The status of reef invertebrate resources and recommendations for management

at Tokelau

July 2013

SPC
Secretariat
of the Pacific
Community

The status of reef invertebrate resources and recommendations for management at Tokelau

July 2013

by

Tumua Pasilio[1], Foliga Pereira[1], Kerat Rikim[1], Kalo Pakoa[2] and Ian Bertram[2]

[1] Department of Economic Development, Natural Resources and Environment, Government of Tokelau
[2] Secretariat of the Pacific Community

Secretariat of the Pacific Community (SPC), Noumea, New Caledonia, 2013

Original text: English

Secretariat of the Pacific Community Cataloguing-in-publication data

Pasilio, Tumua

The status of reef invertebrate resources and recommendations for management at Tokelau: July 2013 / by Tumua Pasilio, Foliga Pereira, Kerat Rikim, Kalo Pakoa and Ian Bertram

1. Sea cucumbers — Tokelau.
2. Marine resources — Tokelau.
3. Marine invertebrates — Tokelau.

I. Pasilio, Tumua II. Pereira, Foliga III. Rikim, Kerat IV. Pakoa, Kalo V. Bertram, Ian

VI. Title

VII. Tokelau. Department of Economic Development, Natural Resources and Environment

VIII. Secretariat of the Pacific Community

593.96099615 AACR2

ISBN: 978-982-00-0669-0

Photographs and illustrations by SPC staff except where noted.
Printed at the Secretariat of the Pacific Community headquarters, Noumea, New Caledonia.

Contents

Acknowledgements

The Department of Economic Development, Natural Resources and Environment (EDNRE) of Tokelau and the Secretariat of the Pacific Community (SPC) acknowledge with gratitude the funding support provided by the Australia Climate Change Multi-Country Support Program to cover the cost of field training and assessment in Nukunonu and for attachment training for three Tokelau inshore fisheries officers at SPC in Noumea.

We acknowledge the collaborative support of the staff of the Department of EDNRE, and their assistance with the surveys. In particular, we acknowledge Director Mika Perez and Fisheries Manager Mose Pelasio for their overall guidance, and Olive Viliamu, Kahimilo Niko and Manatua Rimoni for their assistance with surveys in Atafu and Fakaofo.

We acknowledge the support of Lindsay Chapman (Manager, SPC Coastal Fisheries Programme) and Franck Magron (Information Manager, SPC Coastal Fisheries Science and Management Section) for providing technical assistance with the database and GIS work.

We also thank the Tapulega of Atafu, Nukunonu and Fakaofo and the communities for their support to allow assessments to be undertaken on their respective islands.

Summary

This report presents the results of macro-invertebrate assessments completed in Nukunonu in May 2012, and Atafu and Fakaofo during April and May 2013.

Elongated giant clams and coconut crabs are important food items in Tokelau. Both resources have been managed relatively well in terms of their conservation for local use. However, elongated giant clam resources at Atafu need further management attention; in particular, cost-effective options to introduce large broodstocks, or juveniles clams should be explored to rejuvenate the population. Some improvements in the management of elongated giant clams at Nukunonu and Fakaofo and coconut crabs at all three atolls should be considered.

In the recent past many sea cucumber fisheries in the region have been in an unstable state and beche-de-mer buyers are looking for new suppliers. Commercial exploitation of sea cucumber occurred in Nukunonu in early 2012, and the Tapulega of Atafu and Fakaofo may also receive expressions of interest to harvest sea cucumbers, as many stocks in the region are in a critical state. Densities of lollyfish (*Holothuria atra*) in Atafu and Fakaofo and tigerfish (*Bohadschia argus*) in Fakaofo are greater than healthy reference densities for the region determined by SPC. These resources could support a very small commercial fishery. Should the Tapulega and community of Atafu and Fakaofo choose to harvest sea cucumber resources for the beche-de-mer trade, it will be important to develop, implement and monitor effective fishery management frameworks. Management tools and harvest strategies for consideration are outlined in the recommendations of this report.

1. Introduction

1.1 Background

Tokelau consists of three atolls: Atafu, located at 8° 33′ 06″ S, 172° 30′ 03″ W; Nukunonu, at 9° 10′ 06″ S, 171° 48′ 35″ W; and Fakaofo, located at 9° 21′ 15″ S, 171° 12′ 43″ W. The total land area of the three atolls is just over 12 km^2 within an exclusive economic zone (EEZ) of 319,000 km^2 (Fig. 1). The atolls have relatively deep lagoons with several lagoon patch reefs. The lagoons are surrounded by a coral reef rim and small islands (*motu*), and there are no large, deep reef passages at any of the atolls. Access to the open ocean for artisanal and subsistence fishing is through small passages that are shallower than one metre at low tide. Reef and lagoon areas are 20 km^2, 111 km^2 and 61 km^2 for Atafu, Nukunonu and Fakaofo respectively. Water exchange between the ocean and lagoons occur through tidal movements and oceanic-induced waves.

The population of Tokelau is 1,370 people, of whom 482 reside on Atafu, 397 on Nukunonu and 490 on Fakaofo (Tokelau Census of Population and Dwellings 2011). These communities are highly dependent on the lagoon, reef and ocean resources for sustenance. Excess seafood is stored in freezers, and occasionally shipped to relatives and friends abroad. There are no airstrips in Tokelau; movement into and out of Tokelau atolls is by shipping services operating from Apia, Samoa.

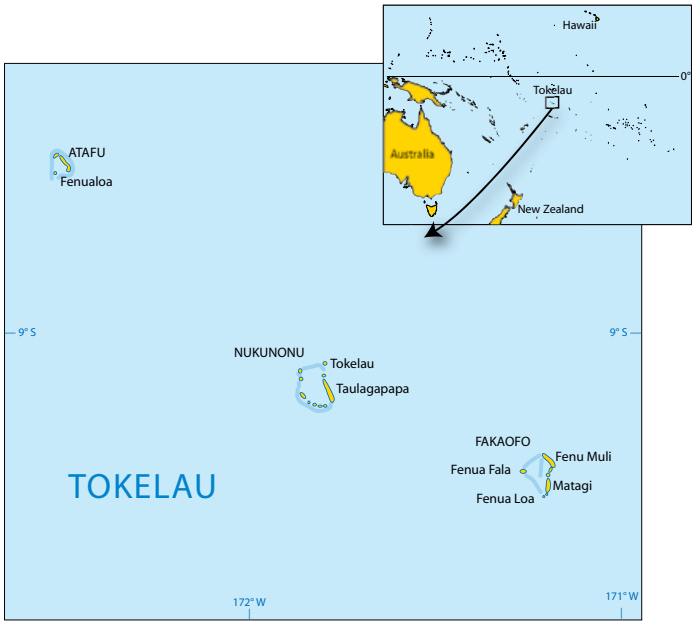


Figure 1. Tokelau.

1.2 Invertebrate resources

Some of the more common invertebrate food resources of Tokelau include octopuses (*Octopus* sp.), giant clams (*Tridacna* sp.), lobsters (*Panulirus* sp.), crabs (*Cardisoma* sp., *Grapsus* sp., *Birgus latro*) and gastropods (*Strombus luhuanus*) (Fig. 2). Triton shell (*Charonia tritonis*) was traditionally used to call communities for gatherings or communal events, and cowrie shells have been used for crafts and jewellery.

The elongated giant clam (*Tridacna maxima*) is widespread throughout the atolls' coral reef habitats. They are filter feeders, feeding on very small drifting plants, and can also obtain food through the process of photosynthesis. After spawning, fertilised eggs hatch into small larvae and drift in the sea for about 7–10 days, then settle on hard substrate such as coral. *T. maxima* first mature as male then later act as both

male and female. *T. maxima* reach full maturity at shell length of between 100 mm and 140 mm; however, there are records of *T. maxima* reaching maturity as males at 55–60 mm (Jameson 1976; Lewis 1987). Maximum *T. maxima* sizes differ across the Pacific, with smaller maximum sizes observed in the islands of the eastern Pacific. For example, a maximum size of 220 mm and a mean size of 61 mm were recorded at Mangaia in the Cook Islands in the eastern Pacific, while a maximum size of 340 mm and a mean size of 150 mm were recorded at Sidea, Papua New Guinea in the western Pacific (Pinca et al. 2010).

The coconut crab is the largest land-dwelling crustacean; sexual maturity is reached at approximately 25 mm thoracic length or at around 5 years of age (Amesbury 1980). Maximum size is reported to be 150 mm carapace length or weight of up to 3.5 kg, with a lifespan of up to 50 years (Amesbury 1980). Females release eggs into the sea at high tide. These eggs hatch and drift in the currents for about a month. Less than one in every thousand survive to crawl up the beach as juvenile coconut crabs. Coconut crab is an important food item for Tokelau communities and is regularly offered at community feasts and to visitors. The coconut crab (*Birgus latro*) is present on many *motu* in Tokelau's three atolls. At Nukunonu the main *motu* where coconut crabs are found are Tokelau mamao, Tapuniu, Fenualoa, and Vaitupu. At Atafu, coconut crabs are found on the *motu* of Teoki, Tekapi, Na utua, Fale and Fenualoa.

Four sea cucumber species have been reported to be present at Fakaofo (Passfield 1998). Sea cucumbers are not a traditional source of food for Tokelauans. Lollyfish (*Holothuria atra*) and surf redfish (*Actinopyga mauritiana*) have been used to stun small fish and invertebrates (e.g. octopus). Passfield (1998) documented high densities of lollyfish (*H. atra*) and moderate densities of surf redfish (*A. mauritiana*) and tigerfish (*Bohadschia argus*) while high-value black teatfish (*Holothuria whitmaei*) were rare in Fakaofo. *H. atra* was thought to be of little commercial interest in 1998 due its small size and low commercial value (Passfield 1998). The sea cucumber species in Tokelau feed on benthic or sediment detritus matter in the first few millimetres of lagoon/reef floor; this helps reduce nutrient loads and control micro-algae growth. All sea cucumbers in Tokelau move slowly, and the majority of species are found in depths of less than 20 m. Most species reproduce sexually, while a few species, such as lollyfish and greenfish, are capable of asexual reproduction. Fertilised sea cucumber eggs hatch and drift in currents for three to four weeks, then settle on the sea floor as juveniles. High densities of mature spawning sea cucumbers are needed for successful recruitment.

Interest in commercial fishing of sea cucumber emerged in 2011 after an investor expressed interest in buying sea cucumber in Nukunonu. The Tapulega (island governing authority) approved a joint venture company to process and export sea cucumber from the atoll. Local communities were involved in the collection of sea cucumber for sale to the company for processing to fully dried beche-de-mer for export. Village fishers began harvesting in early 2012, selling their catch fresh in 18- or 20-litre buckets for NZD 15.00 to NZD 20.00 per bucket of fresh, ungutted sea cucumber.

Figure 2. Coconut crab catch and clam meat are important food items for Tokelau communities.

1.3 Management of invertebrate resources

Marine resources in Tokelau are generally open for community use. Management of each atoll's resources is the responsibility of the respective Tapulega, who may make rules on the use and management of the atoll's resources. A system of sharing (*inati*), where each member of the community receives equal shares or portions of harvested resources, is practised in each of the communities. Restrictions on fishing at particular areas (*fakahao* or *lafu*) are sometimes practised; for example, during periods of bad weather, the Tapulega may restrict fishing on the outer reef slope or open ocean. *Fakahao* may also be imposed to restrict fishing in certain areas for periods ranging from a few days to several months for the purpose of protecting resources in these areas for future community fishing activities. A system of restricted resource use is practised to protect certain resources from harvest. For example, Nukunonu Tapulega introduced a prohibition on harvesting elongated giant clams (*T. maxima*) for export during the period March to October each year. In addition, export of coconut crabs (*B. latro*) from Nukunonu and Fakaofo is prohibited. At Atafu, harvesting clams is prohibited. Fishers in the three communities are encouraged to target the larger size during hunting expeditions.

Coconut crabs and clams are protected from harvest on Fenualoa (a small *motu* located at the southern tip of Fakaofo) and in its immediate surrounding lagoon area in Fakaofo. In the past, *motu* Tokelau in Nukunonu was used as an area for keeping the community's pigs. In an effort to protect coconut crabs, all pigs on the *motu* were killed during the mid-1990s.

Anyone wishing to harvest reef resources for commercial purposes must first provide an environmental impact and cost-benefit analysis and seek the approval from the Tapulega.

1.4 Previous studies

A number of in-water surveys documenting presence, abundance and status of several invertebrate resources have been carried out in Tokelau. Giant clams and pearl oysters were assessed in 1989 (Braley 1989). The introduced species *Tectus niloticus* (trochus) was assessed at all three atolls by Gillett in 1988 and at Fakaofo and Nukunonu by Pelasio in 1989 and 1990. Passfield documented results of rapid in-water assessments of marine resources and presented socio-economic information gathered at Fakaofo in 1998. Comprehensive work and interviews on the state of common marine resources and the ecosystems, the intensity of fishing activities and the community's views of the state of resources and the environment were conducted in 2002 and 2003 at Atafu, Nukunonu and Fakaofo (Fisk et al. 2004a, 2004b, 2004c).

1.5 Objectives

In March 2012, Tokelau's Department for Economic Development, Natural Resources and Environment (EDNRE) asked the Secretariat of the Pacific Community (SPC) Coastal Fisheries Programme for technical assistance in assessing sea cucumber stocks at Nukunonu. The request was prompted by community concerns about the commercial exploitation of sea cucumbers and the resource's sustainability. In May 2012, SPC's Coastal Fisheries Programme trained three EDNRE inshore fisheries officers in underwater visual census survey methods for invertebrates. Data were collected on invertebrate resources at Nukunonu atoll during this field training, and a preliminary report on sea cucumber was subsequently provided to the Nukunonu Tapulega (Bertram et al. 2012).

Through financial support from EDNRE, the trained inshore fisheries officers assessed invertebrate resources at Atafu and Fakaofo in April and May 2013. While sea cucumber was the target species group for the assessments, information on other invertebrate resources that are important as sources of food — such as giant clam and coconut crab — was also gathered and is summarised in this report. This report presents the findings of in-water invertebrate assessments conducted at all three Tokelau atolls. The purpose of the assessments was to gather data that could be used to inform the Tapulega on the status of invertebrate resources in their respective atolls.

2. Assessment methods

2.1 Underwater resource surveys and catch assessment

A stratified sampling design was used for underwater invertebrate resource assessments in the three atolls. The reef and lagoon areas were divided into four sectors: North, South, East and West. Within each sector, fine-scale reef benthos transects (RBt) were used to assess resources on the reef crest, reef flat, back reef and patch reef habitats, and manta tow was used to assess resources in the shallow lagoon habitat to provide information on abundance and size structure, and where possible to determine population sizes.

RBt is suitable for fine-scale assessment in shallow areas (< 3 m). With this method, two snorkellers, equipped with measuring instruments and record boards or slates, record the abundance and size of invertebrates within transects. Each reef benthos station is comprised of six 40 by 1 metre transects spaced around 5 to 10 metres apart (Fig. 3). Manta tow is more suited to broad-scale assessment in water depths of 2–10 m. It involves a boat towing a surveyor at slow speed (Fig. 3). The surveyor observes and records species within a belt 2 m wide by 300 m long. Six 300 by 2 metres manta tow belts constitute a station. Manta tow assessment can overlook the smaller and more cryptic invertebrates. Species and habitat information for RBt and manta tow were recorded and a global positioning system (GPS) waypoint logged for each station.

At all stations, macro-invertebrates were measured, counted and recorded. The particular focus was on sea cucumber but others such as giant clams and sea urchins were also included. All in-water assessments were in depths of less than 10 metres and no in-water assessments were done at night or along the outer reef slope. For more information on invertebrate survey methodology that SPC is promoting for use in the region, see the upcoming publication *Manual for assessing tropical marine invertebrate resources for management purposes in the Pacific islands* (SPC in press).

Information on *T. maxima* size was recorded for catches during the surveys and from shell piles of past harvest in Nukunonu in May 2012.

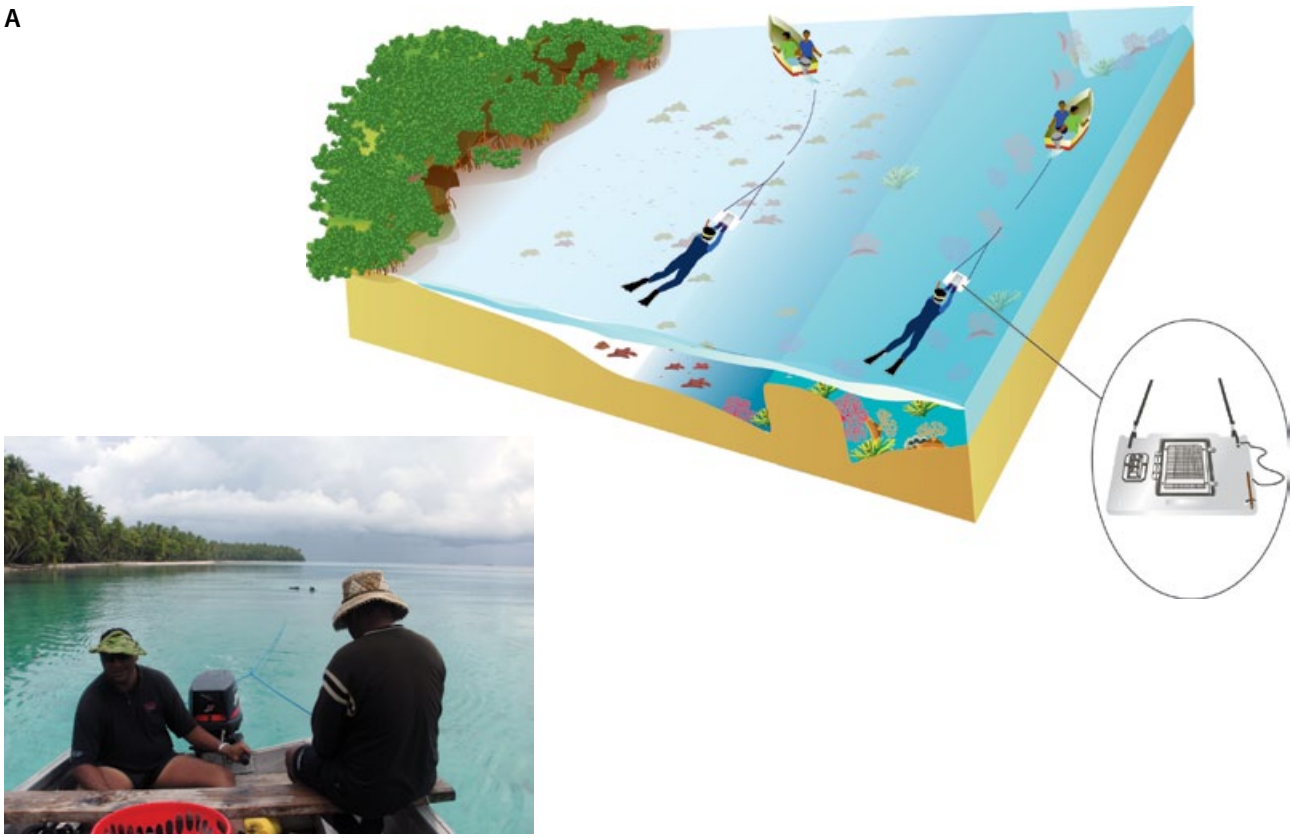
Data were entered into the Reef Fisheries Integrated Database (RFID) during attachment training undertaken in Noumea and were analysed to produce density estimates, size frequency distributions and estimates of population where possible. Density for RBt assessments for all sites and manta for Nukunonu was extracted from RFID. Due to the malfunction of the GPS setting at Atafu and Fakaofo, the trip computer function could not be used to measure tow distances. However the boat speed, and start and finish times of each tow were recorded so transect length could be approximated, resulting in a series of long transects (1300 to 6600 m) instead of a series of six 300 m tows in a station. Data from this modified manta tow assessment were analysed in Excel as they did not conform to RFID format. All analyses of density estimates are presented as overall density for habitats assessed.

2.2 Coconut crab resource survey and catch assessment

Coconut crabs (*B. latro*) were surveyed at *motu* Tokelau (Nukunonu) in May 2012 and *motu* Na Utua (Atafu) in June 2012 (Fig. 4). At *motu* Tokelau, two teams of surveyors conducted night searches for coconut crabs with torches. One survey team consisted of four searchers and one of the searchers also recorded the survey team's data. The second team consisted of four searchers and a dedicated data recorder. Each surveyor searched for coconut crabs within a 4-metre wide swathe across the *motu* and each team completed two sets of transects. The distance covered by each transect was later determined using GIS and a satellite map of the *motu*.

The size of coconut crabs found in a transect path was measured as cephalothoracic length (CL) and thoracic length (TL). The sex of each crab was also determined when possible; female crabs were identified by their egg-carrying appendages beneath the abdomen (Fig. 5).

A



B

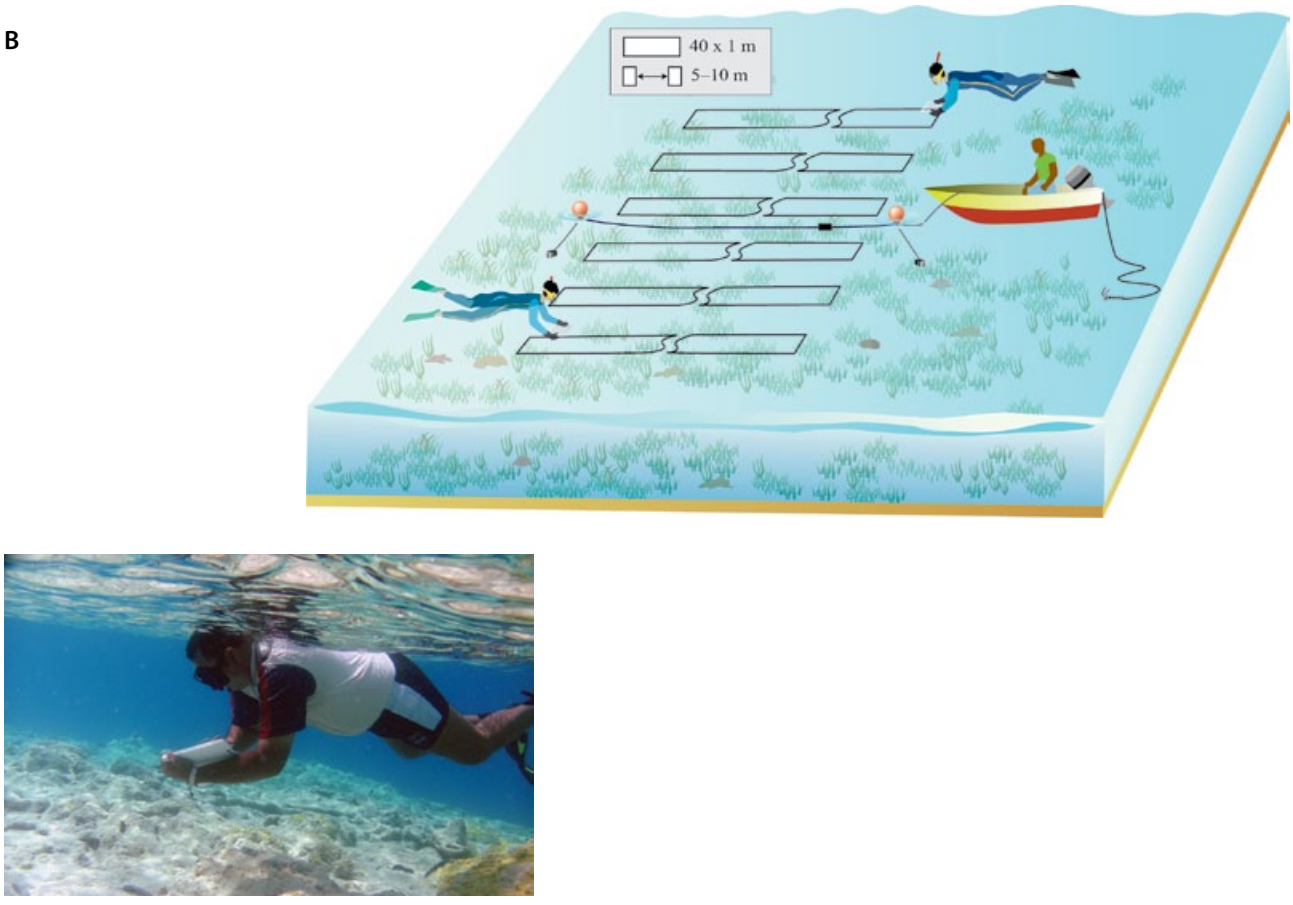


Figure 3. Assessment methods adopted for invertebrate surveys at Tokelau atolls. A: manta tow; B: reef benthos transects (Illustration by Youngmi Choi, SPC).

Coconut crab catch for *motu* Tokelau (Nukunonu) was measured from the catch of a team of five hunters who spent one hour hunting crabs at night. Some of the crabs caught were roasted and eaten on the *motu*, and these were included in the count.

At *motu* Na Utua in Atafu, information such as period of fishing, the number of fishers, and the size and sex of coconut crabs was recorded from catches made during the day by a team of seven hunters. During these day hunts, crab burrows were identified and tested using sticks: hollow burrows indicate the direction in which to search for a coconut crab, which is then located and dug up. CL and TL of captured crabs were measured and their sex determined. Catch from three night-fishing trips by two hunters, who searched for two to three hours each time, was also measured and recorded at Atafu. Coconut crab night surveys were not undertaken at Atafu; at Fakaofo, no night searches were conducted nor was catch information recorded for coconut crabs during this period.

Figure 4. Coconut crab assessment sites:
motu Tokelau, Nukunonu (left) and *motu* Na Utua, Atafu (right).

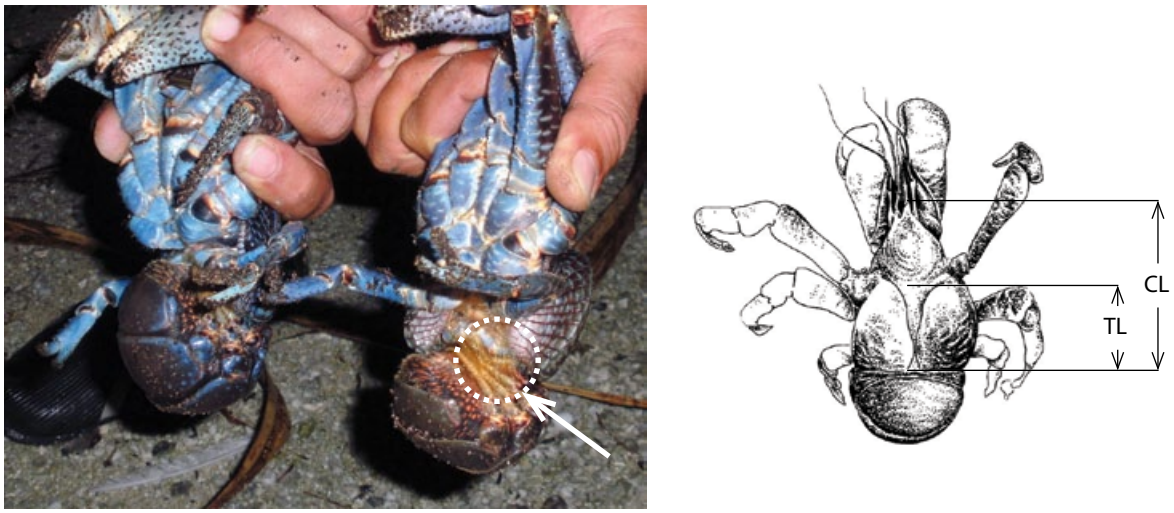


Figure 5. Photo: male crab (left) and female crab with egg-carrying appendages indicated by the white circle (right). Illustration: measures of coconut crab length in terms of cephalothoracic length (CL) and thoracic length (TL)

3. Results

3.1 In-water survey coverage

Sufficient areas were covered through reef benthos transect and manta tow stations in Nukunonu, Atafu and Fakaofo (Table 1). For maps of the station locations and further details, see Appendix 1.

Table 1. Coverage of in-water resources survey.

Atoll	Survey method	Number of survey stations	Total area surveyed (m^2)	Total area (ha)
Nukunonu	RBt	37	8,880	0.88
	Manta	12	43,200	4.32
Atafu	RBt	37	8,880	0.88
	Manta	8	31,100	3.11
Fakaofo	RBt	35	8,400	0.84
	Manta	15	48,560	4.87

3.2 Species present during in-water surveys

Six species of sea cucumber were recorded during the assessments (Fig. 6). Three species were found at Atafu, four at Fakaofo and five at Nukunonu (Table 2). Lollyfish was the most common species found at all three atolls, with 26,756 specimens recorded at Atafu; 5,612 at Nukunonu, and 1,925 at Fakaofo. Three forms of lollyfish were noted at Nukunonu and Atafu: the larger reef lollyfish, which inhabited the high-energy reef flat; the common small lollyfish; and the unusual hard, stubby form (Fig. 7). The stubby form of lollyfish was found in Matalele, Atafu and at the narrow lagoon reef flat of Long Island, Nukunonu. This stubby form has not been found in other sites assessed in the Pacific Island region. The common lollyfish was found throughout all habitats while larger lollyfish was less common but still present in all sites. Greenfish was present only at Nukunonu, and surf redfish only at Atafu and Fakaofo. Tigerfish was recorded at all three atolls. A few specimens of the high-value black teatfish and white teatfish were recorded at Nukunonu and Fakaofo but not at Atafu.

The elongated giant clam, *T. maxima* (*fahua*), was present at all three atolls: it was most common at Nukunonu followed by Fakaofo, and relatively rare at Atafu. Fluted giant clam, *T. squamosa* (*fahuataka*), was present at Fakaofo and Nukunonu and absent at Atafu. It was recorded by manta tow surveys along the lagoon slope, indicating the specimens were in deeper habitats. Its absence in shallow areas assessed by reef benthos transects (Table 2) suggests shallow-water stocks may have been harvested. *T. maxima* is important in Tokelau as a subsistence food and is generally harvested in depths of less than two metres.

Tectus niloticus (trochus) was introduced to Fakaofo in 1986 and through a second attempt in 1988 and later to Nukunonu and Atafu (Gillett 1994). A 1998 assessment at Fakaofo documented 162 trochus ranging from 90–100 mm basal diameter, which were found along the reef crest and reef flat at the south east of the island at Fale to the Catholic Church (Passfield 1998). During this assessment no trochus were found, which may be because they live in habitats not covered in this assessment (e.g. outer reef slope); the finding indicates that trochus are not widespread among Tokelau atolls. The sea urchin (*Echinothrix diadema*) was present at all three atolls. Appendix 2 lists scientific, common and local names for species found during these assessments.

Figure 6. Sea cucumber species recorded during assessments in Tokelau.
A: White teatfish (*Holothuria fuscogilva*); B: Black teatfish (*Holothuria whitmaei*); C: Lollyfish (*Holothuria atra*); D: Tigerfish (*Bohadschia argus*); E: Greenfish (*Stichopus chloronotus*); F: Surf redfish (*Actinopyga mauritiana*).

Table 2. Occurrences of invertebrate species recorded by survey types.

Species	Nukunonu			Atafu			Fakaofo		
	RBt	Manta	Total	RBt	Manta	Total	RBt	Manta	Total
Lollyfish	4,484	1,128	5,612	19,198	4,940	26,756	1,918	7	1,925
Tigerfish	7	49	56	20	18	38	53	314	367
Black teatfish	2	–	2	–	–	–	2	33	35
White teatfish	–	2	2	–	–	–	–	19	19
Greenfish	676	–	676	–	–	–	–	–	–
Surf redfish	–	–	–	6	–	6	5	–	5
Thorny oyster	–	–	–	–	–	–	2	40	42
Elongated giant clam	4,001	8,893	12,894	34	144	178	802	3,397	4,199
Fluted giant clam	–	1	1	–	–	–	–	9	9
Crown of thorns	–	–	–	–	–	–	–	7	7
Green turtle	–	–	–	–	1	1	–	2	2
Blue black urchin	340	–	340	42	–	42	36	8	44
Tiger cowrie	1	–	1	2	–	2	–	–	–
Ring cowrie	–	–	–	2	–	2	–	–	–
Giant spider conch	3	–	3	–	–	–	–	–	–
Strawberry conch	–	–	–	–	–	–	3,091	–	3,091

Figure 7. Three forms of lollyfish (*Holothuria atra*).
A: normal; B: large; C: stubby.

3.3 Density analysis

Species density descriptions — or the number of individuals per hectare — come from both fine-scale surveys targeting reef flat (Table 3) and broad-scale manta tow surveys targeting deeper areas along the lagoon slope (Table 4). The results indicated differences in densities between these two assessment areas: generally common macro-invertebrates, such as blue black urchin (*E. diadema*), are present on the reef flats of the three atolls while lollyfish (*H. atra*) and the elongated giant clam (*T. maxima*) are more concentrated on the shallow reef flats and coral pinnacles than in deeper areas on the lagoon slopes and around the patch reefs.

Table 3. Invertebrate densities (ind. ha^{-1}) from RBt surveys by site.

Species	Nukunonu		Atafu		Fakaofo		Region
	Average	SE	Average	SE	Average	SE	Manta
Lollyfish	3,933	1,615	21,816	5,512	7,918	5,350	5,600
Tigerfish	7	4	20	8	53	29	120
Greenfish	677	474	–	–	–	–	3,500
Black teatfish	1	1	–	–	58	46	50
White teatfish	–	–	–	–	2	14	20
Surf redfish	–	–	7	7	5	3	200
Elongated giant clam	4,002	1,001	34	22	802	542	750
Fluted giant clam	–		–	–	–	–	20–30
Blue black urchin	360	106	43	25	37	32	–
Hyotissa sp.	30	30	–	–	–	–	–
Tiger cowrie	1	1	2	2	–	–	–
Ring cowrie	–	–	1	1	–	–	–
Giant spider conch	3	3	–	–	–	–	–
Terebra sp.	1	1	–	–	–	–	–
Strawberry conch	–	–	–	–	3,092	1,535	–

Table 4. Invertebrate densities (ind. ha^{-1}) from manta tow surveys by site.

Species	Nukunonu		Atafu		Fakaofo		Region
	Average	SE	Average	SE	Average	SE	Manta
Lollyfish	31	10.0	1,727	850.0	2	1.6	2,400
Tigerfish	1	0.2	7	3.2	46	20.5	50
Greenfish	–	–	–	–	–	–	1,000
Black teatfish	–	–	–	–	6	2.3	10
White teatfish	–	–	–	–	3	1.7	–
Elongated giant clam	3,008	658.0	45	17.0	741	241.4	–
Fluted giant clam	–	–	–	–	1	1.0	–
Thorny oyster	–	–	–	–	5	4.5	–
Crown of thorns	–	–	–	–	1	0.6	–
Green turtle	–	–	–	–	< 1	0.2	–

The most abundant sea cucumber species in the three atolls was lollyfish (*H. atra*), with the highest density recorded at Atafu (21,816 ± 5,511 ind. ha^{-1}), followed by Fakaofo (7,918 ± 5,350 ind. ha^{-1}) and lastly Nukunonu (3,933 ± 1,615 ind. ha^{-1}) (Fig. 8). The species is most widely distributed at Atafu, where it appeared in 97% of all stations surveyed; it was less widespread at Nukunonu (68% of stations); and least of all at Fakaofo (46% of stations) (Fig. 8 and Appendix 3). When compared with the regional reference density[1] of 5,600 ind. ha^{-1} for healthy lollyfish stock, densities at Atafu and Fakaofo are healthy as they are above this reference point. However, lollyfish density at Nukunonu was 30% lower than the regional reference level. Commercial fishing for lollyfish has occurred in Nukunonu since February 2012, which has contributed to the lower stock levels, while lollyfish stocks at the other two sites have not been exposed to commercial fishing.

Density for tigerfish was greater at Fakaofo than at Atafu and Nukunonu, with RBt assessments showing relatively high densities of about 300 and 100 ind. ha^{-1} at the Fakaofo reef adjacent to Koko alaala and Talapeka respectively (Fig. 8). From manta tow assessments, however, overall density for the shallow lagoon habitat was much lower at 53 ± 29 ind. ha^{-1}.

Black teatfish density was 58 ± 46 ind. ha^{-1} at Fakaofo. This species was also observed at Nukunonu (2 specimens) but was absent from Atafu.

Giant clam (*T. maxima*) density was higher at Nukunonu (4,002 ± 1,001 ind. ha^{-1}) than Fakaofo, and it was very low at Atafu (Fig. 9). The resource is protected from any harvesting at Atafu so the low density levels may be due to previous heavy fishing pressure, or may have arisen because the stocks are so low that they limit the success of spawning and recruitment. Prior to the 1980s, clam populations at Atafu were in a reasonably healthy state and 100 clams could be collected with relative ease during an hour's gleaning (Temo Lopa, personal communication). Lopa suggests that cyclones during 1987, 1989 and 1991 may have contributed to a rapid decline in clam stocks at Atafu. Fisk et al. (2004a) reported finding 96 clams per hectare in suitable habitat in the Atafu lagoon in 2003, but cautioned this is probably an overestimate due to the aggregated nature of elongated giant clams. The current study estimates there are 34 ± 22 ind. ha^{-1} for the reef flats and coral patch reefs of Atafu.

[1] Regional reference densities for sea cucumber were determined from 91 sites assessed in 17 countries over the period 2002–2012 and taking the mean of the upper 25% of these densities. Effectively, they are an average of the 25% of the highest abundance levels (densities) from the Pacific Island dataset held at SPC. These regional densities can be used as a baseline with which to compare abundances of sea cucumbers at different locations.

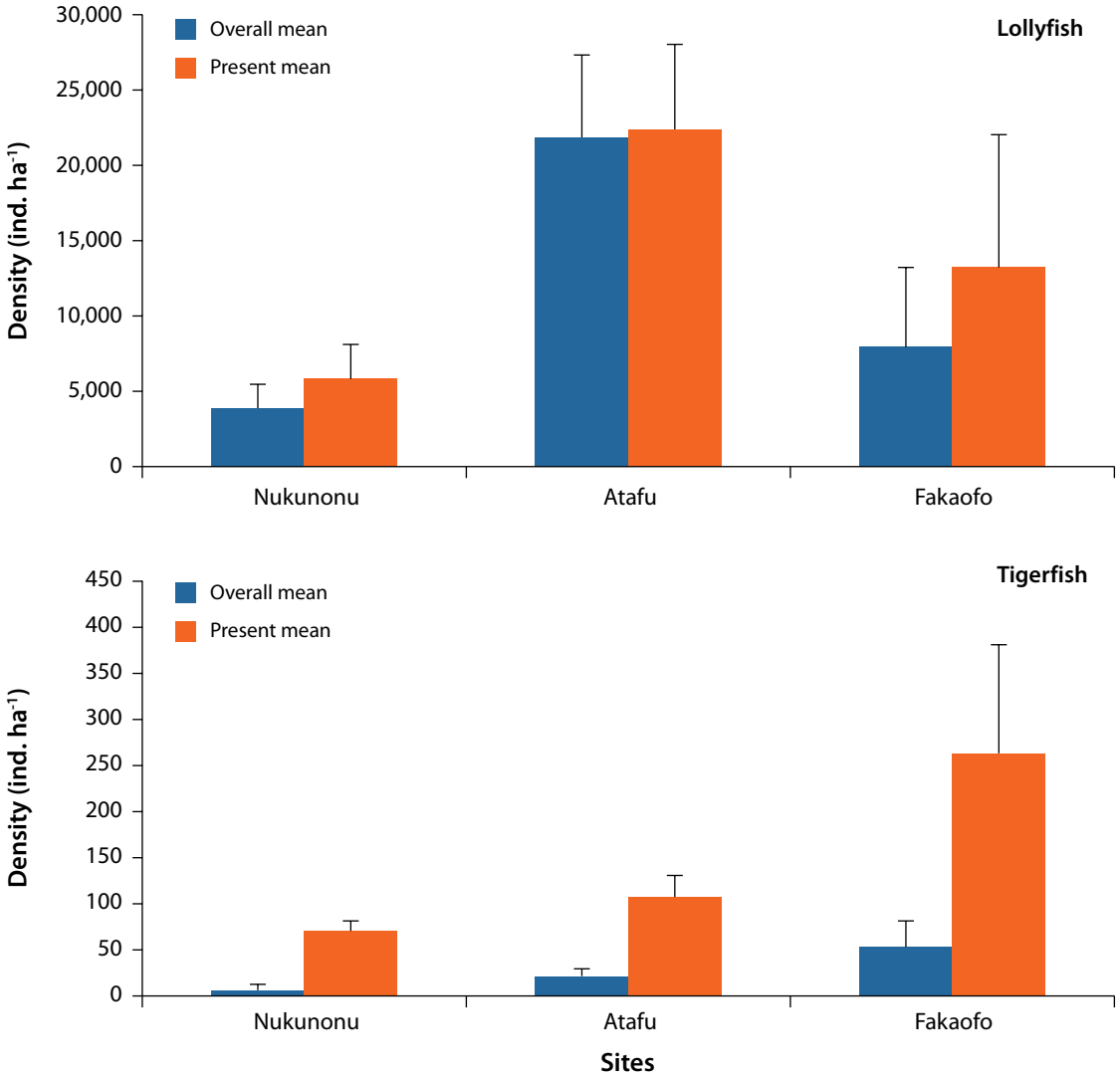


Figure 8. Overall and present mean densities for lollyfish (*Holothuria atra*) (above) and tigerfish (*Bohadschia argus*) (below) assessed by RBt surveys.

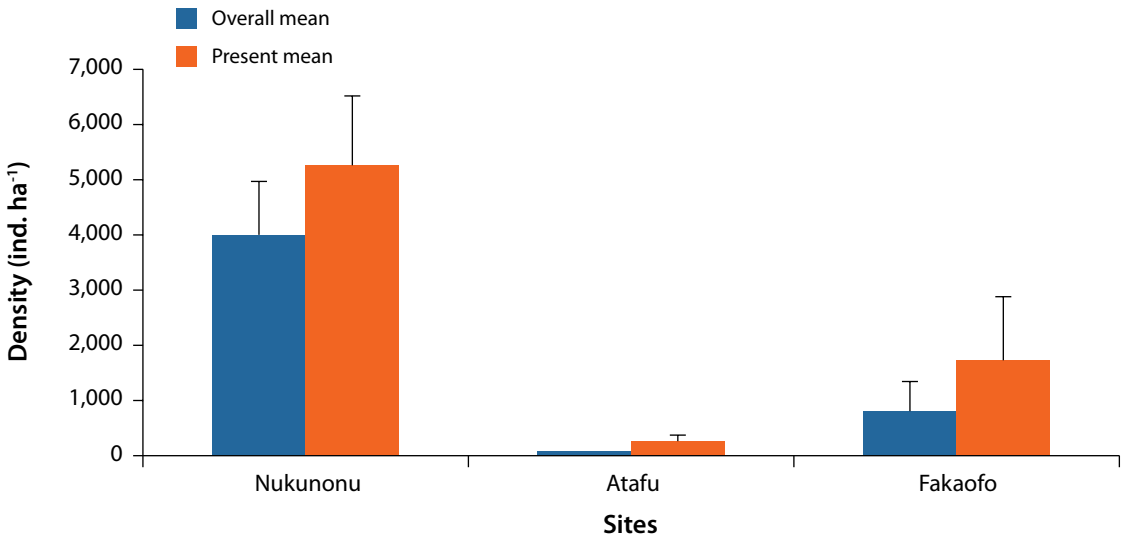


Figure 9. Overall and present mean densities (ind ha^{-1}) of elongated giant clams (*T. maxima*) assessed by RBt surveys.

The blue black urchin (*E. diadema*) was common in the three atolls, with the highest density of 360 ± 106 ind. ha^{-1} at Nukunonu (Table 3). Where there are high numbers of *E. diadema*, they can prevail over other grazing invertebrates in the competition for food (turf algae), space and shelter.

The pest species crown of thorns starfish (*Acanthaster planci*), locally known as *alomea*, was found only in Fakaofo in low densities (1 ind. ha^{-1}) from a manta tow survey at Koko alaala (Fakaofo). Densities of around 8–10 ind. ha^{-1} cause damage to live coral; and densities greater than 30 ind. ha^{-1} cause serious damage to coral reef systems.

3.4 Mean size and distribution from in-water surveys

To further understand status of stocks, the mean size of invertebrates was calculated for all species whose length was measured at the three atolls (Table 5). Note that mean sizes are based on sample size; the larger the sample, the more representative the mean size is.

Table 5. Mean size (mm) of invertebrates by atoll.

Species	Statistics	Nukunonu	Atafu	Fakaofo
Lollyfish	Average size (mm)	126	124	107
	SE	1.6	1.2	2.0
	Sample size	710	1,438	574
Tigerfish	Average size (mm)	309	319	310
	SE	37.0	16.0	10.0
	Sample size	6	18	43
Black teatfish	Average size (mm)	300	–	257
	SE	–	–	14.0
	Sample size	1	–	11
Surf redfish	Average size (mm)	–	302	260
	SE	–	11.0	37.2
	Sample size	–	6	4.0
Greenfish	Average size (mm)	116	–	–
	SE	3.4	–	–
	Sample size	121	–	–
White teatfish	Average size (mm)	–	–	265
	SE	–	–	5.0
	Sample size	–	–	2
Elongated giant clam	Average size (mm)	76	126	82
	SE	1.2	5	2.4
	Sample size	744	29	219
Tiger cowrie	Average size (mm)	–	95	80
	SE	–	5	–
	Sample size	–	2	1
Strawberry conch	Average size (mm)	–	–	37
	SE	–	–	0.6
	Sample size	–	–	199

The mean size for lollyfish is provided as one mean size for all three forms of the species found; the longest was 340 mm recorded at Atafu. Their size distribution shows how much the stock structure differs between the three sites (Fig. 10). The lower maximum size recorded at Nukunonu (275 mm) is partly due to commercial fishing of lollyfish there, which removes many of the larger specimens.

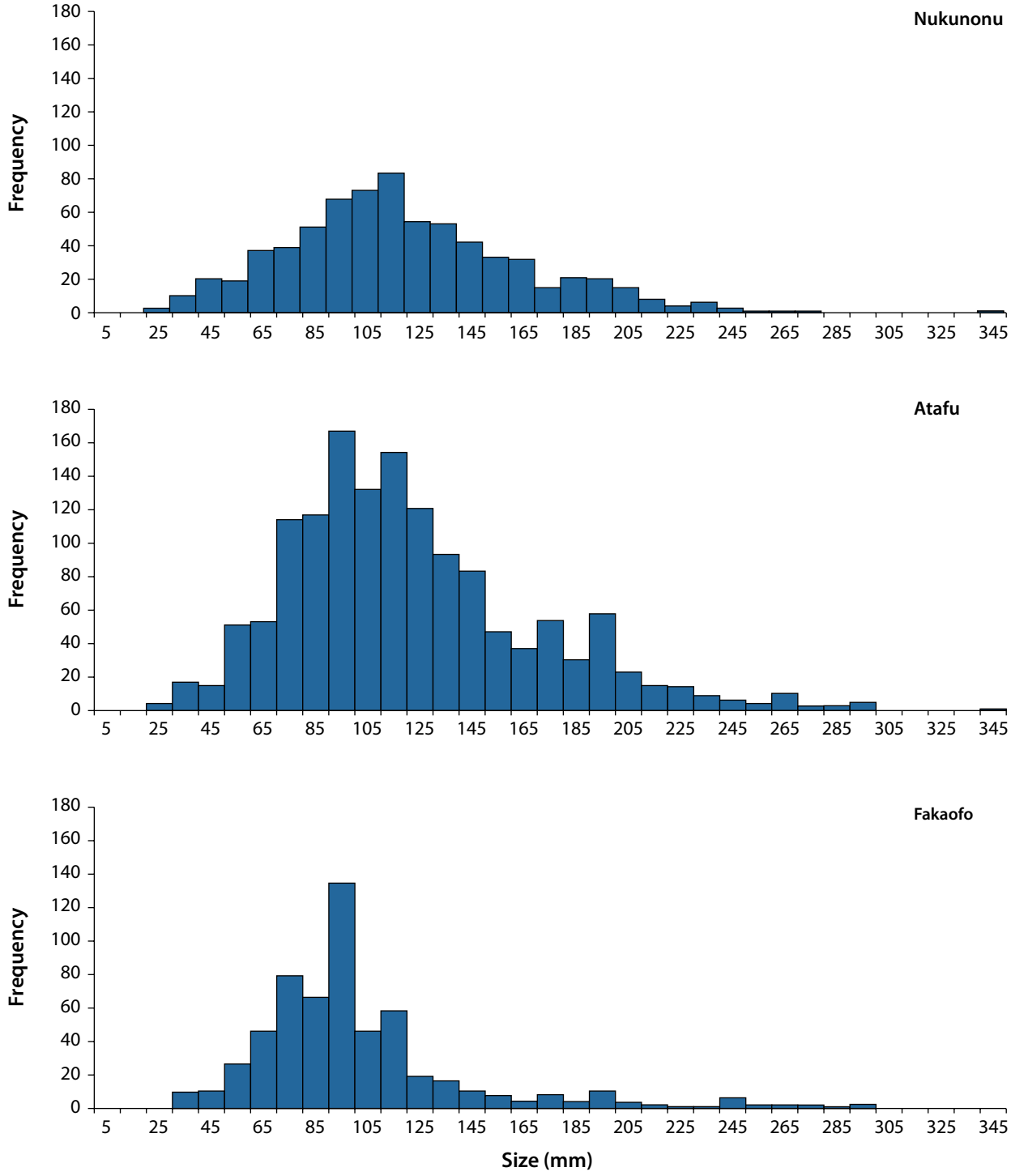


Figure 10. Size distribution of lollyfish (*H. atra*) by atoll. In the Pacific Island region, the mean size observed is 230 mm and maximum size reported is 650 mm.

Tridacna maxima is naturally smaller in the eastern Pacific, reaching a maximum size (shell length) of 200 mm at Fangatau and Tatoko in French Polynesia and 210 mm to 240 mm at Mangaia, Aitutaki, Palmerston and Rarotonga (Pinca et al. 2009). The lower mean sizes recorded in this assessment (Fig. 11) are consistent with those found in atolls of French Polynesia and Cook Islands. The maximum size was around 230 mm at Fakaofo. Nukunonu and Fakaofo have larger lagoon systems which support relatively healthy stocks of *T. maxima* while the stock in Atafu is of concern. Harvesting of giant clam at Atafu for domestic consumption or for export has been restricted since the late 1980s. The average size of *T. maxima* at Atafu is larger (126 mm) (although this figure is based on a limited sample) and there is a general absence of juvenile clams less than 75 mm (Fig. 11). The size range of 70 mm to 120 mm for clams harvested at Nukunonu (Fig. 12) corresponds with the finding that this atoll had the population with the greatest size range (Fig. 11). At Nukunonu 67% of harvested *T. maxima* had a shell length of less than 100 mm (Fig. 12).

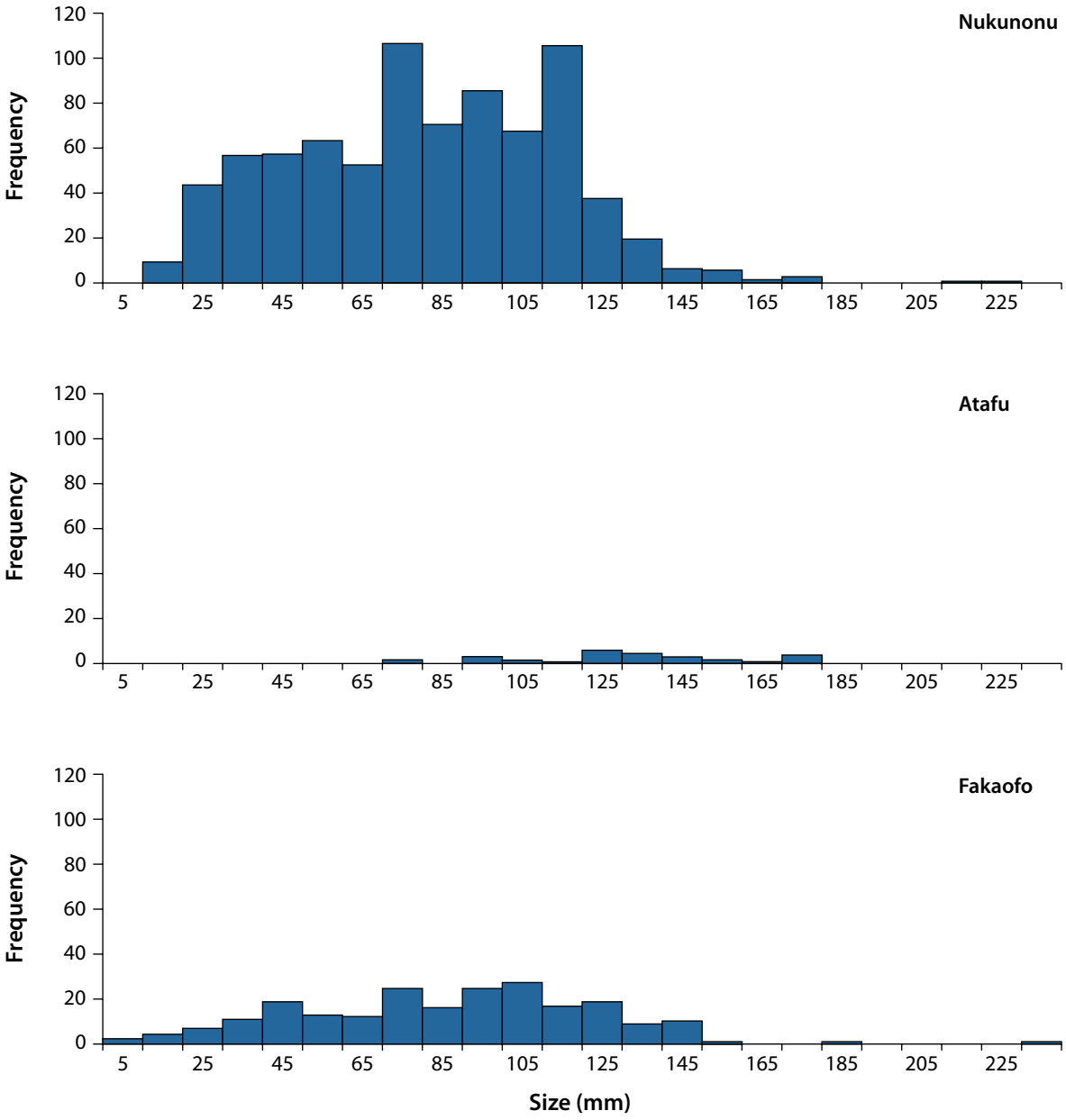


Figure 11. Size distribution of *Tridacna maxima* at Tokelau atolls.

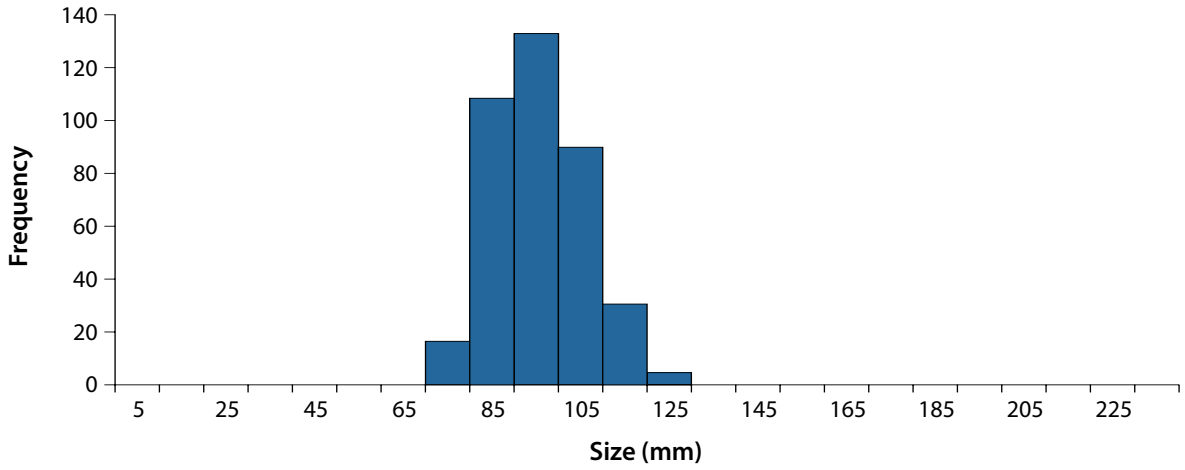


Figure 12. Size frequency distribution of *T. maxima* harvested at Nukunonu (May 2012).

3.5 Stock estimates for selected species

Stock estimates are determined by pooling the mean densities established by manta tow and reef benthos transect assessments at each atoll. Estimated total areas of the different types of lagoon and reef habitats are derived from classifications by Andréfouët et al. (2005) (see Appendix 4). Population estimates were determined for the habitats of reef flat, inner lagoon slope, enclosed lagoon and lagoon pinnacle. Population estimates were derived for lollyfish and elongated giant clams at each of the atolls, and for tigerfish at Fakaofo. The proportion of populations of a size above full maturity was also determined for these species (Table 6). No estimates were derived for the deep lagoon and forereef habitats.

Table 6. Population estimates for lollyfish (*Holothuria atra*) and elongated giant clam (*Tridacna maxima*) at Nukunonu, Atafu and Fakaofo and for tigerfish (*Bohadschia argus*) at Fakaofo.

Lollyfish (*Holothuria atra*)

Atoll	Population range		Estimate population	Specimens > 200 mm (%)	Specimens > 200 mm (population)	Wet biomass (mt)
	Minimum	Maximum				
Atafu	2,807,600	5,102,700	3,955,150	6	237,300	84,245
Nukunonu	358,420	806,310	582,360	5	29,120	10,335
Fakaofo	1,399,870	7,237,070	4,318,470	4	172,740	61,320

Elongated giant clam (*Tridacna maxima*)

Atoll	Population range		Estimate population	Specimens > 100 mm (%)	Specimens > 100 mm (population)
	Minimum	Maximum			
Atafu	11,980	32,380	22,180	83	18,410
Nukunonu	3,651,490	5,743,250	4,697,370	31	1,456,180
Fakaofo	42,320	1,012,740	527,530	38	200,460

Tigerfish (*Bohadschia argus*)

Atoll	Population range		Estimate population	Specimens > 300 mm (%)	Specimens > 300 mm (population)
	Minimum	Maximum			
Fakaofo	32,640	103,480	68,060	56	38,110

3.6 Coconut crab assessment

This assessment provides baseline information on the stock of the resource for *motu* Tokelau in Nukunonu and *motu* Na Utua in Atafu. Thoracic length is most commonly used to describe size structure of the coconut crab populations in Vanuatu (Fletcher et al. 1991), French Polynesia (Chauvet and Kadiri-Jan 1999), Palau and Marshall Islands (Helfman 1973). In this Tokelau study, both the cephalothoracic length (CL) and thoracic length (TL) were measured (Fig. 5) and the cephalothoracic length has been used to assess the size distribution of coconut crabs. To allow its results to be compared with other studies, a CL to TL regression was developed for crabs measured in this study. The regression (Fig. 13) is explained by the formula:

$$TL = 0.412 \times CL + 5.4863 \quad \text{or} \quad CL = TL - 5.4863 \times \sqrt{0.412}$$

This equation is used to transform the maturity size of the coconut crab (TL = 25 mm), as determined by Amesbury (1980), to its corresponding CL length, which is 47.5 mm.

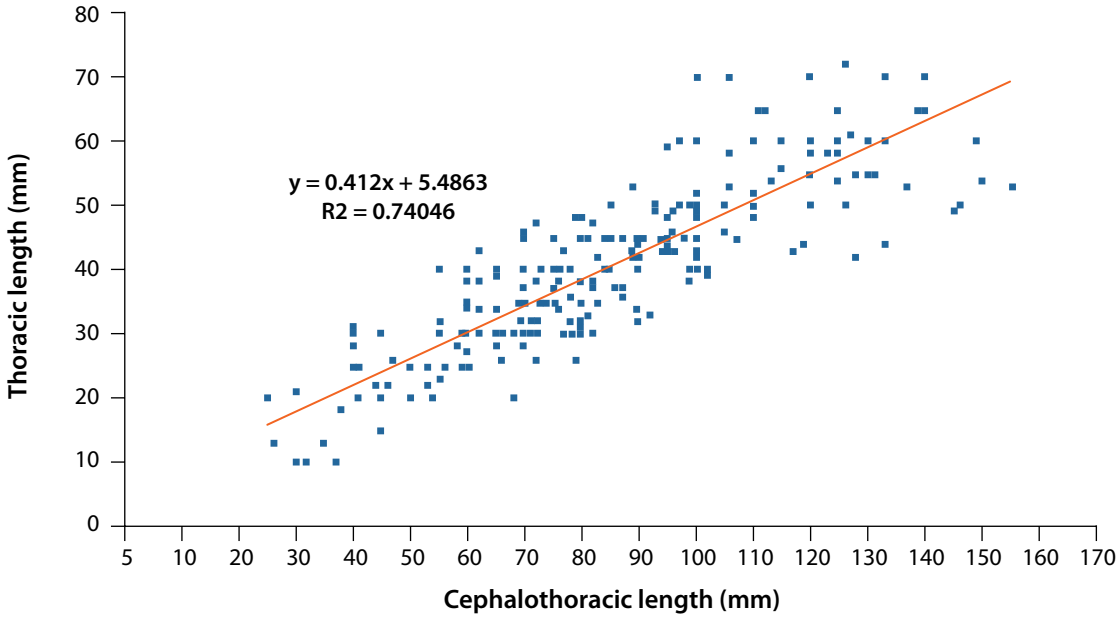


Figure 13. Linear regression for cephalothoracic and thoracic lengths for coconut crab (*Birgus latro*) at Tokelau.

3.6.1 Catch per unit effort and catch size structure

Catch per unit effort (CPUE) and catch size distribution were assessed from the results of:

- night searches for foraging crabs — where the CPUE is the number of crabs caught per hour of night search; and
- day searches that target burrowing crabs — where the CPUE is the number of crabs captured per person per hour searching for crab burrows and digging up crabs.

At *motu* Tokelau (Nukunonu), five hunters captured 72 coconut crabs in one hour of searching at night. Nukunonu catch per unit of effort was therefore 14.4 crabs per hour night search. At Atafu the CPUE for daytime searches was 1.5 crabs per person per hour and for night searches it ranged from 4.5 to 7.5, averaging 5.7 crabs per person per hour (Table 7). The CPUE for crab night searches at Atafu was nearly four times higher than the CPUE for day searches for crab burrows. Catch rates are higher during the night partly because that is when coconut crabs come out of hiding to forage. In addition, searching for crabs underground during the day requires knowledge of the period when coconut crabs go underground to moult and the structure of moulting coconut crab burrows. In a comparison of night searches between atolls, the CPUE at Nukunonu was just over three times more productive than at Atafu.

Table 7. Catch per unit effort for coconut crab (*Birgus latro*) hunting trips at Nukunonu and Atafu.

Motu	Trips	Date	Time	Hunters	Catch	Hours	CPUE	Average CPUE
Motu Tokelau (Nukunonu)	1	28/05/12	Night	5	72	2.0	14.4	–
Motu Na Utua (Atafu)	1	05/06/12	Day	7	53	5.0	1.5	–
Motu Na Utua (Atafu)	2	11/04/13	Night	2	25	3.0	4.2	
Motu Na Utua (Atafu)	3	20/05/13	Night	2	27	2.5	5.4	5.7
Motu Na Utua (Atafu)	4	08/07/13	Night	2	30	2.0	7.5	

Of the 72 crabs captured at *motu* Tokelau (Nukunonu), 57 were measured; the remainder was eaten soon after the hunt and therefore not measured. At Nukunonu the smallest crab captured for consumption was 95 mm and largest 150 mm CL, with a mean size of 116 mm CL. At Atafu the smallest crab caught was 79 mm and largest 155 mm CL, with a mean size of 113 mm CL (Fig. 14). No weight information was gathered because weighing scales were unavailable at both atolls. Moreover, at Nukunonu no information to determine sex ratio was gathered because of the speed at which the crabs were distributed among the hunters. The sex ratio for captured coconut crabs at Atafu was 1 male to 0.6 females (Fig. 14). Catches for both atolls were generally large crabs dominated by males. Harvested crabs are well above size at first maturity.

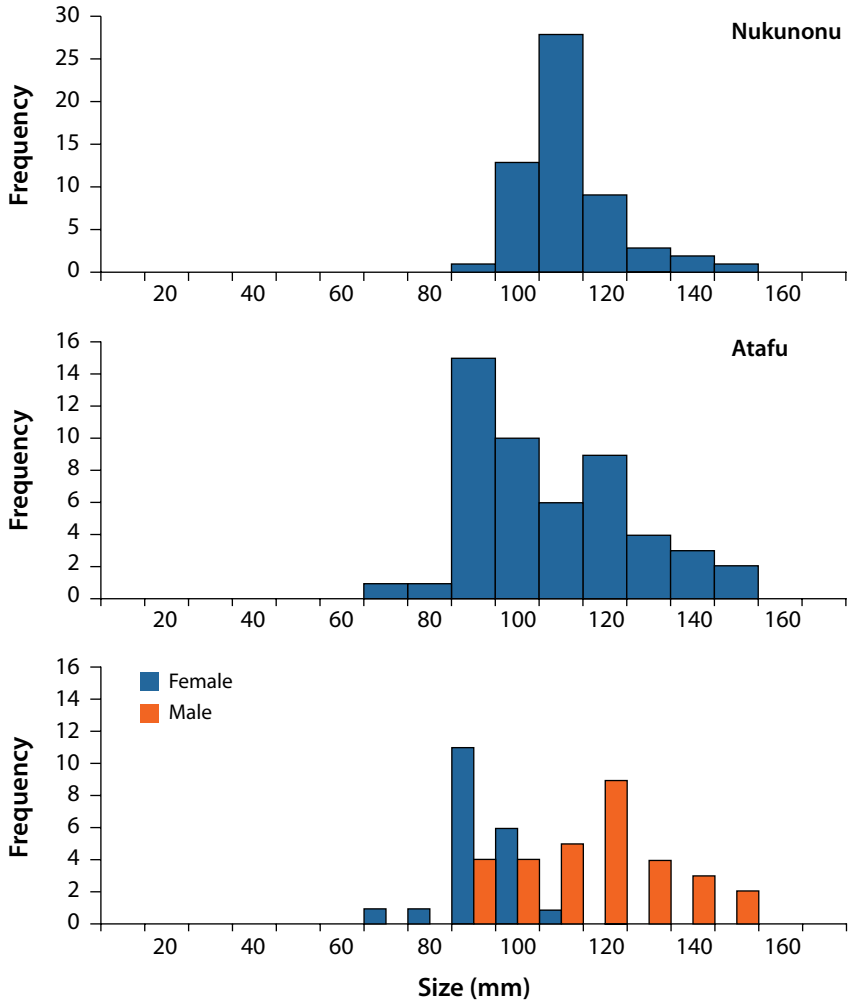


Figure 14. Size (CL, in mm) structure of coconut crabs (*Birgus latro*) caught for consumption at Nukunonu and Atafu.

3.6.2 Coconut crab sizes, density and stock estimates from night surveys at Nukunonu

Of the 231 coconut crabs recorded during night surveys in April 2012 at *motu* Tokelau (Nukunonu), 195 were measured and their sex was determined, 12 were measured but their sex was undetermined, and 24 were counted (not measured nor sex-determined). Of the sex-determined sample, 114 (58%) were male and 81 (42%) were female. Overall, the coconut crab population in *motu* Tokelau showed a healthy stock structure, with a range of sizes represented (Fig. 15). The presence of young crabs < 70 mm CL indicates that recruitment into the population is healthy.

Male and female coconut crabs differ clearly in size, with females having a smaller mean body size. As reported in Figure 15 (bottom graph), the mean size of female crabs was 72 mm while for male crabs it was 80.5 mm CL. In comparison, the mean size of female coconut crabs in Vanuatu was about 20–25% smaller than that of male crabs (Fletcher et al. 1991). The coconut crab stock at *motu* Tokelau is dominated by larger male crabs: the sex ratio is 1 male to 0.7 female, which is slightly lower than the 1:0.9 ratio for coconut crab populations reported for Palau and Eniwetok (Helfman 1973) and Vanuatu (Fletcher 1988). The male stock of coconut crab is more vulnerable to higher fishing pressure because hunters prefer the larger crabs, as demonstrated by the higher proportion of large males in the catch observed in Atafu (Fig. 14). This stock at *motu* Tokelau is relatively healthy; however, larger female crabs are impacted by fishing as shown in Figure 15 (lower graph), which is consistent with the overall data on catch sizes from the same *motu* (Fig. 14, top graph).

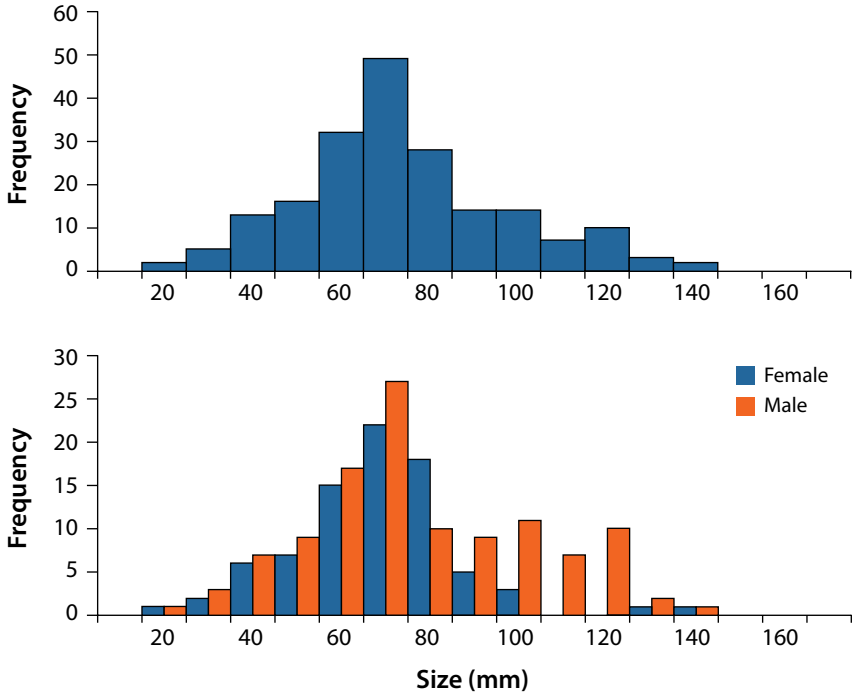


Figure 15. Size frequencies of coconut crab (*Birgus latro*) — male and female combined (above) and by sex (below) at *motu* Tokelau, Nukunonu from transect survey.

At *motu* Tokelau, the density was estimated to be an average of 129 ± 26,9 crabs per hectare. Given that the total area of thick forest, as suitable habitat for the coconut crab, is an estimated 34.02 hectares (excluding the cleared area on the northeast side of the *motu*), it can be estimated that the current coconut crab population at *motu* Tokelau is 4,386 (Table 8).

Table 8. Coconut crab (*Birgus latro*) density and population estimate at *motu* Tokelau, Nukunonu.

Transect	Transect size (m^2)	Number of crabs	Density (crabs ha^{-1})	Average density (SE)	Dense forest area (ha)	Estimate population
1	4,736	42	88.7	129 (26.9)	34	4,386
2	4,240	35	82.5			
3	4,384	86	196.2			
4	4,256	63	148.0			

Crab populations vary by geographical location, habitat, predation and fishing pressures. In high islands the release of fertilised eggs can be less successful because female crabs need to travel long distances to shed eggs and on the way are exposed to predators such as feral pigs. Table 9 lists densities of coconut crabs in various Pacific Island countries and territories. Densities can be compared more meaningfully where island systems are geographically similar. Therefore crab density for *motu* Tokelau is more realistically comparable with Eniwetak atoll in the Marshall Islands and the Tuamotus in French Polynesia, both of which are atoll island systems.

Table 9. Comparison of estimated coconut crab (*Birgus latro*) density with estimates from other studies.

Country	Site	Year	Density (ind ha^{-1})
French Polynesia*	Tuamotu	1999	190
Palau**	Palau	1973	667
Marshall Islands**	Eniwetak	1973	135–147
Niue†	Niue	1992	46
New Caledonia††	Loyalty Islands	?	28
Tokelau	*Motu* Tokelau	This study	129

Sources: * Chauvet and Kadiri-Jan (1999); ** Helfman (1973); † Schiller (1972); †† Source unknown.

Note: Density numbers from the different sources were converted into a standard unit, individuals per hectare.

3.6.3 Note on coconut crab poisoning

Coconut crabs are known to consume coconuts, pandanus, other fruits including sea mango, and vegetation. Cases of poisoning and death after eating coconut crabs have occurred in New Caledonia (Maillaud et al. 2010). Such cases have been found to originate from toxins from the kernel of sea mango, *Cebera manghas* (Maillaud et al. 2010). In Tokelau, where the sea mango plant is absent (Mose Pelasio, personal communication), there are no reports of poisoning after eating cooked crabs.

Tokelauans enjoy their coconut crab partly cooked by roasting on open fire made from coconut leaves and consuming it with coconut flesh or the apple of the germinating coconut (Fig. 16). Partly cooked crabs are cleaned in seawater. From the personal experience of one author, Kalo Pakoa, who has eaten coconut crab meat in Vanuatu, where the abdominal content often gives it a bitter taste, and has been poisoned from eating coconut crab from the Loyalty Islands in New Caledonia, it appears that the flesh and abdomen of Tokelau coconut crabs are more tasty, with sweeter flesh and rich abdomen. Coconut crabs in Tokelau or similar low-lying islands feed primarily on coconut, pandanus fruit and vegetation and have relatively easy access to the sea to maintain salt intake.

Figure 16. Cooked crab (*Birgus latro*) soaked in seawater (top) and ready to eat (bottom) in Tokelau.

4. Management recommendations

The low number of invertebrate species recorded in Tokelau corresponds with the size of island habitats and low species diversity found in the eastern Pacific Islands, which are distant from the centre of biodiversity (Papua New Guinea and Indonesian region). Many of the coral reef invertebrates are isolated from or have limited access to sources of replenishment from other major coral reef systems beyond Tokelau. Therefore, to be sustained in the long term, stocks rely heavily on the health of existing resources.

- It is important to maintain sufficient breeding populations of resources at these atolls to contribute to recruitment and population growth.

This final section outlines management recommendations for each of the main species groups covered in this study, before finishing with recommendations for general resource management.

4.1 Sea cucumber

The sea cucumber resources of Tokelau are small and vulnerable to fishing pressure. Any commercial harvest would require stringent fishery management if it was to be sustainable. Stocks could be reassessed at two- to three-year intervals to determine stock status. Lollyfish is the most abundant sea cucumber species, which is found in all the three atolls. However, lollyfish stocks are below reference density at Nukunonu due to commercial fishing, which has also reduced the stock of greenfish and tigerfish.

Lollyfish stock at Atafu and Fakaofo and tigerfish stock at Fakaofo could support a very small fishery. If commercial sea cucumber harvesting in Atafu and Fakaofo was approved, a monitoring programme would need to be established to accurately record harvest and export quantities of each species. Restricting the harvest of specimens below size at maturity is recommended. If fishing was allowed, fishable quantities should be determined for each species at a conservative proportion (for example, 10–30% of the proportion of the population above minimum size). To protect stocks, an area with high densities could be declared as an area protected from fishing. To improve returns to local fishers, sea cucumber could be sold at a predetermined price by the piece (i.e. individual pieces by species) rather than by 18- or 20-litre buckets of sea cucumber.

Summary of recommendations:

- In the immediate future, further commercial exploitation of sea cucumber is not recommended for Nukunonu.
- If commercial sea cucumber harvesting in Atafu and Fakaofo was approved, a monitoring programme would need to be established.
- A minimum harvest size limit of 200 mm for lollyfish and 300 mm for tigerfish should be introduced.
- An area with high densities should be declared as an area protected from fishing.

4.2 Giant clams

Stocks of fluted giant clams (*T. squamosa*), locally known as *fahua taka*, are rare in the three atolls and should be protected from harvest.

The stocks of *T. maxima* are healthy at Nukunonu and Fakaofo but in poor condition at Atafu. Harvest control is currently in place at Atafu and should be maintained. Restocking of mature adult clams or collection of juvenile clams through spat collection programmes from other areas, preferably from within the county (e.g. Nukunonu), could be explored to help improve the population status of clams at Atafu. It is recommended that both Nukunonu and Fakaofo put in place measures to control harvesting, such as by permanently closing to harvesting one or more areas with highest clam densities and by introducing harvest size limits. Prohibit if acceptable or restrict the export of clams, for example by setting an annual limit (e.g. xx kilograms of clams per resident family per year) for export to families abroad.

Summary of recommendations:

- Fluted giant clams should be protected from harvest.
- Collect mature adult clams or juvenile clams from other locations and restock at Atafu to improve the population status.
- Nukunonu and Fakaofo could introduce controls on harvests, such as permanent closure of one or more areas with highest densities of elongated giant clams.
- Restrict the export of clams.

4.3 Coconut crab

The management measures to protect an area from harvesting crabs, as practised by Tapulega and the communities of Fakaofo and Atafu, are excellent and to be encouraged. Likewise, coconut crab hunters' practice of targeting only large crabs is excellent and should be maintained. As coconut crab populations are extremely vulnerable to fishing pressures, restrictions on harvesting egg-bearing female crabs are encouraged to further improve crab resource management. Similar to clams, an export quota could be introduced. We also recommend applying a quota on the number of crabs caught for feasting dignitaries, regardless of whether those dignitaries are locals or foreign. Feral pigs prey on crabs so should be controlled on *motu*.

Further assessment of coconut crab resources (transect and monitoring catch for CPUE, sex ratio and size) on *motu* in Nukunonu, Atafu and Fakaofo is encouraged.

Summary of recommendations:

- Protect female crabs for harvesting during the season when they are carrying eggs.
- Encourage hunters to target only larger crabs.
- An export or feasting quota (number of crabs per family per year permitted for export or communal feasting) could be introduced.

4.4 Crown of thorns

At this stage, crown of thorns (*alomea*) are not a problem in the three atolls and are present in low numbers. When their numbers are low, crown of thorns eat fast-growing coral which allows space for slower-growing coral to grow and in this way balances the coral reef ecosystem. However, if present in large numbers — for example, more than 8–10 individuals per hectare or more than 5 *alomea* are seen in a five-minute swim — they begin to cause significant damage to coral reefs. At these densities, management intervention is required.

Effective management action is to organise large-scale community programmes to eradicate *alomea*. Specimens collected should be disposed of on shore and can be buried as fertiliser for food crops such as bananas. Fishers should be encouraged to keep watch for *alomea* population growth. Do not cut up *alomea* in the water, as this can promote population growth. *Alomea* outbreaks are thought to be related to high nutrient loads in the lagoon.

Summary of recommendations:

- If *alomea* outbreaks occur, initiate large-scale community programmes to eradicate *alomea*.

4.5 General resource management

We recommend a total ban on the introduction and use of underwater breathing apparatus (UBA) for fishing. Such a ban will protect species in deeper areas where they produce juveniles that may settle in shallower areas.

To counteract unpredictable recruitment, impacts of climate change and fishing pressure, and to improve the resilience of resources, we encourage the establishment of long-term or preferably permanent protected areas. Protected areas allow resources to grow and breed without fishing pressures. The areas chosen could be one or two areas of around 50 to 200 hectares within the lagoon. They should cover a range of habitats and locations where there are high densities of mature resources. Due to prevailing south-easterly oceanic currents and wind, it is recommended (if possible) that a protected area should be positioned around a south area of the lagoon, provided that it includes good habitats and a high density of mature marine resources. Data from these protected areas can be used to make comparisons with resources in fished areas and to assess the performance of the community's resource management actions.

Summary of recommendations:

- Establish permanent protected areas covering 50 to 200 hectares.

Suggested options as areas for protection of all resources, based on the above criteria, are:

Nukunonu

- Section of the reef/lagoon of *motu* Te Afua to *motu* Fala including Te akau loa coral patch reef;
- Southeastern section of reef/lagoon to the east and south of *motu* Tokelau, including *motu* Tokelau.

Atafu

- Reef/lagoon area around *motu* Te Alofi to Ava o te Puka;
- South section or reef/lagoon adjacent to *motu* Na Utua, including coral patch reefs in lagoon.

Fakaofo

- Section of the reef/lagoon south of Nukutakia to Akegamatu;
- One or two selected large coral patch reefs in the lagoon.

5. References

Amesbury S.S. 1980. Biological studies on the coconut crab (*Birgus latro*) in the Mariana Islands. Marine Laboratory Technical Report, No. 66: University of Guam, Guam. 46 pp.

Andréfouët S., Muller-Karger F.E., Robinson J.A., Kranenburg C.J., Torres-Pulliza D., Spraggins S.A. and Murch B. 2005. Global assessment of modern coral reef extent and diversity for regional science and management applications: A view from space. pp. 1732–1745. *In:* Suzuki Y., Nakamori T., Hidaka M., Kayanne H., Casareto B.E., Nadaoka K., Yamano H., Tsuchiya M. and Yamazato K. (eds). 10th International Coral Reef Symposium. Japanese Coral Reef Society: Okinawa, Japan.

Bertram I., Pakoa K., Pasilio T., Foliga P. and Rikim K. 2012. Sea cucumber assessment: Nukunonu: Tokelau. Secretariat of the Pacific Community: Noumea, New Caledonia.

Braley R.D. 1989. A giant clam stock survey and preliminary investigation of pearl oyster resources in the Tokelau Islands. FAO South Pacific Aquaculture Development Project: Suva, Fiji.

Chauvet C. and Kadiri-Jan T. 1999. Assessment of an unexploited population of coconut crabs, *Birgus latro* (Linnaeus,1767) on Taiaro atoll (Tuamotu archipelago, French Polynesia). Coral Reefs 18:297–299.

Fisk D., Axford J. and Power M. 2004a. Marine resources of Tokelau atolls; Atafu. Marine Resources Management Plan. Secretariat of the Pacific Regional Environment Programme: Apia, Samoa.

Fisk D., Axford J. and Power M. 2004b. Marine resources of Tokelau atolls; Fakaofo. Marine Resources Management Plan. Secretariat of the Pacific Regional Environment Programme: Apia, Samoa.

Fisk D., Axford J. and Power M. 2004c. Marine resources of Tokelau atolls; Nukunonu. Marine Resources Management Plan. Secretariat of the Pacific Regional Environment Programme: Apia, Samoa.

Fletcher W.J. 1988. Coconut crab biology and resources in Vanuatu. *In:* Proceedings of "Resources, development and environment of Vanuatu". 17 pp.

Fletcher W.J., Brwon I.WE., Fielder D.R. and Obed A. 1991. Structure and dynamics of populations. *In:* Brown I.W. and Fielder D.R. (eds). The coconut crab: Aspects of *Birgus latro* biology and ecology in Vanuatu. ACIAR Monograph Series 8:61–86.

Gillett R. 1994. Trochus survey at Fakaofo atoll, Tokelau. SPC Trochus Information Bulletin 3:2–8.

Helfman G.S. 1973. The ecology and behavior of the coconut crab *Birgus latro* (L). MSc thesis: University of Hawaii, Hawaii. 158 pp.

Jameson S. 1976. Early life history of the giant clams *Tridacna crocea* Lamarck, *Tridacna maxima* (Röding), and *Hippopus hippopus* (Linnaeus). Pacific Science 30:219–233.

Lewis A.D. 1987. Aitutaki giant clams (*pa'ua*) resources profile no. 1. Suva Program, FAO/UNDP Regional Fishery Support Programme RAS/87/002. 12 pp.

Maillaud C., Lefebvre S., Sebat C., Barguil Y., Cabalion P., Cheze M., Hnawia E., Nour M. and Durand F. 2010. Double lethal coconut crab (*Birgus latro* L.) poisoning. Toxicon 55(1):81–86.

Passfield K. 1998. A report of a survey of the marine resources of Fakaofo atoll, Tokelau. Fisheries and Environmental Resource Consultants Ltd.

Pelasio M. 1989. Trochus distribution in Nukunonu, October 1989. Tokelau Fisheries internal report.

Pelasio M. 1990. Trochus distribution in Nukunonu, October 1990. Tokelau Fisheries internal report.

Pinca S., Boblin P., Friedman K.J., Kronen M., Magron F., Awira R., Pakoa K., Lasi F., Tardy E. and Chapman L.B. 2009. Cook Islands country report: Profiles and results from survey work at Aitutaki, Palmerston, Mangaia and Rarotonga (February and October 2007). Secretariat of the Pacific Community: Noumea, New Caledonia. 339 pp.

Pinca S., Kronen M., Friedman K., Chapman L., Tardy E., Pakoa K., Awira R., Boblin P. and Lasi F. 2010. Regional assessment report: Profiles and results from surveys work at 63 sites across 17 Pacific Islands countries and territories (1 March 2002 to 31 December 2009). Secretariat of the Pacific Community: Noumea, New Caledonia. 540 pp.

Schiller C. 1992 Assessment of the coconut crab *Birgus latro* on Niue island with recommendations regarding an appropriate resource management strategy. South Pacific Aquaculture Development Project. Food and Agricultural Organization: Rome, Italy. 152 pp.

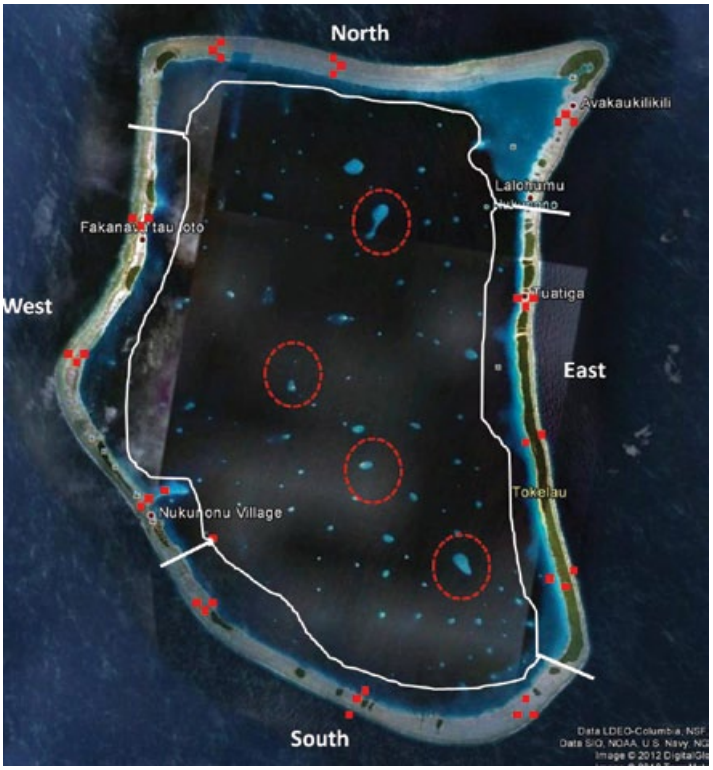
Secretariat of the Pacific Community (SPC). In press. Manual for assessing tropical marine invertebrate resources for management purposes in the Pacific islands. Noumea, New Caledonia: Coastal Fisheries Science and Management Section, Secretariat of the Pacific Community.

Tokelau Census of Population and Dwellings. 2011.

Appendix 1.

Location of reef benthos transect at each survey station

Nukunonu survey stations



Location of reef benthos transect at each survey station (cont.)

Atafu survey stations

Date of survey	Station number	RBt location by name
13 May 2013	1	Tuagafulu
13 May 2013	2	Te Kapi
13 May 2013	3	Na Utua
13 May 2013	4	*Motu* Fakalalo
13 May 2013	5	Malatea
13 May 2013	6	Hapiti
13 May 2013	7	Fenualoa
14 May 2013	8	Alai Ioa
14 May 2013	9	Te Alofi
14 May 2013	10	Papa Motumotu
14 May 2013	11	Matalele
14 May 2013	12	Fogalaki
14 May 2013	13	Lotomau

Location of reef benthos transect at each survey station (cont.)

Fakaofo survey stations

Date of survey	Station number	RBt location by name
30 April 2013	1	Nukumatini
30 April 2013	2	Lotoalai
01 May 2013	3	Akegamutu
01 May 2013	4	Te Vaigagie
01 May 2013	5	Palea
02 May 2013	6	Te Mahini
02 May 2013	7	Koko Alaala
02 May 2013	8	Fatu Nuti
02 May 2013	9	Mulifenua
03 May 2013	10	Talapeka
03 May 2013	11	Agahala
03 May 2013	12	Alai o te Fakanava
03 May 2013	13	Maloto
03 May 2013	14	Alai Nukumatini

Appendix 2.

Scientific, common and Tokelauan names for species found in the surveys

Scientific name	Common name	Tokelauan name
Holothuria atra	Lollyfish	*Loli uliuli*
Bohadschia argus	Tigerfish	*Funafuna paepae tutu*
Holothuria whitmaei	Black teatfish	*Funafuna uliuli*
Holothuria fuscogilva	White teatfish	*Funafuna paepae*
Stichopus chloronotus	Greenfish	*Loli meamata patupatu*
Actinopyga mauritiana	Surf redfish	*Funafuna kukula*
Spondylus varius	Thorny oyster	
Tridacna maxima	Elongated giant clam	*Fahua*
Tridacna squamosa	Fluted giant clam	*Fahua taka*
Acanthaster planci	Crown of thorns	*Alomea*
Chelonia mydas	Green turtle	*Kea, fonu*
Echinothrix diadema	Blue black sea urchin	*Vana*
Cypraea tigris	Tiger cowrie	*Pule tutu uliuli*
Cypraea annulus[1]	Ring cowrie	*Tama pule paepae*
Lambis truncata	Giant spider conch	*Kalea talatala*
Strombus luhuanus[2]	Strawberry conch	*Figota*

Notes:

[1] The scientific name has changed recently from *Cypraea annulus* to *Monetaria annulus*.

[2] The scientific name has changed recently from *Strombus luhuanus* to *Conomurex luhuanus*.

Appendix 3.

RBt summary statistics for the three study sites at Nukunonu, Atafu and Fakaofo

Species	Overall mean density[1]	SE[2]	Number of stations	Present mean density[3]	SE[2]	n_P[4]	%_P[5]
Nukunonu							
Giant clam	4,002	1,001	37	5,288	1,231	28	76
Lollyfish	3,933	1,615	37	5,820	2,309	25	68
Tigerfish	7	4	37	69	14	4	11
Greenfish	677	474	37	6,260	3,643	4	11
Black teatfish	1	1	37	42		1	3
Echinothrix diadema	360	106	37	701	175	19	51
Hyotissa sp.	30	30	37	1,125		1	3
Cypraea tigris	1	1	37	50		1	3
Lambis truncata	3	3	37	125		1	3
Terebra sp.	1	1	37	50		1	3
Atafu							
Giant clam	35	22	37	215	166	6	16
Lollyfish	21,816	5,512	37	22,422	5,632	36	97
Tigerfish	20	8	37	107	24	7	19
Surf redfish	7	7	37	250		1	3
Echinothrix diadema	43	25	37	396	149	4	11
Cypraea tigris	2	2	37	42	0	2	5
Cypraea annulus	1	1	37	36		1	3
Fakaofo							
Giant clam	802	542	35	1,755	1,160	16	60
Lollyfish	7,918	5,350	35	13,197	8,810	21	46
Tigerfish	53	29	35	264	117	7	20
Black teatfish	58	46	35	336	253	6	17
White teatfish	2	14	35	83		1	3
Surf redfish	5	3	35	61	19	3	9
Echinothrix diadema	37	32	35	431	348	3	9
Strombus luhuanus	3,092	1,535	35	21,642	6,310	5	14

Notes:

[1] 'Overall mean density' represents statistics for all transects.

[2] SE is the standard error.

[3] 'Present mean density' represents statistics for transect where a species was recorded.

[4] n_P is the number of stations where the species was present.

[5] %_P is the proportion of all stations where the species was present.

Appendix 4.

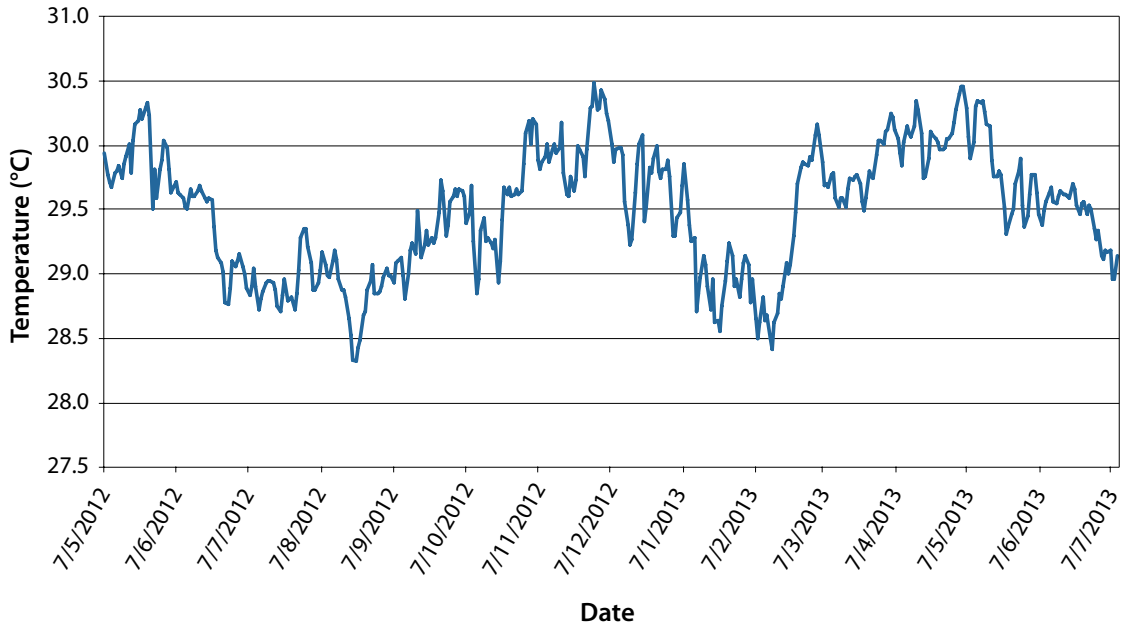
Habitat types and surface area for each site

Habitat	Area (ha)
Nukunonu	
Deep lagoon	8,115
Enclosed lagoon or basin	-
Inner lagoon slope	1,379
Lagoon pinnacle / patch reef	137
Reef flat	1,463
Forereef[1]	490
Atafu	
Deep lagoon	774
Enclosed lagoon or basin	52
Inner lagoon slope	357
Lagoon pinnacle / patch reef	153
Reef flat	709
Forereef[1]	240
Fakaofo	
Deep lagoon	3,249
Enclosed lagoon or basin	119
Inner lagoon slope	781
Lagoon pinnacle / patch reef	545
Reef flat	1,478
Forereef[1]	421

Source: Andréfouët et al. 2005.
Note:
[1] Forereef is the outer reef slope.

Appendix 5.

Nukunonu average lagoon temperature at 8 m depth



Secretariat of the Pacific Community (SPC)

BP D5 • 98848 Noumea Cedex • New Caledonia

Phone: +687 26 20 00 • Fax: +687 26 38 18

www.spc.int/fame • cfpinfo@spc.int