plan needs to be developed and implemented prior to any harvest.

Both plans need to be transparent and agreed on by stakeholders through consultation meetings. The different aspects presented in both plans are based on results from this survey and in relation to comments made during the stakeholder meeting held on 26 May 2017 in Pohnpei.

Commercial sea cucumber export fishery management plan

The commercial sea cucumber export fishery management plan needs to include:

1) **Harvest strategies (quotas) and prescribed species.**
Successful implementation of quotas in the long term is a challenge. This is especially true when looking at the few active sea cucumber fisheries in the region, as it requires a well-defined monitoring strategy of catches, which can prove costly (i.e. considerable involvement of staff) for the resource-limited fisheries agencies of Pacific Island countries and territories. While there are various quotas (export quota, total quota and individual quota) and non-quota options, from consultations it appears that an individual fisher harvest quota is the government's preferred option for managing the commercial fishery.

   If the individual fisher harvest quota strategy is favoured for commercial species, the quota should be established based on up-to-date scientific data available from field surveys. Following the recommendations of Pakoa et al. (2014), only those species observed in densities exceeding regional reference densities should be subject to harvest. Accordingly, in this report, quotas have been proposed (for a single harvest) only for two species: pinkfish, 0.5 mt and surf redfish, 0.5 mt, based on the 2017 assessment. In future, survey methodologies and estimations of stock size and harvestable quotas should follow the same process and the same conservative methodological approach as this report with: densities, size frequencies to determine proportion of adults, estimation of area of suitable habitat, stocks estimates (Pakoa et al. 2014). Spatial distribution and abundance of sea cucumbers around Pohnpei were highly variable. It is not recommended to set quotas for specific locations because it may interfere with the fair division of resources among communities and with the monitoring during harvest. In addition to these critical considerations, the following points should be discussed:

   a. The budget of agencies involved with harvests, including at the planning and implementation stages, should be allocated in advance to match the corresponding workload during a commercial harvest;

   b. Enforcement during a commercial harvest should be increased, both on the water and at landing sites, possibly with the help of local police and NGOs;

   c. Logsheets should be filled in at: landing sites, processing sites and exporting sites. Inspections must be carried out to avoid poaching;

   d. If quotas are exceeded, penalties should be levied to all involved parties on a sliding scale.

2) **Size limits**
With the exception of the 2016 harvest strategy plan, there were no size recommendations for the commercial harvest, meaning that all components of the sea cucumber stock, including juveniles, were available for harvest.

   Mean sizes of commercially targeted sea cucumber species during the 2017 assessment were mostly below regional common sizes. This result is consistent with the findings of surveys of the University of Guam (CSP 2016) and COM (Bourgoin and Pelep 2017), and suggests that populations may be composed of young individuals, likely juveniles and subadults. To allow all species the chance to reproduce before being harvested, minimum size limits should be introduced. Minimum sizes for species harvested for the beche-de-mer trade are proposed in Table 12. Sizes could be adapted based on knowledge of local size-at-maturity when available. Given that the export value of sea cucumbers is often positively correlated with body size (Purcell 2014b), introducing minimum harvest sizes would also help to maximise economic benefits.

3) **Permits and licence**
The 2016 sea cucumber harvest allowed for one company to export up to 67 mt through an expression of interest process, and up to 3500 individual fisher permits. The expression of interest seems to be a fair way of selecting the most suitable candidates. The selection of a single company may reduce the risk of overharvesting (no competition for profits) and simplify the monitoring process post-harvest. The most suitable candidate should be among the most profitable to fishing communities (i.e. will buy sea cucumber at a good price) and the most conscientious in terms of resource availability at the time of harvest (to avoid overexploitation). The number of individual permits seemed excessive for the amount of sea cucumbers to be harvested, and some irregularities were recorded through the registration process. Irregularities reflected the lack of

controls, which allowed fishers the possibility of being awarded several permits through multiple registrations or by the registration of an ineligible family member (e.g. children) or pets. The following points should, therefore, be discussed:

a. Fair division of resources among communities and permit holders with the possibility of awarding permits only to households with limited or no other means of revenue;

b. Limiting the number of permits and improving traceability through a better registration process in order to avoid one person being awarded several permits;

c. Quota defined on resource availability (based on the most recent assessment results) with regard to species and numbers, with possible use of different permits (as in 2016) to facilitate the monitoring of catches.

4) **Seasonality**

Most sea cucumber species in the Pacific Islands region reproduce during summer. For successful egg fertilisation, sea cucumbers must aggregate together when spawning. At these times, they are highly vulnerable to overfishing. Accordingly, it is recommended that commercial harvests be prohibited during this period. Moreover, to ensure effective monitoring of catches, the commercial fishery should take place over a very short time frame and even limited to one or several days as planned for the 2016 harvest.

5) **Raising awareness and prohibiting detrimental practices**

In addition to their critical role in reef ecosystems, sea cucumbers have other proven uses in the region, and not including their high value on the Asian market. In addition to the management measures discussed above, there are several ways to ensure the biology and ecological role of these species is well understood and to make sure that these resources will be available for future generations, such as:

a. raising awareness of these species, especially in the fishing community to develop communication on newly implemented management measures, including species identification; and

b. prohibiting detrimental fishing practices, such as the collection of lollyfish for use as soil fertiliser.

Table 12. Minimum size limits for sea cucumber species used in 2016 and proposed new size limits.

Common name	Scientific name	2016 harvest minimum size (wet)	Proposed new minimum sizes (wet)	Proposed new minimum sizes (dry)
Amberfish	*Thelenota anax*		16 in	8 in
Black teatfish	*Holothuria whitmaei*	10 in	14 in	8 in
Brown sandfish	*Bohadschia vitiensis*	8 in	12 in	6 in
Chalkfish	*Bohadschia similis*	12 in	8 in	4 in
Deepwater redfish	*Actinopyga echinites*	10 in	8 in	4 in
Deepwater blackfish	*Actinopyga palauensis*	10 in	11 in	
Elephant trunkfish	*Holothuria fuscopunctata*	12 in	16 in	8 in
Flowerfish	*Pearsonothuria graeffei*		12 in	6 in
Greenfish	*Stichopus chloronotus*	8 in	8 in	4 in
Grey impatient	*Holothuria arenicola*		4 in	
Hairy blackfish / greyfish	*Actinopyga miliaris*	8 in	8 in	4 in
Impatient sea cucumber	*Holothuria impatiens*		7 in	
Lollyfish	*Holothuria atra*	8 in	12 in	6 in
Pinkfish	*Holothuria edulis*	8 in	8 in	5 in
Prickly redfish	*Thelenota ananas*	12 in	16 in	6 in
Red snakefish	*Holothuria roseomaculata*	20 in	14 in	8 in
Snakefish	*Holothuria coluber*	20 in	16 in	8 in
Stonefish	*Actinopyga lecanora*	8 in	8 in	4 in
Surf redfish	*Actinopyga mauritiana*	10 in	9 in	4 in
Tigerfish / Leopardfish	*Bohadschia argus*	10 in	12 in	6 in
White snakefish	*Holothuria leucospilota*		16 in	8 in
White teatfish	*Holothuria fuscogilva*	10 in	14 in	8 in

Subsistence sea cucumber fishery management plan

A number of sea cucumber management measures are proposed for a commercial sea cucumber export management plan; however, only some of these would be adapted to the local subsidence fishery.

Quotas and permit allocation are unlikely to be suitable for the local subsistence fishery because they would require costly ongoing monitoring of catches and rigorous up-to-date data management. Other options, presented below (including area closures through the MPA network, and minimum legal harvest sizes, permits, seasonality and community education and awareness programs), may be more suitable to managing the local fishery:

- **Size limits.** Minimum sizes for the harvest of subsistence species have never been recommended for Pohnpei. As for commercially targeted species, mean size of locally harvested species were (when available) low and consistent with findings of previous surveys (CSP 2016; Bourgoin and Pelep 2017). Imposing minimum harvest sizes for curryfish, sandfish, brown curryfish, dragonfish, grey impatient sea cucumber and red impatient sea cucumber would allow for a greater portion of their populations to reproduce. Proposed minimum harvest sizes are presented in Table 13 but could be adapted based on knowledge of local size-at-maturity.

- **Seasonality.** Enforcing a seasonal closure during summer while local subsistence species aggregate for reproduction is likely to reduce fishing pressure. However, better knowledge on the species' reproduction patterns in FSM could be useful to adapt closure times.

- **Raising awareness.** As for the commercial fishery management plan, it is critical to raise awareness about local subsistence species, especially among the fishing community, in order to develop communication on their ecological importance, on newly implemented management measures, including species identification.

Table 13. Proposed minimum sizes for harvesting subsistence sea cucumber species.

Common name	Scientific name	Proposed new minimum sizes (wet)
Brown curryfish	*Stichopus vastus*	12 in
Curryfish	*Stichopus herrmanni*	14 in
Dragonfish	*Stichopus horrens*	8 in
Grey impatient	*Holothuria arenicola*	4 in
Impatient sea cucumber	*Holothuria impatiens*	7 in
Sandfish	*Holothuria scabra*	9 in

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Appendix 1:
Densities of sea cucumber species observed during manta tow surveys.

Site	Common name	Overall Mean Density (ind/ha)	SE	n	Present Mean Density (ind/ha)	SE_P	n_P	%_P
Ant 2017	Tigerfish	3.42	1.30	13	6.34	1.79	7	54
Ant 2017	Brown sandfish	1.71	1.71	13	22.22		1	8
Ant 2017	Lollyfish	12.82	11.45	13	33.33	29.17	5	38
Ant 2017	White teatfish	0.85	0.57	13	5.51	0.05	2	15
Ant 2017	Elephant trunkfish	2.35	1.57	13	10.19	4.90	3	23
Ant 2017	Black teatfish	0.21	0.21	13	2.78		1	8
Ant 2017	Greenfish	1.28	1.28	13	16.67		1	8
Ant 2017	Curryfish	1.28	1.07	13	8.33	5.56	2	15
Ant 2017	Prickly redfish	9.58	3.44	13	17.79	4.42	7	54
Ant 2017	Amberfish	2.73	2.73	13	35.52		1	8
Pohnpei MPA 2017	Surf redfish	2.78	2.01	7	9.72	4.17	2	29
Pohnpei MPA 2017	Tigerfish	36.11	23.61	7	50.56	31.43	5	71
Pohnpei MPA 2017	Lollyfish	263.49	94.15	7	368.89	94.32	5	71
Pohnpei MPA 2017	Snakefish	0.60	0.60	7	4.17		1	14
Pohnpei MPA 2017	Pinkfish	114.09	64.42	7	133.10	72.83	6	86
Pohnpei MPA 2017	Elephant trunkfish	12.50	8.08	7	43.75	2.08	2	29
Pohnpei MPA 2017	Flowerfish	7.34	4.52	7	17.13	7.71	3	43
Pohnpei MPA 2017	Greenfish	71.83	50.98	7	100.56	68.82	5	71
Pohnpei MPA 2017	Curryfish	37.30	18.94	7	87.04	18.59	3	43
Pohnpei MPA 2017	Prickly redfish	0.99	0.66	7	3.47	0.69	2	29
Pohnpei Open 2017	Deepwater redfish	0.19	0.19	45	8.33		1	2
Pohnpei Open 2017	Stonefish	0.06	0.06	45	2.78		1	2
Pohnpei Open 2017	Surf redfish	2.96	1.27	45	19.05	4.98	7	16
Pohnpei Open 2017	Hairy blackfish	1.17	0.88	45	13.19	8.66	4	9
Pohnpei Open 2017	Tigerfish	28.85	5.63	45	39	6.82	33	73
Pohnpei Open 2017	Brown sandfish	0.25	0.25	45	11.11		1	2
Pohnpei Open 2017	Lollyfish	189.83	95.30	45	251.24	124.74	34	76
Pohnpei Open 2017	Snakefish	2.53	1.34	45	14.24	6.29	8	18
Pohnpei Open 2017	Pinkfish	43.42	7.15	45	67.38	8.19	29	64
Pohnpei Open 2017	Red snakefish	0.86	0.47	45	9.72	2.89	4	9
Pohnpei Open 2017	White teatfish	0.12	0.12	45	5.56		1	2
Pohnpei Open 2017	Elephant trunkfish	8.60	2.40	45	23	4.65	17	38
Pohnpei Open 2017	Black teatfish	3.36	1.25	45	15.11	3.82	10	22
Pohnpei Open 2017	Flowerfish	6.07	1.76	45	13.67	3.28	20	44
Pohnpei Open 2017	Greenfish	28.36	8.21	45	42.54	11.52	30	67
Pohnpei Open 2017	Curryfish	14.60	4.76	45	36	9.99	18	40
Pohnpei Open 2017	Brown curryfish	0.06	0.06	45	2.78		1	2
Pohnpei Open 2017	Spotted-worm sea cucumber	0.06	0.06	45	2.78		1	2
Pohnpei Open 2017	Prickly redfish	7.59	2.38	45	21.35	5.22	16	36

Appendix 2:
Densities of sea cucumber species observed during reef benthos transects.

Site	Common name	Overall Mean Density (ind/ha)	SE	n	Present Mean Density (ind/ha)	SE_P	n_P	%_P
Ant 2017	Tigerfish	17.05	8.52	22	75.00	24.30	5	23
Ant 2017	Lollyfish	71.97	33.71	22	226.19	81.76	7	32
Ant 2017	Prickly redfish	3.79	3.79	22	83.33		1	5
Pohnpei MPA 2017	Surf redfish	31.25	26.21	16	250.00	166.67	2	13
Pohnpei MPA 2017	Hairy blackfish	5.21	3.56	16	41.67		2	13
Pohnpei MPA 2017	Tigerfish	106.77	37.26	16	170.83	49.86	10	63
Pohnpei MPA 2017	Brown sandfish	2.60	2.60	16	41.67		1	6
Pohnpei MPA 2017	Lollyfish	2505.21	607.21	16	2505.21	607.21	16	100
Pohnpei MPA 2017	Snakefish	96.35	46.07	16	256.94	93.43	6	38
Pohnpei MPA 2017	Pinkfish	1166.67	436.44	16	1435.90	510.72	13	81
Pohnpei MPA 2017	Red snakefish	5.21	5.21	16	83.33		1	6
Pohnpei MPA 2017	Flowerfish	5.21	3.56	16	41.67		2	13
Pohnpei MPA 2017	Greenfish	151.04	65.43	16	268.52	101.61	9	56
Pohnpei MPA 2017	Curryfish	7.81	5.67	16	62.50	20.83	2	13
Pohnpei MPA 2017	Prickly redfish	2.60	2.60	16	41.67		1	6
Pohnpei Open 2017	Deepwater redfish	4.01	3.29	52	104.17	62.50	2	4
Pohnpei Open 2017	Surf redfish	8.81	3.68	52	76.39	12.80	6	12
Pohnpei Open 2017	Hairy blackfish	3.21	1.55	52	41.67	0.00	4	8
Pohnpei Open 2017	Deepwater blackfish	4.81	3.56	52	125.00	41.67	2	4
Pohnpei Open 2017	Tigerfish	76.92	16.87	52	153.85	26.23	26	50
Pohnpei Open 2017	Brown sandfish	4.81	3.37	52	83.33	41.67	3	6
Pohnpei Open 2017	Lollyfish	3995.99	704.84	52	4155.83	724.01	50	96
Pohnpei Open 2017	Snakefish	475.96	156.15	52	1125.00	324.34	22	42
Pohnpei Open 2017	Pinkfish	922.28	292.19	52	1410.54	425.36	34	65
Pohnpei Open 2017	Red snakefish	41.67	27.13	52	361.11	204.88	6	12
Pohnpei Open 2017	Tiger tail	4.01	2.36	52	69.44	13.89	3	6
Pohnpei Open 2017	Black teatfish	34.46	10.28	52	119.44	24.69	15	29
Pohnpei Open 2017	Flowerfish	16.83	10.57	52	109.38	61.97	8	15
Pohnpei Open 2017	Greenfish	306.09	81.22	52	468.14	115.29	34	65
Pohnpei Open 2017	Curryfish	0.80	0.80	52	41.67		1	2

Appendix 3:
Densities of sea cucumber species observed during soft benthos transects.

Site*	Common name	Overall Mean Density (ind/ha)	SE	n	Present Mean Density (ind/ha)	SE_P	n_P	%_P
Pohnpei MPA 2017	Lollyfish	11684.03	3397.57	12	17526.04	3547.23	8	67
Pohnpei MPA 2017	Snakefish	13.89	10.68	12	83.33	41.67	2	17
Pohnpei MPA 2017	Pinkfish	416.67	282.92	12	1250.00	730.26	4	33
Pohnpei MPA 2017	Red snakefish	6.94	6.94	12	83.33		1	8
Pohnpei MPA 2017	Tiger tail	6.94	6.94	12	83.33		1	8
Pohnpei MPA 2017	Greenfish	38.19	23.76	12	152.78	60.54	3	25
Pohnpei MPA 2017	Brown curryfish	45.14	35.33	12	270.83	145.83	2	17
Pohnpei Open 2017	Deepwater redfish	6.17	4.82	27	83.33	41.67	2	7
Pohnpei Open 2017	Hairy blackfish	10.80	9.33	27	145.83	104.17	2	7
Pohnpei Open 2017	Tigerfish	3.09	3.09	27	83.33		1	4
Pohnpei Open 2017	Chalkfish	4.63	3.40	27	62.50	20.83	2	7
Pohnpei Open 2017	Brown sandfish	4.63	4.63	27	125.00		1	4
Pohnpei Open 2017	Lollyfish	4496.91	1652.16	27	7588.54	2533.79	16	59
Pohnpei Open 2017	Snakefish	74.07	44.61	27	500.00	213.14	4	15
Pohnpei Open 2017	Pinkfish	268.52	165.15	27	1450.00	727.37	5	19
Pohnpei Open 2017	Red snakefish	20.06	12.26	27	135.42	59.84	4	15
Pohnpei Open 2017	Tiger tail	239.20	223.60	27	2152.78	1946.82	3	11
Pohnpei Open 2017	Sandfish	10.80	6.89	27	97.22	36.75	3	11
Pohnpei Open 2017	Greenfish	55.56	36.41	27	500.00	209.72	3	11
Pohnpei Open 2017	Brown curryfish	413.58	396.11	27	2233.33	2119.26	5	19

*Soft benthos transect method was not used in Ant

Appendix 4:
Densities of sea cucumber species observed during reef front transects.

Site**	Common name	Overall Mean Density (ind/ha)	SE	n	Present Mean Density (ind/ha)	SE_P	n_P	%_P
Pohnpei MPA 2017	Deepwater redfish	10.42	10.42	4	41.67		1	25
Pohnpei MPA 2017	Surf redfish	1697.92	668.05	4	1697.92	668.05	4	100
Pohnpei MPA 2017	Lollyfish	614.58	295.79	4	614.58	295.79	4	100
Pohnpei MPA 2017	White teatfish	10.42	10.42	4	41.67		1	25
Pohnpei Open 2017	Deepwater redfish	10.42	10.42	8	83.33		1	12.5
Pohnpei Open 2017	Surf redfish	1208.33	339.14	8	1380.95	337.09	7	87.5
Pohnpei Open 2017	Lollyfish	812.50	256.13	8	812.50	256.13	8	100
Pohnpei Open 2017	Black teatfish	5.21	5.21	8	41.67		1	12.5
Pohnpei Open 2017	Greenfish	46.88	41.25	8	187.50	145.83	2	25

**There were no records of sea cucumber at reef front transect stations in Ant Atoll.

Appendix 5:
Mean lengths of sea cucumber species observed at each site.

Site	Common name	Mean length (mm)	SE (mm)	No. specimens measured	Total no. specimens observed
Ant 2017	Tigerfish	272.22	17.00	9	25
Ant 2017	Lollyfish	204.08	7.34	38	98
Ant 2017	Prickly redfish	405.00	65.00	2	47
Pohnpei MPA 2017	Deepwater redfish	205.00		1	1
Pohnpei MPA 2017	Surf redfish	203.65	2.62	104	111
Pohnpei MPA 2017	Hairy blackfish	270.00	40.00	2	2
Pohnpei MPA 2017	Tigerfish	293.90	8.00	41	103
Pohnpei MPA 2017	Brown sandfish	210.00		1	1
Pohnpei MPA 2017	Lollyfish	138.53	1.38	1155	4872
Pohnpei MPA 2017	Pinkfish	151.43	1.97	391	806
Pohnpei MPA 2017	Red snakefish	350.00	50.00	2	4
Pohnpei MPA 2017	White teatfish	195.00		1	1
Pohnpei MPA 2017	Tiger tail	87.50	12.50	2	2
Pohnpei MPA 2017	Flowerfish	267.50	12.50	2	17
Pohnpei MPA 2017	Greenfish	184.62	5.25	68	242
Pohnpei MPA 2017	Curryfish	290.00	5.77	3	59
Pohnpei MPA 2017	Brown curryfish	153.46	7.48	13	13
Pohnpei MPA 2017	Prickly redfish	410.00		1	3
Pohnpei Open 2017	Deepwater redfish	173.64	9.66	11	14
Pohnpei Open 2017	Surf redfish	200.37	2.04	301	362
Pohnpei Open 2017	Hairy blackfish	187.00	16.08	10	30
Pohnpei Open 2017	Deepwater blackfish	245.00		1	6
Pohnpei Open 2017	Tigerfish	250.29	6.08	86	542
Pohnpei Open 2017	Chalkfish	116.67	47.02	3	3
Pohnpei Open 2017	Brown sandfish	185.56	11.80	9	13
Pohnpei Open 2017	Lollyfish	144.28	0.90	2618	10998
Pohnpei Open 2017	Pinkfish	136.70	1.46	695	1989
Pohnpei Open 2017	Red snakefish	216.50	12.74	16	79
Pohnpei Open 2017	Tiger tail	96.14	4.98	56	160
Pohnpei Open 2017	Sandfish	180.71	20.60	7	7
Pohnpei Open 2017	Black teatfish	244.95	6.77	44	94
Pohnpei Open 2017	Flowerfish	303.25	25.53	20	119
Pohnpei Open 2017	Greenfish	168.13	2.47	336	869
Pohnpei Open 2017	Curryfish	230.00		1	239
Pohnpei Open 2017	Brown curryfish	102.19	3.17	73	269