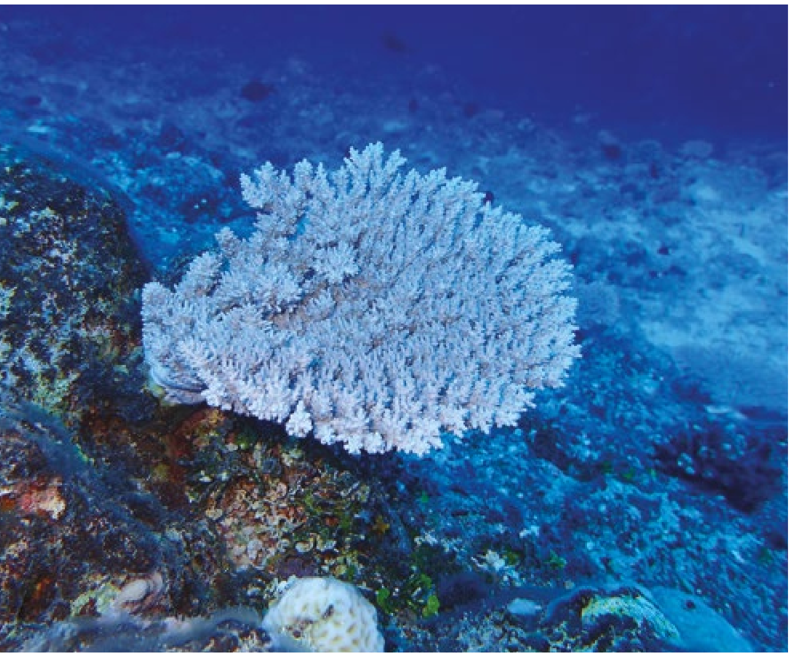
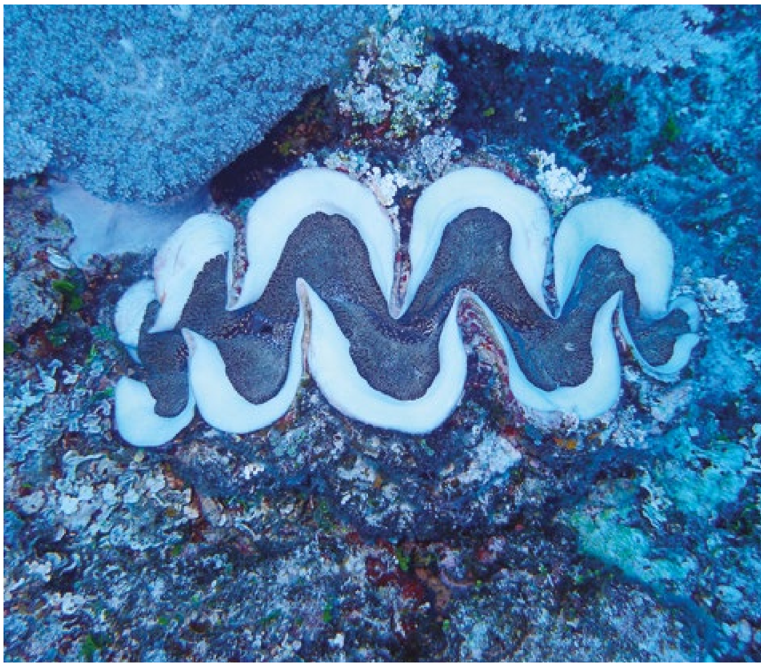
Pacific Community
Communauté du Pacifique





Niue
Marine Ecological Surveys, 2016 and 2017

Pauline Bosserelle, Navneel Singh, Nadia Helagi Kavisi, Launoa Gataua, Fiafia Rex and Andrew Halford

DAFF
DEPARTMENT OF AGRICULTURE, FORESTRY AND FISHERIES

gef

FAME
Fisheries, Aquaculture and Marine Ecosystems Division

Niue Marine Ecological Surveys
• 2016 and 2017 •

Pauline Bosserelle[1], Navneel Singh[1], Nadia Helagi Kavisi[1,2],
Launoa Gataua[2], Fiafia Rex[2,3] and Andrew Halford[1]

[1] Coastal Fisheries Programme, Pacific Community
[2] Niue Department of Agriculture, Forestry and Fisheries
[3] Niue Ridge to Reef Project

Pacific Community
Communauté du Pacifique

Noumea, New Caledonia, 2018

Original text: English

Pacific Community Cataloguing-in-publication data

Bosserelle, Pauline

Niue marine ecological surveys 2016 and 2017 / Pauline Bosserelle, Navneel Singh, Nadia Helagi Kavisi, Launoa Gataua, Fiafia Rex and Andrew Halford

1. Marine ecology – Niue.
2. Ecological surveys – Niue.
3. Ecological assessment (Biology) – Niue.
4. Marine resources – Niue.
5. Fishery resources – Niue.

I. Bosserelle, Pauline II. Singh, Navneel III. Kavisi, Nadia Helagi IV. Gataua, Launoa V. Rex, Fiafia VI. Halford, Andrew VII. Title VIII. Pacific Community

577.7099626 AACR2

ISBN: 978-982-00-1150-2

Prepared for publication and printed at SPC's headquarters
B.P. D5, 98848 Noumea Cedex, New Caledonia, 2018
www.spc.int

Contents

Acknowledgements

The authors thank Niue's Ministry of Natural Resources, the Government of Australia's Department of Foreign Affairs and Trade, New Zealand's Ministry of Foreign Affairs and Trade, the National Geographic Pristine Seas Project, Tofia Niue (Niue Ocean Wide Project), and the Niue Global Environment Fund/United Nations Development Programme Ridge to Reef Project for financial and in-kind support during fieldwork and data analysis.

The authors are grateful to Josie Tamate, Brendon Pasisi, Poi Okesene and James Tafatu for administrative and logistical support for the 2016 and the 2017 Niue Marine Ecological Surveys.

The authors also thank the other surveyors (Brendon Pasisi, James Tafatu, Ioane Mamaia, Vaughn Mitileki, Huggard Tongatule, Daniel Makaia) who contributed to this work. Paul Pasisi provided much appreciated assistance during both surveys.

2016 survey team, from left to right: Fiafia Rex, Pauline Bosserelle, Brendon Pasisi, Launoa Gataua, Nadia Helagi Kavisi (Photo: DAFF)

2017 survey team, from left to right: Launoa Gataua, Huggard Tongatule, Daniel Makaia, Vaughn Mitileki, Ioane Mamaia, Fiafia Rex (Photo: Navneel Singh)

Summary

Niue is a small, remote, upraised island with limited reef development and no lagoon system. The eastern and southern coasts are exposed to swells driven by southeasterly trade winds, resulting in limited reef extension along these coasts. There is a marginally greater extension of reef terrace on the more sheltered west coast. Ten years ago, the annual consumption of fresh fish per person was estimated to be lower than the regional average; however, a more recent survey stated that over 80% of households fish for home consumption, suggesting that there has been significant fishing pressure on Niue's reefs in the intervening period.

There have been no extensive surveys of Niue's coral reef fisheries stocks over the past 10 years since the 2005 Pacific Regional Oceanic and Coastal Fisheries (PROCFish/C [1]) survey. To rectify this, the Coastal Fisheries Programme of the Pacific Community, in collaboration with the Niue Government's Department of Agriculture, Forestry and Fisheries and Environment (DAFF), the National Geographic Pristine Seas (NGPS) Project, Tofia Niue (NOW project), and the Global Environment Fund/United Nations Development Programme Ridge to Reef project, conducted two marine ecological surveys around Niue in September and October 2016 and in September and October 2017. The aim of these surveys was to provide an update on the status of reef-associated communities around Niue.

Survey work covered three components: invertebrate, finfish and benthic communities. Invertebrate resource assessments were conducted during both surveys (2016 and 2017) while finfish and supporting habitat assessments were conducted in 2017 only. DAFF and Department of Environment staff were trained on the methodologies to be employed as part of the surveys.

Invertebrates were surveyed using the standard methodologies of the Pacific Community (SPC). In all, the surveys included 13 manta tow stations, 10 reef benthos transect stations, and 8 reef front searches (at night). Results of these surveys revealed highly variable densities around the island, which likely reflects patchiness in the local environment. Densities also varied according to methodology, with the highest densities recorded for drupes and urchins, while several popular seafood species, such as giant clams, turban snails, spiny lobsters and slipper lobsters were recorded in low densities. Sea cucumber densities were also low.

Finfish were surveyed using distance sampling visual census (D-UVC) at 16 stations, which revealed that fish diversity, density and biomass are relatively low around Niue. A comparison with the two earlier surveys (PROCFish/C 2005 and NGPS 2016) revealed significant differences in biomass and densities. Major differences were recorded between the 2005 PROCFish/C survey and the 2017 survey, with the surgeonfish family (Acanthuridae) accounting for a major part of these differences. A lack of data between the surveys does not allow us to clearly identify the reasons for this variability. Nevertheless, a few factors are potentially responsible: surveyor bias, environmental changes and fishing effort.

Benthic communities were surveyed using the photoquadrat methodology. The stations surveyed were the same as the ones surveyed for finfish. A comparison with the 2005 PROCFish/C survey revealed a small increase in coral cover, indicating a slight recovery since cyclone Heta in 2004. This recovery process was also described by the 2016 NGPS survey.

Based on the results of the 2016 and 2017 Niue Marine Ecological Surveys, a number of recommendations have been made to improve data collection and to help with developing sound management actions. We suggest that invertebrates, finfish and benthic habitat surveys should be carried every three to five years – using the same methodology – to provide more certainty around trends in reef fishery resources. A socioeconomic survey should also be conducted to identify priority species (invertebrate and reef fish) for Niueans, and to update consumption, catch and effort figures. It is also recommended that DAFF continues collecting artisanal catch data in order to have a better understanding of local fisheries. There is a lack of information on past disturbances affecting reef communities, which is needed to provide a clearer understanding of environmental effects versus fishing effects on local reefs. Local departments involved in resource management should keep records of disturbances (e.g. massive species die-offs, coral bleaching, cyclones) with the help of local communities who are often the first to notice changes in their local reef system. Given the isolation of Niue and its likely reliance on local stocks for providing new recruits to the reef system, we also highly recommend creating a well-designed and managed marine protected area to allow for breeding stock to grow and continue producing new recruits. There should be a complementary community awareness programme to inform locals of the benefits of any management plans and to invite their participation in deciding how and where a marine protected area might be located.

[1] Pacific Regional Oceanic and Coastal Fisheries Development Programme. The survey took place in 2005, with the aim of providing information on the status of reef fisheries around Niue (Kronen et al. 2008). The survey involved both finfish and invertebrate resource assessments, as well as a socioeconomic survey.

Introduction

Context

Niue is an upraised coral island – among the largest of its kind in the world – with a land area of approximately 259 km^2. Niue's population is low, with approximately 1,470 people living on the island (in 2015) while over 20,000 Niueans live abroad, mostly in New Zealand, taking advantage of the free association that exists between the two nations. Niue has an exclusive economic zone (EEZ) of 317,508 km^2, and is surrounded by the EEZs of Cook Islands to the east, Tonga to the west, and American Samoa to the north. International waters lie south of Niue. To help ensure a sustainable future for fishing, the Niuean Government announced the creation of a large marine protected area in October of 2017. The area encompasses 40% of Niue's EEZ, including Beveridge Reef, which is the largest of three outlying emergent coral reefs within Niue's EEZ (Fig. 1).

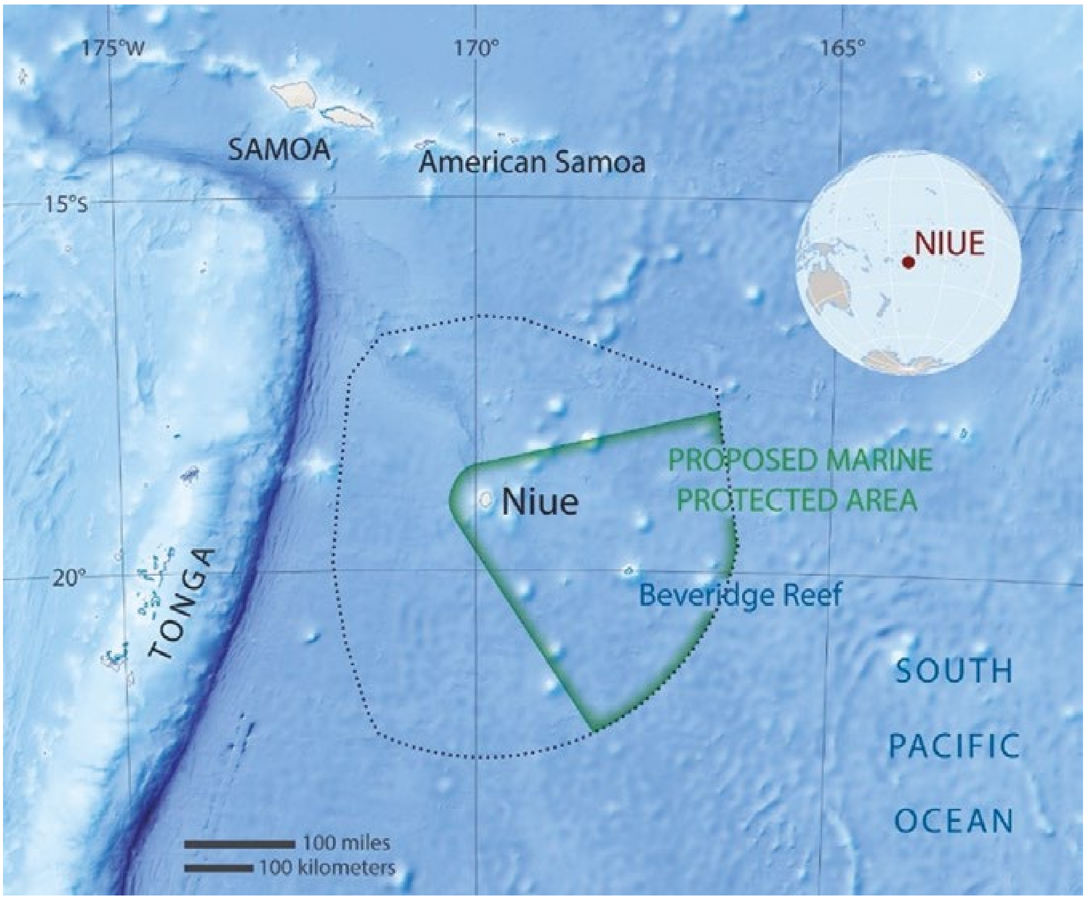


Figure 1. Niue's exclusive economic zone and the recently proposed large marine protected area.

The island's coastline consists mostly of limestone cliffs, with adjacent narrow reef flats along the more sheltered western and northern edges, while the cliffs along the more exposed southern and eastern edges bear the direct force of winds and swell (Fig. 2). The small size and height of the island provides minimal protection from extreme weather such as cyclones, which have caused significant damage to local coral reefs as recently as 2004. There are no lagoons within the reef system but the western side of the island (especially Alofi) is, nevertheless, more protected from the trade winds, and consequently, this is where most fishing activity takes place.

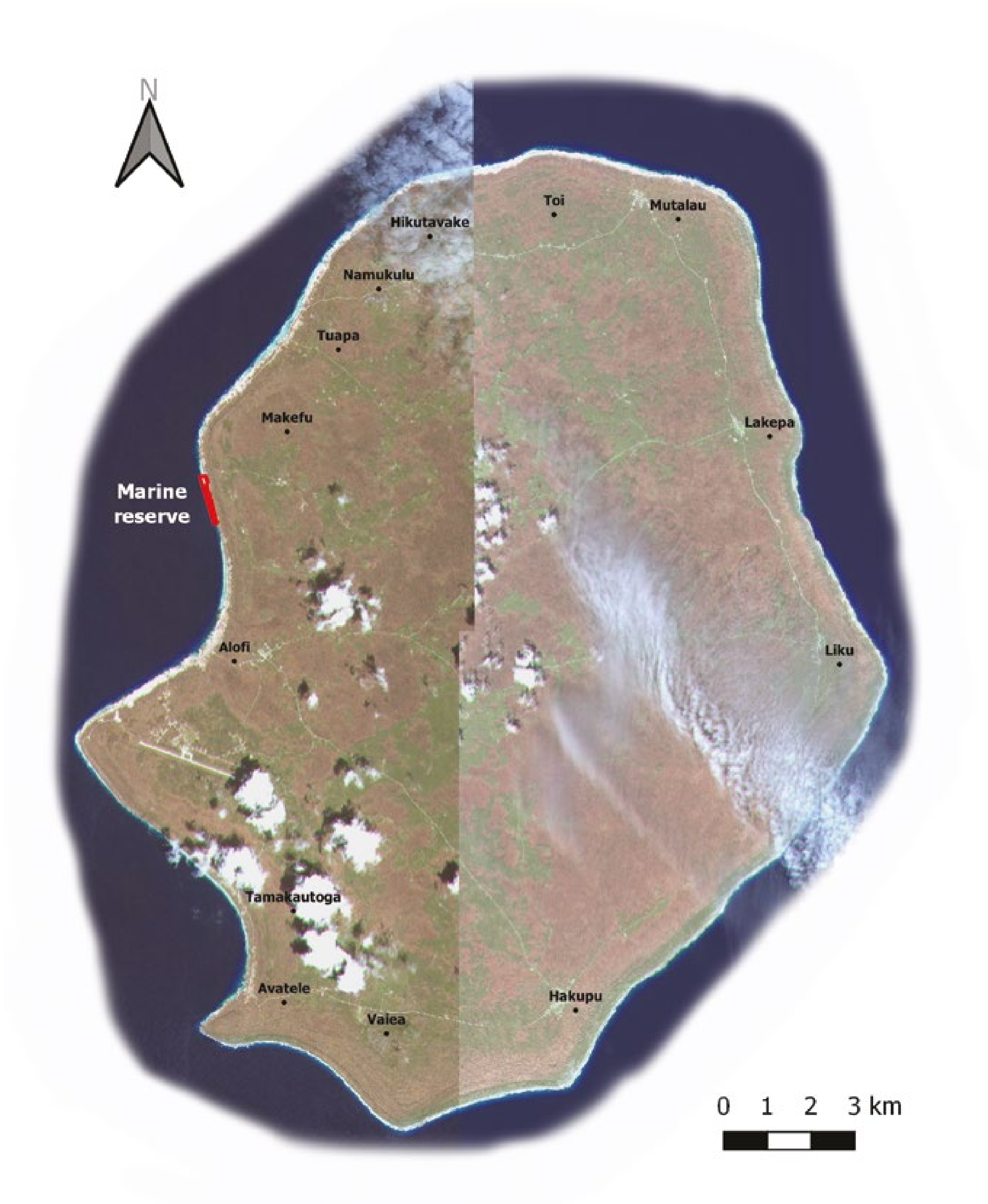


Figure 2. Niue Island's main villages and the Namoui marine reserve.

According to survey work done in 2005 (Kronen et al. 2008), which covered almost half of the households at the time, "people do not depend on fishing for food or incomes but fish for traditional values and frequently exchange seafood" as gifts or in exchange of goods with other Niueans from the island or living in New Zealand). The calculated fresh fish consumption at the time was 31.1 kg $person^{-1}$ $year^{-1}$, which was lower than the 35 kg $person^{-1}$ $year^{-1}$ regional average. A more recent survey (Statistics Niue 2010) indicated that 82% of households fished for home consumption, 16% sold part of their catch, and 2% of households sold most of their catch. In 2014, it was estimated that coastal fisheries production was 165 tonnes (t), consisting of 11 t of commercial catch and 154 t of subsistence catch (Gillett 2015). In 2016, the offshore foreign-based fishery catch was estimated to be 296 t (Anon. 2017). This corresponds to an estimated value of NZD 148,500 (to fishers) for commercial fisheries catches, and NZD 1,455,300 (to fishers) for subsistence fisheries catches (Gillett 2015). The contribution of fisheries to Niue's gross domestic product (GDP) in 2014 was estimated at 4.3%, comprising NZD 1,337,000 of an overall GDP of NZD 31,273,000 (Gillett 2015).

Marine resources

Invertebrates

Although Niue has a limited habitat for invertebrate resources, a number of invertebrates are locally consumed. Giant clams represent a local delicacy and are heavily fished along the shallow reef slope by a limited number of local free divers. Lobsters (including slipper lobsters) are also greatly valued and while rarely consumed due to their nocturnal behaviour and the relative roughness of the sea (especially on the east coast), they are considered to be heavily exploited on the western coast similar to the giant clams. Catches are likely to be opportunistic while fishing on the reef flat for other invertebrates. Turban snails, belligerent rock shells, drupes, tube worms, octopuses and other gastropods are regularly collected from the reef flats by both men and women, sometimes in great numbers (Launoa Gataua, DAFF Monitoring Control and Surveillance officer, pers. comm.).

Finfish

Both pelagic fish and reef fish are caught in Niue's waters. Pelagic catches are facilitated through the use of numerous fish aggregation devices (FADs) deployed around the island, especially on the west coast. Pelagic catches are mostly represented by yellowfin tuna, skipjack, wahoo and mahi mahi, and represent just over half of the annual artisanal catch (in weight) from Niue's waters. Reef fish species are traditionally caught for home consumption by a limited number of fishers, and this is confirmed by the presence of mainly pelagic fish for sale in local shops and restaurants. Deepwater cods and snappers are highly valued for home consumption and gifts, and are considered heavily exploited. There is also a relatively high demand for flying fish as food or bait. These are caught at night from aluminium boats using a scoop net. However, except for the well-known mackerel scad fishery (Kronen et al. 2008), the catch composition of reef fish is poorly described.

Local fisheries

Commercial tuna

Historically, Niue's offshore fishery has been low in terms of commercial interest or activity. There have been no commercial vessels flagged in Niue since 2007, and over the same period, the number of foreign-licensed vessels has fluctuated from 0 to 7. In 2016, seven foreign longline vessels were licensed to fish in Niue's EEZ (Anon. 2017), with their catch nearly reaching 300 t and dominated by albacore tuna (80%). The rest of the catch was mostly yellowfin tuna with some bigeye tuna. Because tuna data-reporting from foreign vessels is a licensing requirement to fish within Niue's EEZ, significant data are available for reporting.

Artisanal pelagic fish

Niue's FAD deployment programme started in the early 1980s, with further development occurring in the 1990s and early 2000s to support small-scale tuna and coastal pelagic fisheries. Management of the FAD system is done by Niue's Department of Agriculture Forestry and Fisheries. Artisanal catches are made through charter fishing boats (sport fishing), aluminium dinghies and outrigger canoes, although activities of the latter two are more for subsistence fishing rather than commercial. In addition to regular fishing activities, a number of fishing competitions are held each year, where all fishing boats take part, including charter boats, aluminium dinghies and outrigger canoes. Charter boats are strongly linked to tourism-led competitions while dinghies and canoes are linked to traditional or cultural events and village marine days. Data collection for the artisanal fishery was inconsistent for a number of years until 2015/2016, when the Pacific Community funded a dedicated local data officer to collect artisanal data and using the Tuffman 2 database, which is designed to store catch and effort information from artisanal vessels. Although there is no formal report based on the 2015/2016 data, the PROCFish/C survey[2] (Kronen et al. 2008) estimated the total annual catch from mid-water fishing and trolling to be 76.2 t.

Charterboat fishing

In Niue, charterboat fishing has existed for at least two years and has become more popular as tourism has increased (Paul Pasisi, charterboat fishing operator pers. comm.). The increase in boat numbers has been more pronounced over the last six to eight years, but especially in the last three years. Recent changes in boats have been made to improve visitors' experience, including increases in boat size and engine power (which in turn, increases boat capacity and comfort). There are currently 14 charters boats on Niue, ranging in size from 5.5 m to 7.5 m, of which only half have full-time operators. Fishing activities on these charter boats focus mainly on pelagic fish around offshore FADs and along the reef, with a few also undertaking bottom fishing above seamounts. Fish caught from charter boats are gutted and sold to local stores and restaurants for about NZD 15 kg^{-1} (Anon. 2017). However, demand from businesses outstrips the local supply so many pelagic fish are imported from Fiji (Avi Rubin, Kaiika restaurant owner, pers. comm.).

[2] Pacific Regional Oceanic and Coastal Fisheries Development Programme. The survey took place in 2005, with the aim of providing information on the status of reef fisheries around Niue (Kronen et al. 2008). The survey involved both finfish and invertebrate resource assessments, as well as a socioeconomic survey.

Aluminium dinghy and outrigger canoe

Traditional canoes have been used in Niue for centuries. From the 1980s, FAD development programmes have had an impact on the number of licensed aluminium dinghies and outrigger canoes, with significant increases seen in the late 1990s. In 2011, 273 small craft were registered in Niue, comprising 142 canoes, 115 aluminium dinghies, and 16 'other' vessel types, which represented a significant proportion of the population (about 1,500 people) who own a canoe or aluminium dinghy (Vaha 2012). Although most fishers target either pelagic fish or reef fish, aluminium dinghies and outrigger canoes are also involved in fishing for deepwater snappers and flyingfish. The agricultural census in 2009 (Statistics Niue 2010) indicated that 31% of households were involved in both inshore and offshore fishing, with only 7% exclusively in offshore fisheries.

Reef fishing

Many fishing activities occur on Niue's coral reefs, and are carried out from shore, on boats or underwater, using either traditional or modern means. Various fishing tools and methods are used such as a gill net, handline, spearfishing and gleaning.

Reef fishing (reef-associated fish and bottomfish)

In 2005, the PROCFish/C survey[2] estimated that the annual catch of reef finfish was approximately 53.4 t (all fishing activities combined). Fishing methods include trolling, handlining including with rod and line), spearfishing, droplining and netting, with trolling and handlining being the most commonly used among fishing communities. A wide variety of fish families are targeted (Table 1), with sea chubs, soldierfish, jacks and hawkfish making up the highest catch of reef species (Kronen et al. 2008). Ciguatera fish poisoning has been a concern of local communities over the years due to sporadic outbreaks, and has likely influenced coastal reef fishing behaviour over the years. Many fishers claim that Niue's west coast, especially around Alofi wharf, is prone to ciguatera poisoning, and this was confirmed by a ciguatera survey in 2003 (Yeeting 2003). The survey found high concentrations of the dinoflagellate, *Gambierdicus toxicus* (which is known to be the primary cause of ciguatera poisoning), found in algae samples from three sites in the area surrounding the wharf.

Table 1. Common fish families targeted by coastal fisheries.

Family name	English common name
Acanthuridae	Surgeonfishes
Balistidae	Triggerfishes
Belonidae	Needlefishes
Caesionidae	Fusiliers
Carangidae	Jacks
Cirhitidae	Hawkfishes
Holocentridae	Sodierfishes
Kyphosidae	Sea chubs
Labridae	Wrasses
Lethrinidae	Emperors
Lutjanidae	Snappers
Mugilidae	Mullets
Mullidae	Goatfishes
Polynemidae	Threadfins
Priacanthidae	Bigeyes
Scaridae	Parrotfishes
Serranidae	Groupers
Sphyraenidae	Barracudas

Reef gleaning

Although this activity is also done in shallow water (e.g. to collect clams), it is usually practiced on the reef flat around low tide during the day or night, depending on which species are being targeted. Many Niueans of both sexes take part in this fishery where, traditionally, one could only fish or glean in the village where one lived or where one is from (Launoa Gataua, DAFF Monitoring Control and Surveillance officer, pers. comm.). The collected animals include molluscs (e.g. clams, turban snails, octopuses), crustaceans (e.g. lobsters and slipper lobsters), echinoderms (e.g. urchins) or fish. Annual productivity is considered low, as measured by the PROCFish/C survey, but fishing pressure is relatively high on invertebrates considering the reduced available fishing habitat due to the local reef configuration (Kronen et al. 2008). Using PROCFish/C figures, Gillett (2015) recently estimated that annual invertebrate productivity could reach 35.3 t.

Coconut crabs

Coconut crab is considered a delicacy in Niue. The most recent survey in 2015 (Helagi et al. 2015) noted a slightly increasing coconut crab population, with a relatively stable size-frequency. However, the size structure of the coconut crab population was mostly represented by relatively small size individuals compared with other less exploited stocks in the region, indicating that collecting pressure has decreased the abundance of larger individuals in the population. After this survey, a ban on coconut crab exports was implemented in order to reduce hunting pressure on the population, which was being exacerbated by the demand from overseas family members.

Current marine management approaches and previous assessments

General regulations

The main fisheries regulations in Niue are the Domestic Fishing Act 1995, the Domestic Fishing Regulations 1996, the Territorial Sea and Exclusive Economic Zone Act 1996, the Niue Coastal Fisheries Management and Development Plan 2017—2022 (still in draft form), and the Niue Pelagic Fishery Management and Development Plan. A Marine Spatial Plan is also currently being designed. There is also the Niue Whale Sanctuary Regulations 2003.

The Domestic Fishing Act 1995 and the Domestic Fishing Regulations 1996 include:

- export prohibitions (e.g. on turtles, sea snakes, whales, porpoises, dolphins, live tropical fish, sea cucumbers, live sea shells, crayfish, egg-carrying or soft-shelled crustaceans);
- size limits (on crayfish, slipper lobsters, coconut crabs, clams);
- quota limits (clams and coconut crabs);
- protection of selected species (Niuean banded sea snake, large spotted green/brown moray eel, whales, porpoises, dolphins, turtles, live corals, egg-carrying and/or soft-shelled crustaceans, giant wrasse *Cheilinus undulatus*, and rays);
- vessel safety equipment requirements;
- annual vessel licence fees;
- prohibition of illegal fishing means (e.g. use of explosives, natural or chemical poisoning, firearms, nets with a mesh size less than 75 mm, scuba diving gear);
- a fishing ban on Sundays;
- a regulation on marine reserves, or *fono*, for fishing; and
- a regulation on bait fishing of *ulihega* (*Decapterus macarellus*).

The Niue Pelagic Fishery Management and Development Plan regulates the pelagic fishery, with reference to:

- Management measures of the pelagic fishery, including:
  - establishment of a Pelagic Fisheries Management Advisory Committee;
  - enhancing FAD programme;
  - spearfishing on FADs;
  - data collection;
  - catch limits.
- Species covered under the plan
- Fish processing and associated waste processing and exports, including:
  - post-harvest handling;
  - fish silage;
  - tourism diversification.
- Exclusion of bottomfish and reef species from this plan
- Development opportunities and arrangements to promote greater utilisation of pelagic resources, including:
  - regional longline fishing and purse seine fishing development opportunities;
  - development of charter boat and sport fishing activities.

- Threatened, endangered and protected species management, including:
    - sea turtles,
    - sharks,
    - whales and other cetaceans (under the Niue Whale Sanctuary Regulations 2003).
- Research, monitoring and data collection
- Western Central Pacific Fisheries Convention
- Interaction between fishing sectors (longlining, sports fishing);
- Licensing
- Monitoring and control surveillance

The National Coastal Fisheries Management and Development Draft Plan 2017–2022 aims at providing policy guidance into the management and development of coastal fisheries in Niue. This plan aims at representing the policy of the government. The plan's objectives are to:

- ensure food security and maximise benefits for Niuean communities;
- enhance and maintain stocks at levels that ensure productivity to optimise sustainable benefits;
- fostering the care of coastal marine habitats and fisheries, and enhance resilience against climate change and environmental impacts;
- promote awareness and applied research to ensure the sustainability of coastal resources, taking into account traditional knowledge and practices;
- maintain sustainable fisheries culture, traditional knowledge and practices;
- strengthen coastal fisheries management policies through appropriate legal frameworks; and
- ensure adequate resources for implementing this plan.

The Niue marine spatial planning process intends to:

- balance ecological, social, economic, cultural and governance objectives, with the over-riding objective, which is biodiversity conservation and resource sustainability;
- enhance development benefits for Niue and its people through the sustainable management of the ocean space;
- be spatially focused. The ocean area to be managed must be clearly defined, ideally at the ecosystem level (certainly being large enough to incorporate relevant ecosystem processes);
- be integrated. The planning process should address interrelationships and interdependences of each component within the defined management area, including natural processes, activities, and authorities.

Each village also has the opportunity to establish bylaws within the given framework of customary tenure. More recently, through the support of the NOW Project, the Niuean Government has agreed and announced its intentions to create a large-scale marine protected area that will encompass 40% of Niue's EEZ, including Beveridge Reef.

Species-specific regulations

For invertebrates protected under the previously cited regulations, species-specific details are provided below:

- Molluscs
    - Giant clams
        - Minimum harvest length: 180 mm
        - Catch limit: 10 clams person^{-1} day^{-1}
- Crustaceans
    - Spiny lobsters
        - Minimum harvest size: tail length 130 mm
        - Catch limit: 10 lobsters person^{-1} day^{-1}
        - No taking of egg-bearing females

- No taking of soft-shelled animals

- Slipper lobsters
  - Minimum harvest size: total length 80 mm
  - No taking of egg-bearing females
  - No taking of soft-shelled animals
- Coconut crab
  - Minimum harvest size: thoracic length 36 mm
  - No taking of egg-bearing females
  - No taking of soft-shelled animals

Previous fisheries studies

Although fisheries development programmes have been carried out almost continuously in Niue since the early 1980s, only a few studies have been conducted to assess fisheries resources since the 1990s.

The first significant survey of marine resources was conducted in 1990 (Dalzell et al. 1990, 1993). All existing fisheries and marine resources information was reviewed, along with a fisheries socioeconomic assessment and an invertebrate assessment, with a special focus on clams, considering their cultural importance. This first survey provided baseline information on fishing activities, including how catches were utilised.

Handlining, rod fishing, hand-and-line fishing, and trolling were the main reported fishing activities, with half of the catch being taken from the reef and the rest from beyond the reef. While most of the catch was for home consumption, a greater proportion of the pelagic component was used for sharing or selling. The invertebrate assessment (using manta tow) reported that the density of the giant clam *Tridacna maxima* was low at 89 individuals (referred to as 'ind' when associated to a density in the rest of the report) per hectare (ha) while that of *T. squamosa* was very low at 14 ind. ha^{-1}. The low densities and the reduced sizes of giant clams indicated the need for monitoring. Three lobster species (*Panulirus penicillatus*, *P. versicolor* and *P. longipes*) and one slipper lobster (*Parribacus caledonicus*) were also recorded during the survey. Sea cucumber populations were dominated by *Holothuria atra*. Species of commercial value were not abundant, thereby limiting the commercial potential of this group. The survey recommended an increased effort in the collection of catch data by local fisheries officers, and monitoring the export of marine resources to New Zealand by air.

Attempts were made to introduce a population of *Tectus niloticus* on Niue (in 1992 and 1996) with the hope that it could become a commercial resource. Subsequent follow-up surveys, however, indicated that while the species was able to survive there was no sign of recruitment or breeding, both of which are necessary for the population to persist and grow (Gillett 1993, 2002; Pasisi 1995).

In 1998, another survey (Labrosse et al. 1999) was conducted in water with two particular areas of focus: the Namoui marine reserve (south of Makapu Point) and Avatele (north of Tepa Point). The reserve was the first marine reserve on Niue, and was originally designed to serve as an example and to demonstrate its possible benefits. Its location was defined as a suitable area that would limit interference with the fishing activities of nearby communities. Fish and invertebrate densities and diversities were not taken into account for the reserve establishment. During this survey, underwater visual censuses of fishes and invertebrates were conducted on the slope and subtidal reef flat, using methodologies that use transects and quadrats. The 1998 survey was conducted in order to provide an insight into the potential of commercial species in the recently declared marine reserve, and to provide reference locations for future monitoring of these species.

In 2001 and 2002, there were several cases of ciguatera fish poisoning and these became a public health issue for the Niuean Government, which subsequently requested assistance to understand the situation. The sampling of fish from the affected areas revealed a high concentration of the toxic dinoflagellate *Gambierdiscus toxicus* (Yeeting 2001, 2003). Coral cover was also assessed as part of the 2002 survey around Alofi wharf and the west coast of the island.

In late 2003 and 2004, baseline surveys were conducted through the International Waters Programme at Alofi North, Makefu and other selected villages on the western coast (Fisk 2007). Because benthic surveys had been conducted before and after Cyclone Heta, which struck in January 2004, an assessment of damage was possible. The cyclone's impact on the reef was patchy, ranging from no damage to extreme damage (reef structure completely wiped out). An explosion of the macroalgae species *Liagora* sp. as well as turf algae and blue-green algae was recorded after the cyclone hit, which is a typical response when large areas of coral reef are damaged or removed.

The PROCFish/C (coastal component of the Pacific Regional Oceanic and Coastal Fisheries Development Programme) survey took place in 2005, with the aim of providing information on the status of reef fisheries around Niue (Kronen et al. 2008). The survey involved both finfish and invertebrate resource assessments, as well as a socioeconomic survey. The socioeconomic survey demonstrated that Niueans do not rely on fisheries resources for food or income, but rather fish as part of a traditional way of life. The small annual export of fish and/or invertebrates back to Niuean families living in New Zealand supports this finding. The report concluded that overall fishing pressure on finfish stocks appeared moderate while fishing pressure on invertebrates was high.

Despite only moderate fishing pressure, finfish diversity and abundance around Niue are considered poor. This is mostly due to the combination of Niue's remoteness (and, hence, its lack of connectivity to other reef systems) and the narrow coral reef habitat surrounding the island. The other significant survey finding was the lack of difference between the Namoui marine reserve and other locations, despite its designation as a protected area. The invertebrate manta tow assessment revealed a considerably reduced clam population (5.56 ind. ha^{-1}), which was predominantly due to heavy local exploitation but may have been accentuated by cyclone-induced mortalities from Cyclone Ofa in 1990 and Cyclone Heta in 2004. The survey also pointed out the lack of potential for exploiting sea cucumber stocks.

In 2016, the National Geographic Pristine Seas project carried out a survey that was conducted in collaboration with the Government of Niue, Oceans 5 (an international, philanthropic group), the local non-profit organisation Tofia Niue, and the Pacific Community (SPC). This collaborative effort carried out a comprehensive marine survey of Niue and adjacent Beveridge Reef in order to gather information on the health of the local marine environment (Friedlander et al. 2017). Various survey methods were used such as transects (for fishes, corals and invertebrates), manta tows, baited remote underwater video systems (for pelagic and reef fishes), and drop cameras. Large population differences were seen between the mainland and offshore reef systems, with Beveridge Reef recording greater overall fish biomass, larger numbers of predatory fish and clams[3] than Niue. Overall, however, fish and coral abundance and biodiversity are low relative to other locations in the Pacific, emphasising, like previous studies, the effects of remoteness, limited reef habitat, and fishing pressure. As reported in the 2005 PROCFish/C survey report, the Namoui marine reserve did not have greater biomass or diversity than adjacent locations outside the reserve, suggesting that a lack of enforcement in the reserve has led to regular poaching since the area was first declared a reserve. The survey report highlighted the importance of careful management and effective enforcement in order to sustain future food security in the marine environment of Niue.

Genetic samples of fish (*Acanthurus nigrofuscus*, *A. triostegus*, *Cephalopholis argus*), giant clam (*Tridacna maxima*) and urchin (*Echinometra mathaei*) – which were collected during 2016 National Geographic Pristine Seas survey – were processed by scientists in New Zealand (Liggins and Arranz-Martinez 2018). The genetic analysis was performed to understand species' genetic profiles and assess the degree and connectivity of individuals between Beveridge Reef and mainland Niue, as well as other locations in the Pacific. The results underline the level of uniqueness and lack of species connectivity, thus underscoring the importance of appropriate management approaches.

Although not typically included in marine surveys, coconut crabs are a regular component of the diet of Niueans and have been studied in several past occasions in Niue. The first account of Niue's coconut crab population was described by Schiller (1992), while unpublished data from a conservation area in 1997, and a draft report from 2008 (Barnett et al. 2008) provided extra information on Niue's coconut crab population. The latest survey – conducted in 2014 (Helagi et al. 2015) – made comparisons with past surveys and provided an up-to-date status of the coconut crab population.

Aims and objectives of this assessment

Few fisheries resource assessments have been carried out in Niue since the 2005 PROCFish/C survey; hence, the work reported herein represents a significant update on the status of Niue's coral reef communities and their associated habitats. Specifically, we conducted ecological surveys of coastal fisheries resources and their supporting habitats in support of both the 'Ridge to Reef Concept for Biodiversity Conservation, and the Enhancement of Ecosystem Services and Cultural Heritage in Niue' project, and the Niue Ocean Wide project for 'Showcasing and Conserving the World's Largest Raised Coral Atoll and its EEZ'.

This work was a collaboration by the Niue Government (coordinated by the Department of Agriculture, Forestry and Fisheries) with strong support from the Department of Environment, the National Geographic Pristine Seas Project, the Ridge to Reef project, and SPC's Coastal Fisheries Programme.

In this report, we provide an updated status of Niue's invertebrates and finfish, and their supporting habitat. Some results of the invertebrate assessments have been presented and discussed in the National Geographic Pristine Seas report (Friedlander et al. 2017), particularly for Beveridge Reef, and will not be duplicated here. The results from the National Geographic Pristine Seas report for Niue correspond to some of the 2016 surveyed stations while the present report considers all stations around Niue for both 2016 and 2017.

Capacity building within communities is a vital part of developing sound management practices for coastal fisheries. Therefore, in addition to providing an update on the status of important finfish and invertebrates, training was provided to staff members of DAFF and the Department of Environment on the methodologies to be used for these surveys.

We expect the results of these surveys to be beneficial to the Ministry of Natural Resources for implementing an effective fisheries management plan that will help maintain adequate stocks of targeted marine species of local and traditional importance.

[3] Clam densities: 1375 ± 675 ind. ha^{-1} recorded during the manta tow, and 1012 ± 643 ind. ha^{-1} recorded during benthic transect surveys

Methodology

In-water resource assessments

In-water surveys were conducted in Niue during two field visits; the first from 13 September to 14 October 2016 (interrupted by the Beveridge Reef assessment work), and the second from 19 September to 10 October 2017. Survey work was divided into three components: invertebrates, finfish and supporting habitats. For each component, standardised SPC methodologies were used (Labrosse et al. 2002; Pakoa et al. 2014), which matched the methodologies and locations of some stations of the PROCFish/C survey (Kronen et al. 2008). Due to rough conditions on the east coast during both survey periods, a reduced number of stations were covered along this coastline.

Invertebrates

Populations of commercially important invertebrates were surveyed in 2016 and 2017 using several different techniques that, in combination, provided for a more complete assessment across multiple scales (Fig. 3).

Manta tow

Manta tows are used to provide a broad-scale assessment of large invertebrate resources over relatively large areas and within acceptable time frames. A snorkeler-surveyor grips a manta board while being towed behind a boat at approximately 4 km hour^{-1} and counts all target species sighted within a 2-m width of a 300-m-long transect. A single manta tow station consisted of six (300 m long x 2 m wide) replicate transects. The length of each tow replicate was measured using a Garmin 64s Map GPS to ensure accuracy when calculating densities of animals. All large (visible from the surface down to a depth of 10 m), sedentary invertebrates observed within each transect were identified to species level and enumerated.

Reef benthos transects

Transect surveys of the reef benthos were conducted to provide information on the finer scale distribution of abundance, density and size structure of invertebrate species. Each station consisted of six (40 m x 1 m) replicate transects laid parallel, approximately 5–10 m apart. Stations were surveyed by two people walking or swimming parallel to one another identifying, enumerating and measuring all macroinvertebrate species encountered (with the exception of urchins, which were not measured).

Night-time reef front searches

Reef front searches were conducted at night to obtain information on abundance, density and length of nocturnal invertebrate species (e.g. spiny lobsters and slipper lobsters). Each survey station consisted of six replicate timed transects, each of 5 min duration and 5 m in width. The transects were laid in pairs 10–15 m apart, resulting in three groups of two transects, also 10–15 m apart, running parallel to the reef edge (Fig. 3) Two groups of surveyors were used, each group comprising an equal number of people (ranging from one to three individuals). Each group worked at the same speed, surveying one transect of each pair. All large sedentary invertebrates (such as sea cucumbers, urchins, spiny lobsters, slipper lobsters, and gastropods measuring > 30 mm) observed within each transect were identified to the species level, enumerated and measured (urchins were not measured).

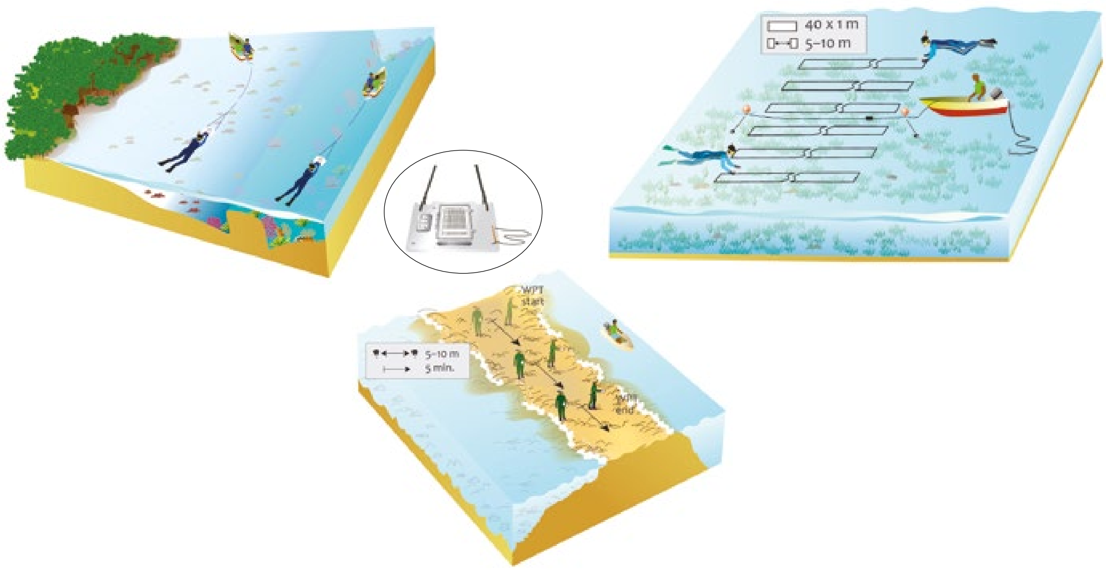


Figure 3. Diagrammatic representations of the three invertebrate survey methods used in Niue: manta tow (top left), reef benthos transect (top right) and reef front search (bottom) (Pakoa et al. 2014).

Finfish

Finfish stations were surveyed in 2017 using two methods: distance-sampling underwater visual census (D-UVC) and timed swims.

Underwater visual census with distance sampling

Fishes were surveyed using the D-UVC methodology after Labrosse et al. (2002). Replicate 50-m transects were surveyed around the reef at several sites that were previously surveyed under the PROCFish/C programme, to allow for comparisons of finfish populations over time. Each transect was completed by two scuba divers who recorded fish to species level and estimated the abundance and length of each fish observed, along with their distance from the transect line. Species surveyed focused on key food fishes and species recognised as good 'indicator' species for changing conditions (e.g. butterflyfish, which are coral grazers, are directly affected by changes in the health of live corals). For the D-UVC method, when a school of fish belonging to the same species and size was encountered, two distance measurements were recorded: the distance of the nearest and farthest fish from the transect line; while for individual fish, only one distance was recorded (Fig. 4)

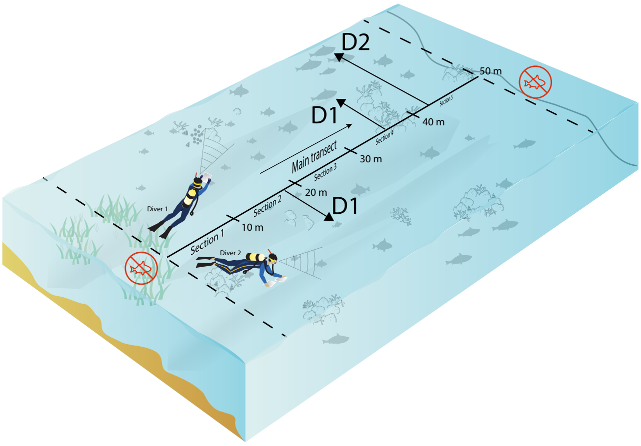


Figure 4. Diagram of the distance-sampling underwater visual census (D-UVC) method.

Table 2. Families of finfish species targeted during the Niue survey.

Family scientific name	Family common name	Local name (Dalzell et al.1993)	Selected species
Acanthuridae	Surgeonfish	Kolala, Hapi, Meito, Tukutea, Humu	All species
Balistidae	Triggerfish		All species
Carangidae	Trevallies	Aheu, Ulua, Tafauli, Malau tea, Ulihega, Atule	All species
Chaetodontidae	Butterflyfish		All species
Didontidae	Porcupinefishes		All species
Haemulidae	Sweetlips		All species
Holocentridae	Soldierfish & Squirrelfish	Selekihi matapulu, Ika to, Ta gutoloa	All species
Kyphosidae	Chubs	Pake nue Nue	All species
Labridae	Wrasses	Tufu, Meai	*Bodianus* spp., *Coris* spp., *Hemigymnus* spp., *Oxycheilinus* spp.
Lethrinidae	Emperors	Kulapu, Fotho	All species
Lutjanidae	Snappers	Palu, Foigo, Hiku ila, Kulapu	All species
Malacanthidae	Blanquillo		All species
Monacanthidae	Filefish		All species
Pomacanthidae	Angelfish	Sifisifi	*Pomacanthus imperator*
Mullidae	Goatfish	Kaloama, Hafulu	All species
Muraenidae	Moray eels	Toke	All species
Nemipteridae	Threadfin Breams		All species
Scaridae	Parrotfish	Paholo	All species
Serranidae	Groupers	Pelepele, Malau pokoahu, Mataele, Talaao, Gatala Gutukafu	Epinephelinae: all species
Siganidae	Rabbitfish	Sikava	All species
Sphyraenidae	Barracudas	Utu, Koho utu	All species
Zanclidae	Moorish Idol		All species

Timed swims

Timed swims were conducted to determine finfish species richness at the same locations as the D-UVC surveys, after the D-UVC surveys had been completed. These swims were also used to train DAFF and environment department staff (snorkelling only) who were involved in both the 2016 and 2017 Niue Marine Ecological Surveys, and were conducted on multiple occasions. The surveys consisted of a single surveyor recording the scientific name of all species encountered during a 30-minute swim, either while snorkelling or diving. Surveys focused solely on documenting species richness, with the results pooled across all locations to provide a detailed list of fish species richness at Niue Island.

Supporting habitat

The supporting habitat (or benthos) assessment was done in 2017 using a single methodology: the photoquadrat.

Characterization of the benthos was conducted along the same D-UVC transects surveyed for finfish populations. After the fish surveys were completed, a diver swam along the 50 m transect photographing the habitat within a 0.25 m^2 quadrat, which was placed every metre. To ensure consistency between the 50 photos, the camera was mounted to a PVC plastic frame at a fixed height (approximately 1.5 m).

Data analysis and reporting

Throughout the survey, all data were entered into a database. Prior to any analyses, the entered data were checked for errors and corrected where necessary. Analyses of the data were performed using SPC software. Reef fish and invertebrate analyses were done using the Reef Fisheries Integrated Database (RFID) software, while analyses of supporting habitat data were done using the SPC Coral Monitoring Portal.

Invertebrates

Diversity was measured by comparing a non-comprehensive list of invertebrates recorded from all methodologies. Numerical density (abundance) of invertebrates is expressed as the number of individuals per hectare (ind. ha^{-1}). For each calculated mean, an associated standard error is also provided. When known, regional reference densities (Pakoa et al. 2014) were used as a comparison with local densities. In addition, where possible, densities were compared with the 2005 PROCFish/C assessment (Kronen et al. 2008) and the 1990 assessment (Dalzell 1993). For species where there were sufficient data, mean sizes and size-frequency distributions were also determined. The methods used for measuring invertebrates are presented in Appendix 1.

Finfish

Finfish diversity is expressed as the number of species recorded during the survey for all methods. Individual specific lengths were converted to body weights using known length-weight relationships. In this report, abundance and density are expressed as a numerical density, with abundance expressed as the number of individuals per 100 m^2 (fish 100 m^{-2}), and biomass as the number of grams per 100 m^2 (g 100 m^{-2}). For each calculated mean, the standard error was also determined. Our survey results were compared with matching stations surveyed by the 2005 PROCFish/C assessment (Kronen et al. 2008) and the 2016 National Geographic Pristine Seas assessment (Friedlander et al. 2017).

Supporting habitat

Quadrat photos were analysed using the SPC Coral Monitoring Portal (see Data Analysis and Reporting section), which provides an analytical system similar to the popular Coral Point Count software of Kohler and Gill (2006). Data were analysed for percent cover of major benthic categories (e.g. live hard corals, macroalgae, rubble, pavement, sand), and other relevant subcategories (e.g. hard coral genera, macroalgae genera). Results were briefly compared with substrate cover estimates from the 2005 PROCFish/C assessment.

Sampling effort

Forty-seven stations, covering approximately 6.1 ha, were surveyed around Niue during the 2016 and 2017 Niue Marine Ecological Surveys. Of these stations, 31 were dedicated to invertebrate surveys and 16 to fish and benthos surveys. While the same stations were used for the fish and benthos surveys, different stations, associated with different methods, were used to assess invertebrates: 13 manta tow stations, 10 reef benthos transect stations and 8 reef front search stations.

Table 3. The number of survey stations and the area surveyed for each method used in 2016 and 2017.

Method	Niue
Manta	
No. stations	13*
Area surveyed	42,600 m^2
Reef benthos transect	
No. stations	10
Area surveyed	400 m^2
Reef front walk**	
No. stations	8
Area surveyed	10,005 m^2
D-UVC and Quadrat	
No. stations	16
Area surveyed	8,000 m^2
Total	**61,005 m^2**

* Two of these station were re-sampled in 2017 for comparison (numbers and area surveyed of the 2017 are not included here).
** The mean walk distance used for surface calculations = 87 m (average length) X 2.5 m (width)

Because the eastern side of Niue is exposed to the prevailing winds and swell, finfish and benthos survey stations were concentrated on the western side of the island, with the exception of one station located on the northeast side.

Similarly to finfish stations, invertebrate stations were mainly along the west coast with the exception of three manta tow stations on the northeast side of the Island, and one reef front night search station on the eastern side of the island.

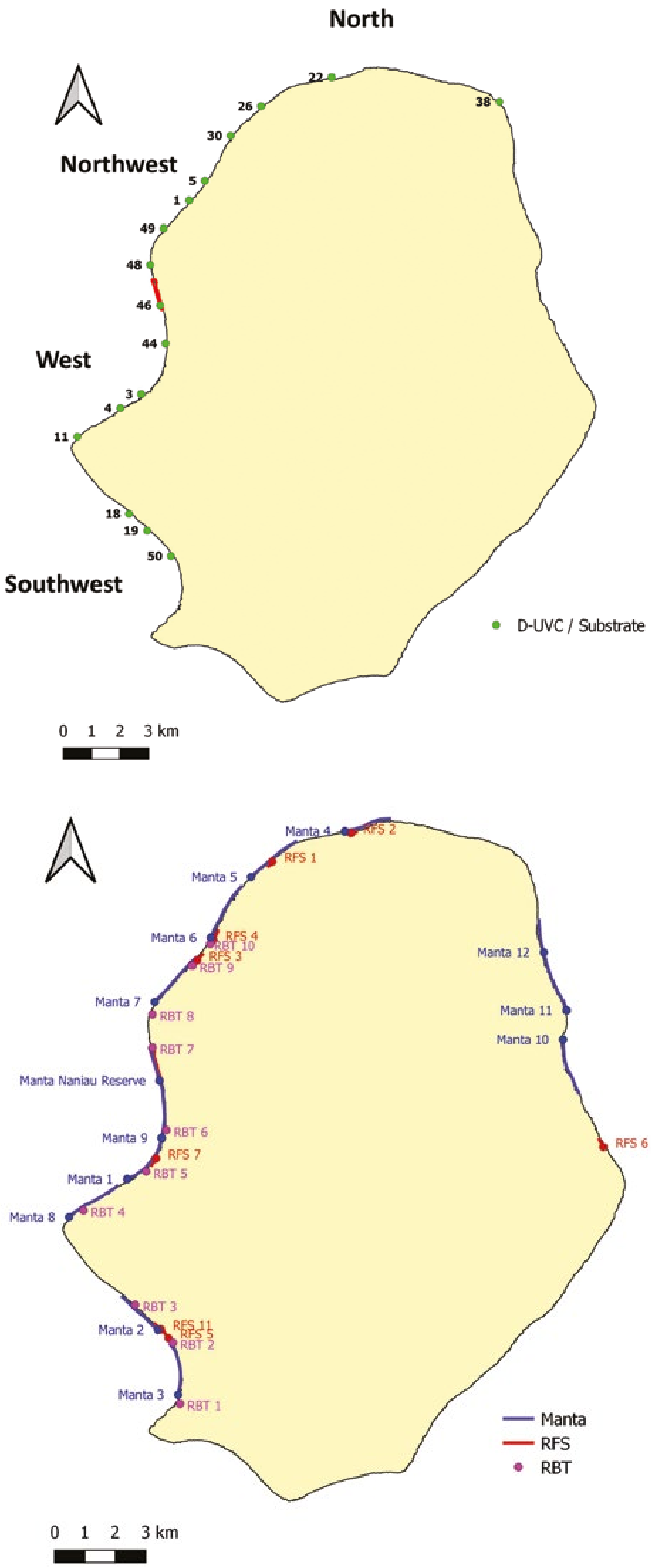


Figure 5. Location of survey stations (2016 and 2017 surveys combined). Top: finfish and substrate survey stations took place at the same locations; bottom: invertebrate survey stations (manta tow, reef benthos transect, reef front search at night).

Results

Invertebrates

Species richness, 2016 and 2017 Niue Marine Ecological Surveys

The species recorded during the invertebrate surveys belonged to three phyla: Echinodermata, Mollusca and Crustacea. The most diverse class recorded was Gastropoda, with 12 taxa identified to species level and 5 to genus level.

Table 4. Invertebrate species observed by survey method in used in the 2016 and 2017 Niue Marine Ecological Surveys.

Group	Category	English common name	Species name	Local name	Manta	RBT	RFS	Other
Echinoderms	Sea cucumbers	Surf redfish	Actinopyga mauritiana		+	+	+	
		Lollyfish	Holothuria atra	Loli	+	+	+	
		White teatfish	Holothuria fuscogilva				+	
		White threadfish	Holothuria leucospilota			+	+	
		Black teatfish	Holothuria whitmaei		+	+		
		Dragonfish	Stichopus horrens				+	
		Prickly redfish	Thelenota ananas		+			
		Amberfish	Thelenota anax		+			
		Tigerfish	Bohadshia argus					+
	Sea stars	Spotted linckia	Linckia multiflora			+		
	Urchins	Rock-boring urchin	Echinometra mathaei			+		
		Needle-spined urchin	Echinostrephus aciculatus			+		
			Echinostrephus sp.			+		
		Black banded sea urchin	Echinothrix calamaris	Vana		+	+	
		Blue-black sea urchin	Echinothrix diadema	Vana	+	+	+	
			Echinothrix sp.	Vana	+	+	+	
		Red pencil urchin	Heterocentrotus mammillatus		+			
		Collector urchin	Tripneutes gratilla					+
Molluscs	Bivalves	Jewel box (reef oyster)	*Chama* sp.	Papahoha		+		
		Elongate giant clam	*Tridacna maxima*	Gege	+	+		
		Fluted giant clam	*Tridacna squamosa*	Gege	+			
			Tridacna noae	Gege				+
	Gastropods		*Astralium* sp.			+		
		Great worm shell	*Ceraesignum maximum*	Matatue		+	+	
		Soldier cone	*Conus miles*			+		
		Cone shell	*Conus* sp.			+		
		Purple pacific drupe	*Drupa morum*	Fufu uli		+		
		Drupe	*Drupa* sp.	Fufu uli		+		
		Seba's spider conch	*Lambis truncata*		+			
		Precious stone shell	*Latirolagena smaragdula*			+		
		Belligerent rock shell	*Mancinella armigera*	Patupatu		+	+	
		Serpent's head cowrie	*Monetaria caputserpentis*	Fuapule		+		
		Money cowrie	*Monetaria moneta*	Fuapule		+		
		Granular drupe	*Morula granulata*			+		
		Drupe	*Morula* sp.			+		
		Grape drupe	*Morula uva*			+		
		Star-shaped limpet	*Patella flexuosa*			+		
			Thais sp.	Patupatu		+		
		Turban snail	*Turbo setosus*	Alili			+	
	Octopuses		*Octopus* sp.	Feke	+	+		
Crustaceans	Lobsters	Pronghorn spiny lobster	*Panulirus penicillatus*				+	
		Caledonian mitten lobster	*Parribacus caledonicus*	Tapatapa			+	
		Red-spotted mitten lobster	*Parribacus holthuisi*	Tapatapa			+	

Invert species presence comparison with previous Niue surveys

A comparison of species between the 2016 and 2017 surveys, and previous surveys from 1990 (Dalzell et al. 1993) and 2005 (Kronen et al. 2008) indicated that far more species were recorded in 2016 and 2017. However, these differences mostly reflect the different methods and objectives of the three surveys. It is also highly likely that some identification errors have been made and in one case, genetic work has led to a newly recognised species (e.g. *Tridacna noae* was newly described from *Tridacna maxima* by Borsa et al. 2014). Differences between surveys were highest among gastropods.

Most of the species recorded are common in the region with the exception of the red-spotted mitten lobster, *Parribacus holthuisi*, which is only found in French Polynesia.

Table 5. Species presence among the 1990, 2005 and 2016 and 2017 Niue Marine Ecological Surveys.

Group	Category	English common name	Species name	Local name	Survey dates		
					1990	2005	2016–2017
Echinoderms	Sea cucumbers	Deepwater blackfish	*Actinopyga palauensis*			+	
		White teatfish	*Holothuria fuscogilva*				+
		White threadfish	*Holothuria leucospilota*				+
		Dragonfish	*Stichopus horrens*				+
		Amberfish	*Thelenota anax*				+
	Sea stars	Spotted linckia	*Linckia multiflora*				+
		Crown-of-thorns starfish	*Acanthaster planci*		+		
	Urchins	Short-spined black urchin	*Echinometra oblonga*			+	
		Collector urchin	*Tripneustes gratilla*				+
Molluscs	Bivalves	Jewel box (reef oyster)	*Chama* sp.	Papahoha			+
			Tridacna noae	Gege			+
	Gastropods		*Astralium* sp.				+
		Soldier cone	*Conus miles*				+
		Cone shell	*Conus* sp.				+
		Money cowrie	*Cypraea moneta*	Fuapule			+
		Great worm shell	*Ceraesignum maximum*	Matatue			≈
		Purple pacific drupe	*Drupa morum*	Fufu uli			+
		Drupe	*Drupa* sp.	Fufu uli			+
		Precious stone shell	*Latirolagena smaragdula*				+
		Granular drupe	*Morula granulata*				+
			Morula sp.				+
		Grape drupe	*Morula uva*				+
		Star-shaped limpet	*Patella flexuosa*				+
		Sirius false limpet	*Siphonaria sirius*			+	
		Mole cowrie	*Talparia talpa*			+	
			Thais sp.	Patupatu			+
		Worm shell	*Thylacodes colubrinus*			+	
Crustaceans	Lobsters	White whisker spiny lobster	*Panulirus femoristriga*		+		
		Painted spiny lobster	*Panulirus versicolor*		+		
		Red-spotted mitten lobster	*Parribacus holthuisi*	Tapatapa			+
	Crabs	Spotted reef crab	*Carpilius maculatus*		+		
		Splendid spooner	*Etisus splendidus*	Feke	+		

+: species recorded during these surveys.[4]

Relative abundance

Relative abundances of invertebrates are described separately for each survey method. Even though species can often be assessed using several methodologies, some methods provide more accurate estimates because they are better suited to the behaviour, size and spatial distribution of the species. These differences are reflected in the changing relative abundances of individual groups across methods.

Manta tow survey

Data collected with this method is biased towards larger animals that are more easily seen. While smaller animals are not as well represented, the area covered is much larger than that of the other methods. Data collected during manta tow surveys are presented in Figure 6. Sea urchins were overwhelmingly the most abundant group, constituting 82% of the invertebrates recorded. Bivalves such as giant clams of the genus *Tridacna* had the second highest percentage at 14%, followed by sea cucumbers at 4%.

[4] +: Some species were observed in previous surveys, but were only given brief mention in reports either because they were observed outside of the transect limits or they were not considered a species of focus, and/or their numbers were too numerous to count.

The presence of gastropods and cephalopods was less than 1% for each.

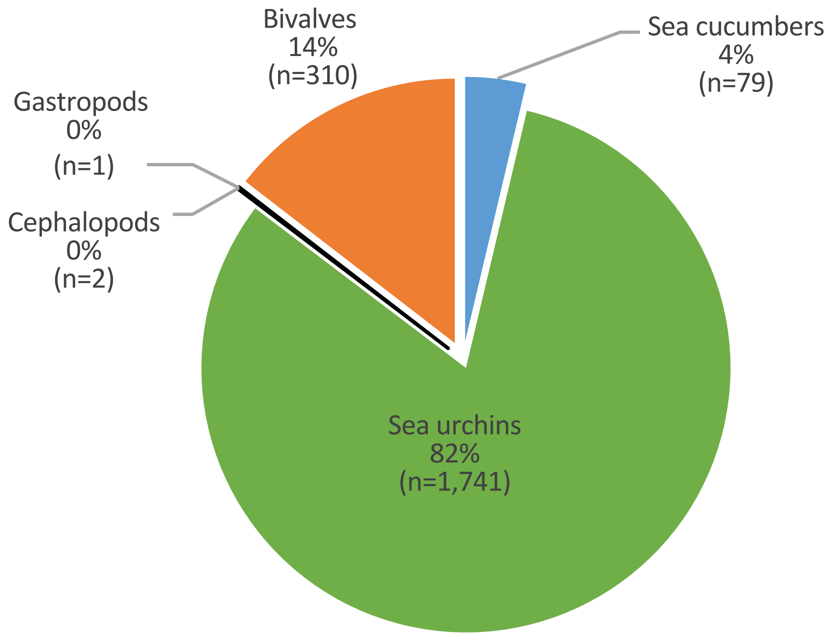


Figure 6. Relative abundance of each invertebrate group during manta tow surveys in Niue in 2016.

Reef benthos transect survey

This method does not cover the same amount of reef area as the manta tow survey but allows for more detailed searching of habitat. It also enables smaller invertebrates such as gastropods to be more effectively counted. The relative abundance of each invertebrate group using this method is summarised in Figure 7. Approximately two-thirds of the invertebrate composition comprised gastropods (68%), sea urchins (20%), sea cucumbers (11%) and bivalves (1%). The numbers of cephalopods and starfish combined were less than 1% of the total.

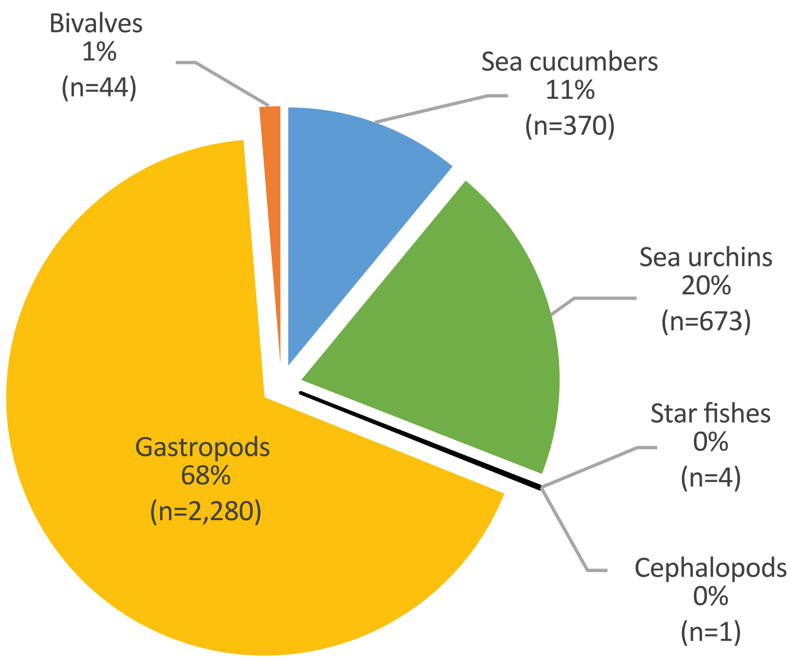


Figure 7. Relative abundance of each invertebrate group for reef benthos transect method in Niue (2016 and 2017).

Nocturnal (night) reef front surveys

Some invertebrates are more active at night, displaying cryptic behaviour during daylight hours, which makes them very difficult to survey effectively during daylight hours. Thus, reef walks were done at night to assess cryptic macroinvertebrates such as lobsters, as well as some species of sea cucumbers and gastropods. Sea cucumbers dominated the nocturnal invertebrate community, constituting 93% of the total numbers seen. The remaining 7% was a mix of sea urchins, gastropods and crustaceans (Fig. 8).

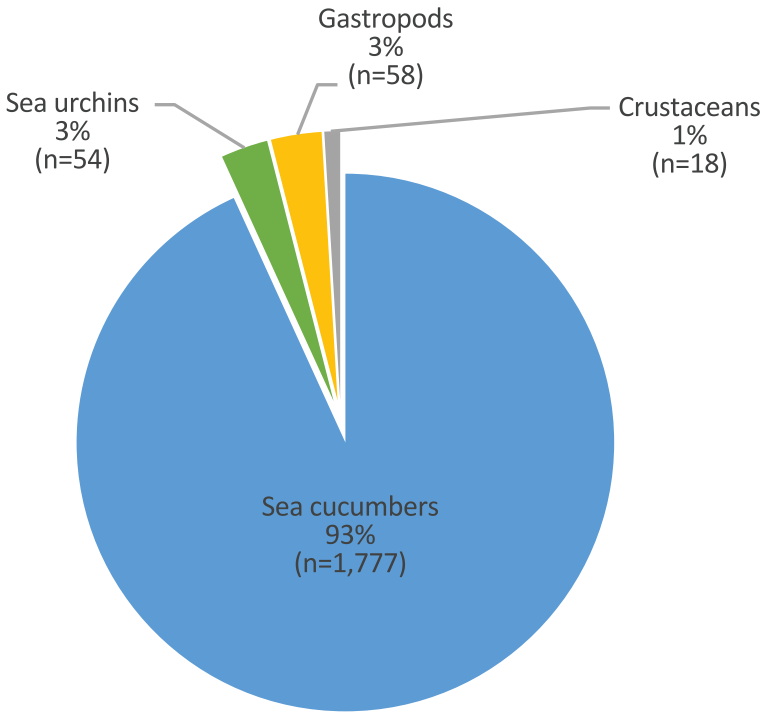


Figure 8. Relative abundance of each invertebrate group using the reef front search method (at night) in Niue 2016 and 2017.

Density

Species densities are presented separately by method as was done for the species richness and relative abundance data. When there was a mix of identified and unidentified species within a particular genus, species were grouped for clarity. For example, *Echinothris calamaris, E. diadema* and *E.* sp. were grouped as *Echinothrix* spp.

Manta tow surveys

Densities of each observed species or species group are reported as well as reference densities for healthy stock levels, when these are available (Fig. 9).

Urchins were overwhelmingly the most abundant group counted during manta tow surveys, with a density of 397.26 ± 123.77 ind. ha^{-1}, and consisting of virtually all *Echinothrix* spp. Elongate giant clams (*Tridacna maxima*) were also well represented at a density of 66.28 ± 22.09 ind. ha^{-1}, while the fluted giant clam (*T. squamosa*) was very scarce at 1.30 ± 0.67 ind. ha^{-1}. None of the sea cucumber species observed reached abundances greater than 9 ind. ha^{-1}, with lollyfish (*Holothuria atra*) density extremely low in comparison to reference values. While the differences were not as pronounced, densities of surf redfish (*Actinopyga mauritiana*) and amberfish (*Thelenota anax*) were also very low compared with reference densities. Other sea cucumber species, while also low, more accurately reflected normal reference densities.

Across all stations, only one individual of red pencil urchin (*Heterocentrotus mamillatus*) and Seba's spider conch (*Lambis truncata*), and two individuals of octopus (*Octopus* sp.) were observed, densities are compiled in Appendix 2 but these species are not represented in Figure 9.

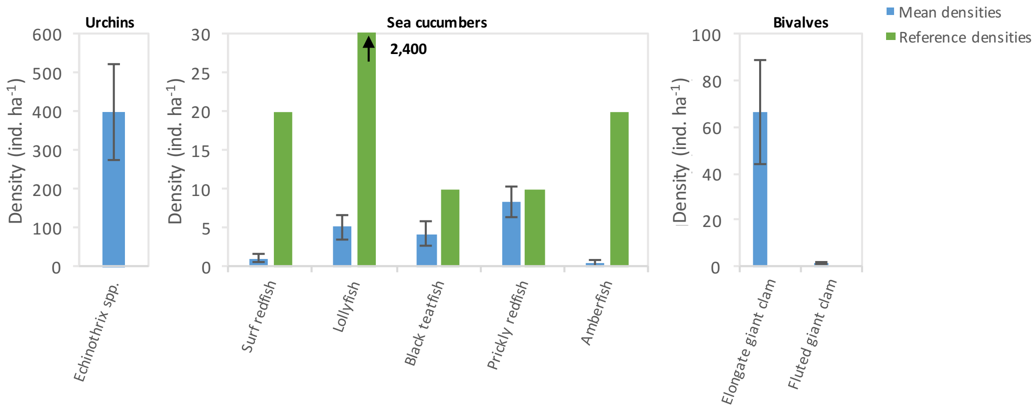


Figure 9. Density (ind. ha^{-1}) of each invertebrate group during manta tow surveys in Niue in 2016. Reference densities are from Pakoa et al. 2014.

Reef benthos transect surveys

Densities of each observed species or species group are reported as well as reference densities for healthy stock levels, when these are available (Fig. 10). Gastropods were the most abundant group surveyed, with densities of 4,442 ± 1,377 ind. ha^{-1} and 3,600 ± 1,677 ind. ha^{-1} for the locally consumed drupe genera *Morula* spp. and *Drupa* spp., respectively. Cone shell densities were lower at 808 ± 318 ind. ha^{-1}. Some of the other gastropod species, such as the great worm shell and reef oyster, which are also consumed locally, were recorded at very low levels (Fig. 10). The elongate giant clam was found at low densities of 59 ind. ha^{-1}, which is well below the reference density of 750 ind. ha^{-1}. Among echinoderms, urchin densities were relatively high, ranging from 379 ± 160 ind. ha^{-1} for *Echinostrephus* spp. to 1,433 ± 1,325 ind. ha^{-1} for *Echinothrix* spp. The highest density recorded for sea cucumbers was for lollyfish at (1179 ± 477 ind. ha^{-1}), which is still far below the reference density of 5,600 ind. ha^{-1}. White threadfish were found in densities of 317 ± 263 ind. ha^{-1}, and densities of surf redfish and black teatfish were very low compared with regional reference densities.

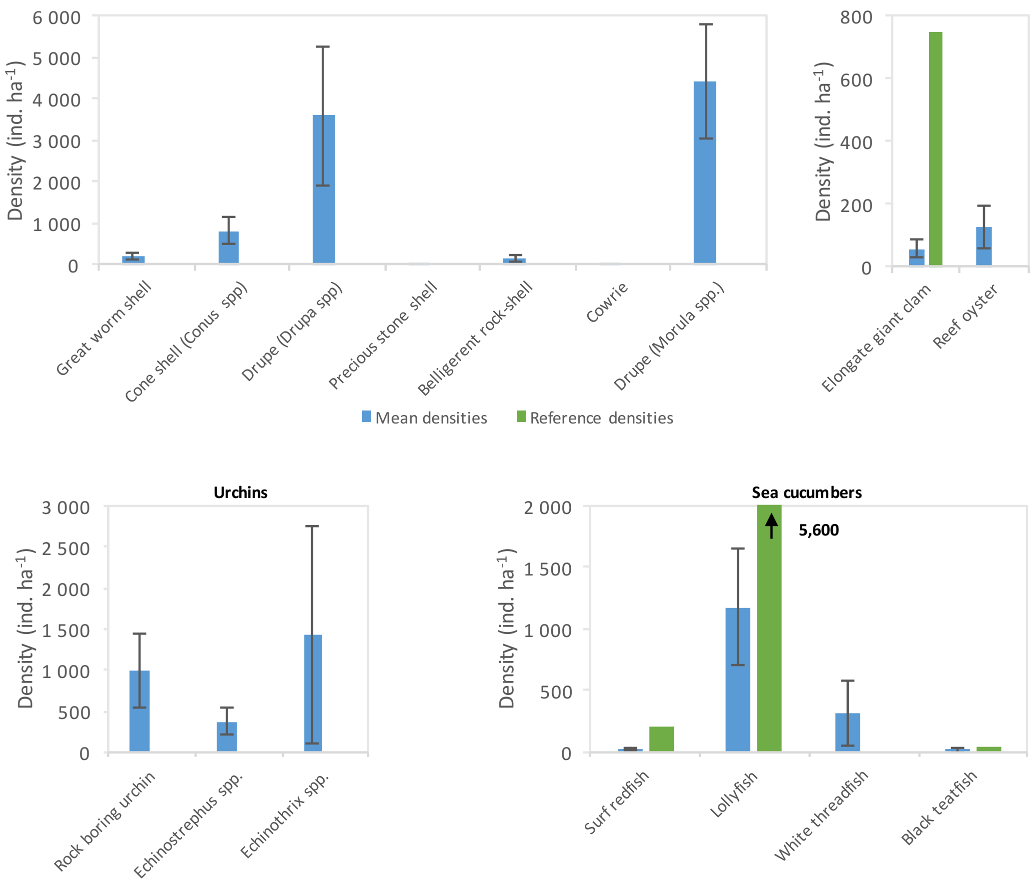


Figure 10. Densities (ind. ha-1) of each invertebrate group using the reef benthos transect method in Niue in 2016 and 2017. Reference densities are from Pakoa et al. 2014.

Nocturnal (night) reef front surveys

This method is usually undertaken to target less common species, and is generally not used to calculate densities. However, because distances and width estimates of walks were available for this survey, densities were estimated (Fig. 11). There are no known reference densities for this method.

Lollyfish and white threadfish were the most abundant sea cucumber species, with values of 513 ± 238 ind. ha^{-1} and 336 ± 306 ind. ha^{-1}, respectively. Urchin (*Echinothrix* spp.) and turban snail densities were low at (24 ± 14 ind. ha^{-1} and 31 ± 17 ind. ha^{-1}, respectively. Other species and/or taxa were encountered in minimal abundances.

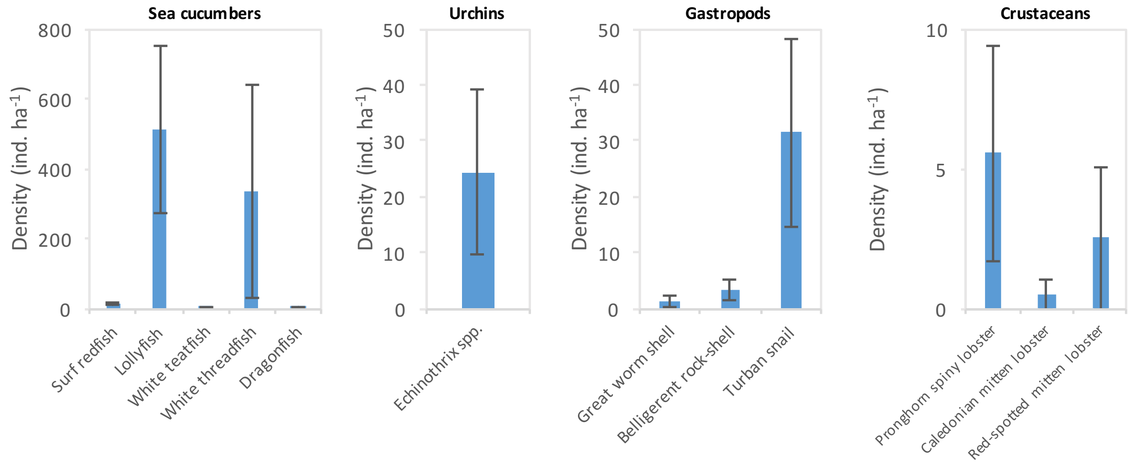


Figure 11. Estimated density (ind. ha^{-1}) of each invertebrate group using the reef front search method (at night) in Niue in 2016 and 2017.

Invert density comparison with previous Niue surveys

Due to considerable variations in invertebrate survey methodology between the 2016 and 2017 Niue Marine Ecological Surveys, and the 2005 survey, only the manta tow method allowed for density comparisons. Figure 12 represents densities of species that were observed during both surveys (with values above 1 ind. ha^{-1} in at least one of the surveys) at the same nine stations. Low density species were recorded in similar numbers for both surveys. The average density of *Echinothrix* spp. was higher during the 2016 and 2017 surveys, although densities were highly variable across stations in both surveys. An unexplained massive die-off of urchins was reported at the end of 2016 (in early November after the survey) but it is not known to what extent it affected the density because the manta tow method was only used during the 2016 survey. There was also a 16-fold increase in mean elongate giant clam densities from 5.56 ± 2.36 ind. ha^{-1} in 2005 to 91.40 ± 28.07 ind. ha^{-1} in 2016 and 2017.

An earlier manta tow survey in 1990 (Dalzell et al. 1993), recorded a mean density of 89.20 ± 15.53 ind. ha^{-1} for the elongate giant clam although the manta tow technique used in the earlier survey was slightly different (location and length of tows) to the 2016 and 2017 Niue Marine Ecological Surveys, so the results are only broadly comparable.

It should be noted that the 2005 survey occurred approximately 12 months after Tropical Cyclone Heta, and the 1990 survey occurred soon after Cyclone Ofa. After Cyclone Heta, a significant impact on the giant clam population was recorded (Brendon Pasisi, Niue Ocean Wide project manager, pers. comm.).

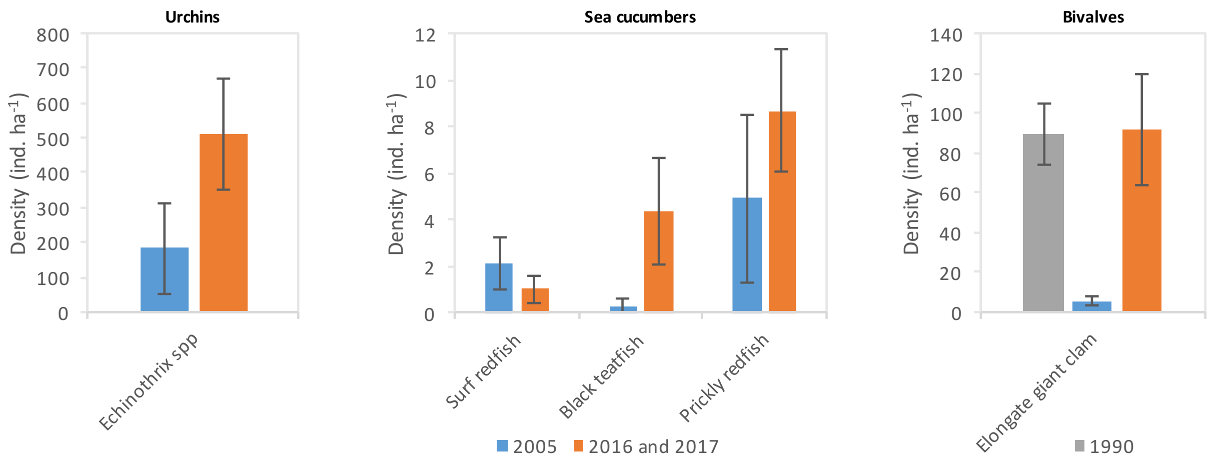


Figure 12. Manta tow density comparisons for the 2005 survey (Kronen et al. 2008) and the 2016 and 2017 Niue Marine Ecological Surveys, with the addition of the 1990 survey (Dalzell et al. 1993) for bivalves.

Three reef benthos transect stations were surveyed in 2005 while 10 stations were surveyed during the 2016 and 2017 Niue Marine Ecological Surveys. All three stations were surveyed in the same general area (southwest) during 2005, allowing for comparisons with three stations from the 2016 and 2017 surveys, which also were in the southwest. Density values are so variable between the surveys for the three species compared (Table 6) that they are unlikely to reflect real changes in growth or mortality, instead more likely reflecting differences in the specific locations of each survey point between years. In all cases, the standard error is very high, indicating large changes in abundance from station to station.

Table 6. Reef benthos density comparisons from the southwest side of Niue for the 2005 survey (Kronen et al. 2008) and the 2016 and 2017 Niue Marine Ecological Surveys.

Survey year(s)	Elongate giant clam (ind. ha^{-1} ± SE)	Lollyfish (ind. ha^{-1} ± SE)	White threadfish (ind. ha^{-1} ± SE)
2005	215.28 ± 120.28	0	0
2016 and 2017	0	2,527.78 ± 1,419.39	1,055.56 ± 874.78

Densities by station

Sea cucumbers

From the manta tow surveys, sea cucumber densities were found to be low at all stations, with the cumulated density varying from 6 ± 6 14 ind. ha^{-1} to 50 ± 14 ind. ha^{-1}. One up to a maximum of four species were observed across all stations, with lollyfish and prickly redfish being observed in 10 of the 13 stations and black teatfish being observed in 9 of the 13 stations. Surf redfish and amberfish were uncommon, found only at three stations and two stations, respectively. There were no differences in density at the station located in the Namoui marine reserve when compared with densities from outside the reserve.

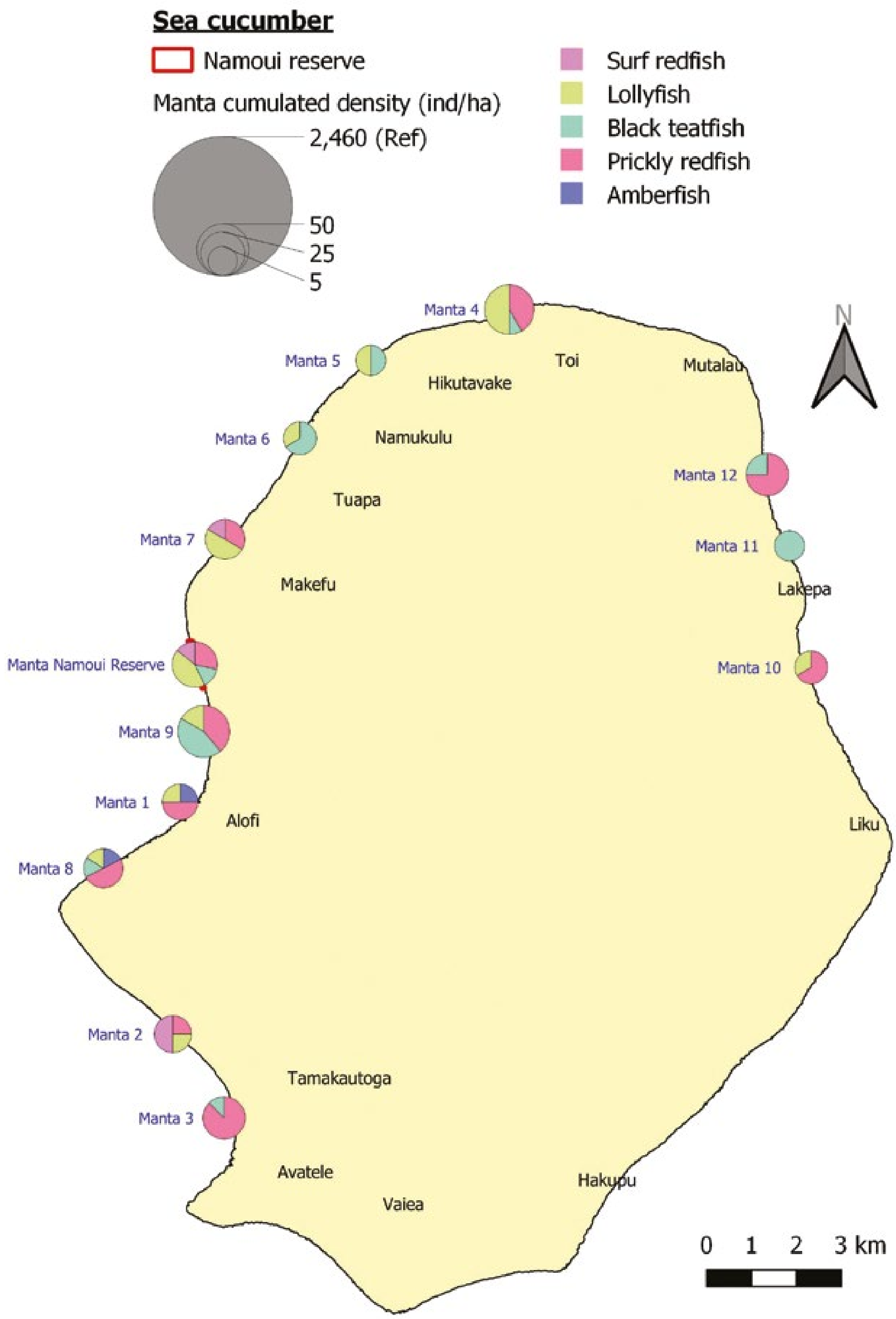


Figure 13. Sea cucumber cumulated densities (ind. ha^{-1}) for manta tow stations around Niue (2016). Densities were square-root transformed to enable very low and very high values to be accurately displayed. The 'Ref' value represents the cumulated manta tow reference densities of all observed species.

From the reef benthos transect surveys, sea cucumber cumulated densities were more variable and higher than those recorded from the manta tow surveys, with the lowest value of 42 ± 42 ind. ha^{-1} recorded at station RBT 10, and up to 5,500 ± 1,095 ind. ha^{-1} recorded at station RBT 2. The two stations with the highest densities were recorded in the southwest of the island. One up to a maximum of three species were observed across all stations with lollyfish being represented in nine of the ten stations. Lollyfish, and to a lesser extent white threadfish, were responsible for the high densities recorded in the southwest. The density at station RBT 7, located at the northern boundary of the marine reserve, was not higher than at other stations.

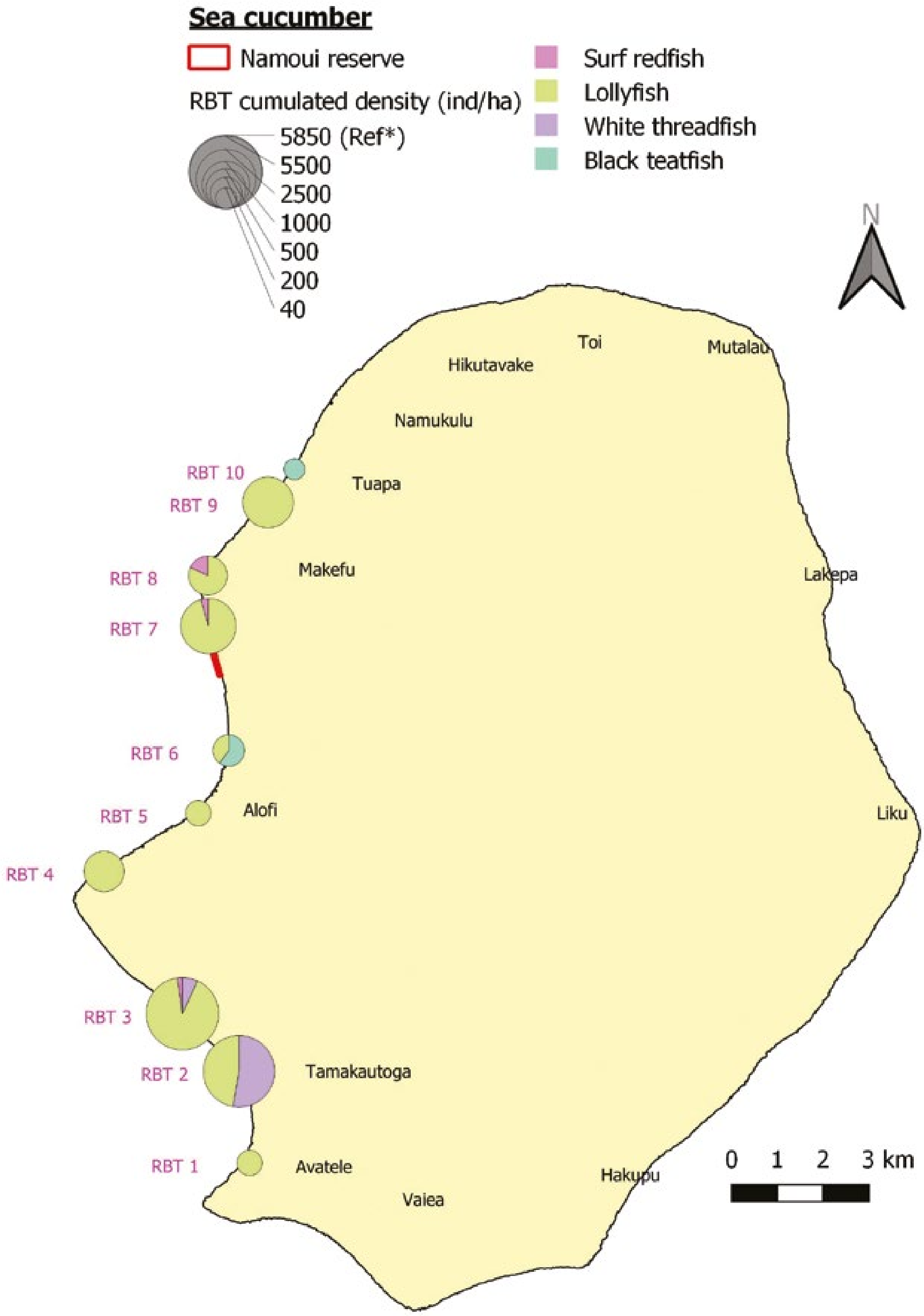


Figure 14. Sea cucumber cumulated densities (ind. ha^{-1}) for reef benthos stations in Niue (2016 and 2017). Densities were square-root transformed to enable very low and very high values to be accurately displayed. The 'Ref' value represents the cumulated reef benthos transect reference densities of all observed species except for white threadfish for which no reference densities are known.

Molluscs (Drupa, Morula and Conus)

The reef benthos transect surveys found relatively high densities of drupe (*Drupa* spp. and *Morula* spp.) and cone (*Conus* spp.) shells, although densities varied greatly among stations. The lowest density was recorded at station RBT 2 with 667 ± 271 ind. ha^{-1}, while the highest density was at station RBT 7, located at the northern boundary of the marine reserve, with 24,083 ± 3,900 ind. ha^{-1}. Densities in the northwest were slightly higher than in the rest of the survey locations.

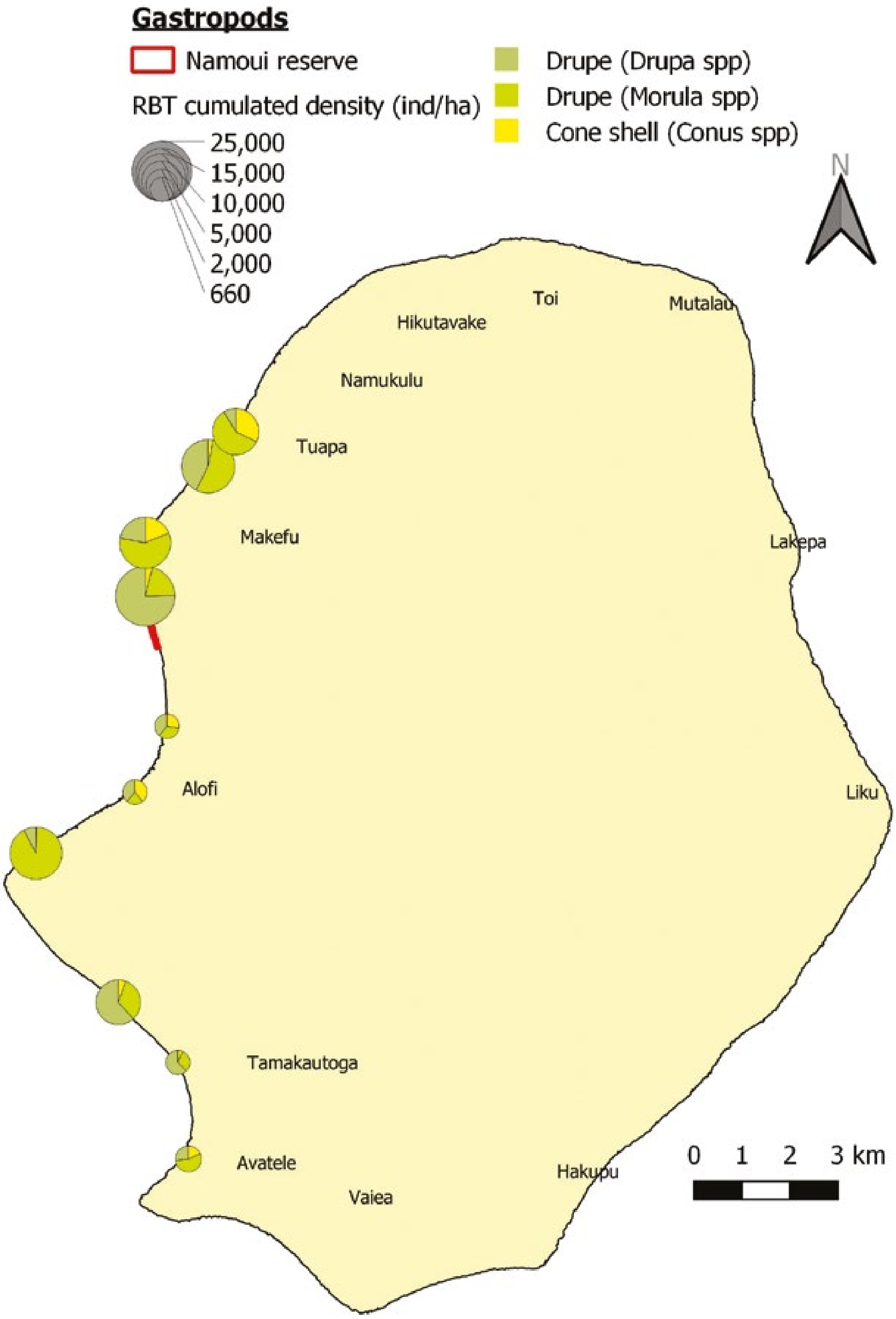


Figure 15. Drupe (*Morula* spp. and *Drupa* spp.) and cone shell (*Conus* spp.) cumulated densities (ind. ha^{-1}) for reef benthos stations in Niue in 2016 and 2017. Densities were square-root transformed to enable very low and very high values to be accurately displayed.

Other gastropods

From the reef benthos transect surveys, several other gastropod taxa were recorded across all stations, all of which are locally consumed. Combined densities for these taxa varied from 0 ind. ha^{-1} at station 7 (northern boundary of the Namoui marine reserve) to 1,417 ± 422 ind. ha^{-1} at station 10. Densities were slightly higher in the northwest of the island.

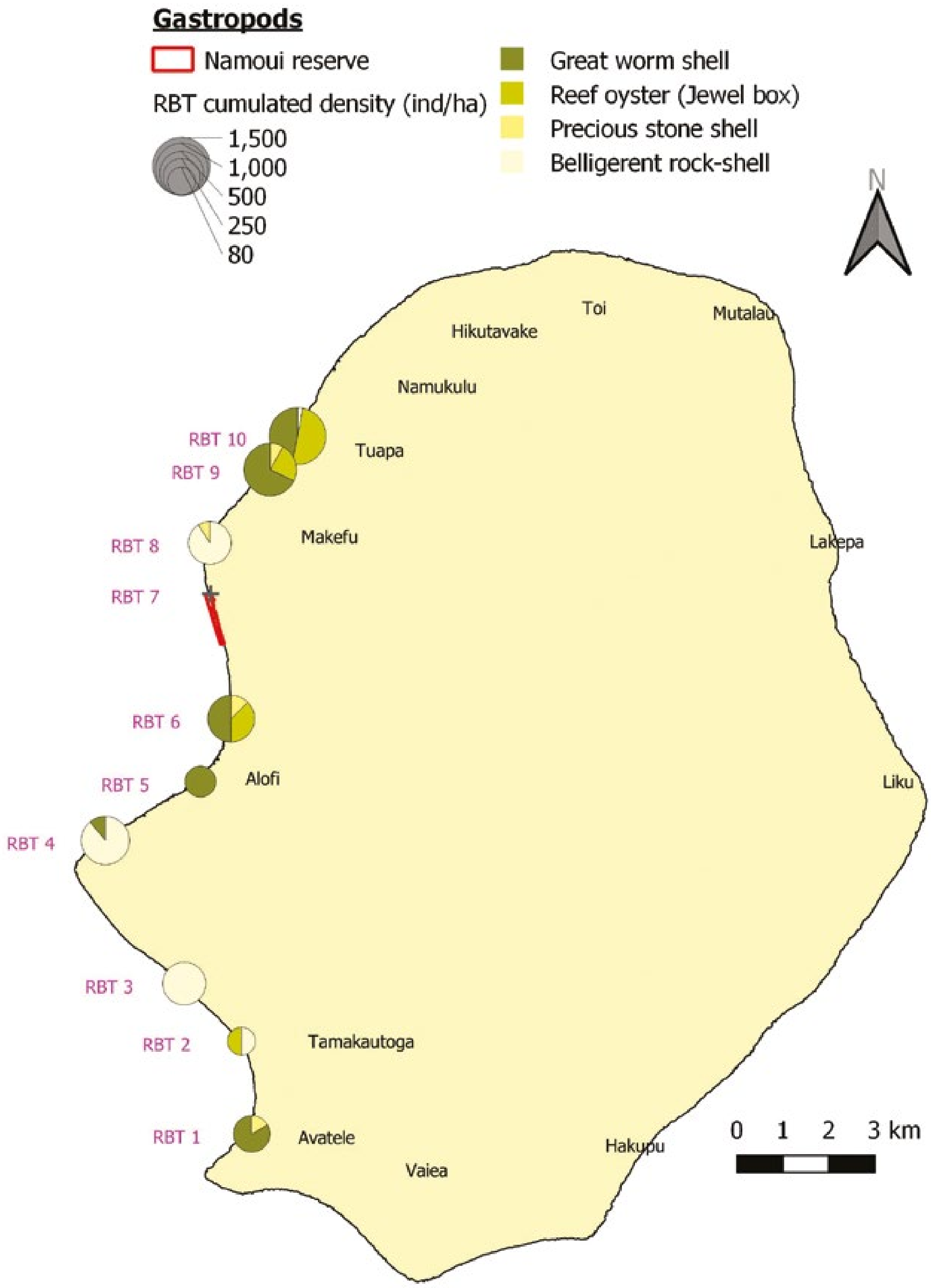


Figure 16. Other locally consumed gastropod densities (ind. ha^{-1}) for reef benthos stations in Niue (2016 and 2017). Densities were square-root transformed to enable very low and very high values to be accurately displayed. At station 7 (the '+' symbol), there were no observation of these gastropod species.

Giant clams

Elongate giant clams were recorded during both manta tow and reef benthos transect surveys. The species has a high cultural value as it is considered a local delicacy in Niue.

Densities from the manta tow surveys were low, ranged from 0 to 293 ± 67 ind. ha^{-1}, with the minimum density recorded at manta tow stations 11 and 12, and the maximum at manta tow station 6. There were no elongate giant clams encountered at survey sites along the Niue's east coast and densities were extremely low at the northern end of the island, along the southwest coast and in the marine reserve. Densities were slightly higher on the west and northwest coasts.

Densities from the reef benthos transect surveys were also low and ranged from 0 ind. ha^{-1} for stations RBT 1–4 in the southwest and station RBT 8 in the northwest, to 292 ± 77 ind. ha^{-1} at station RBT 10.

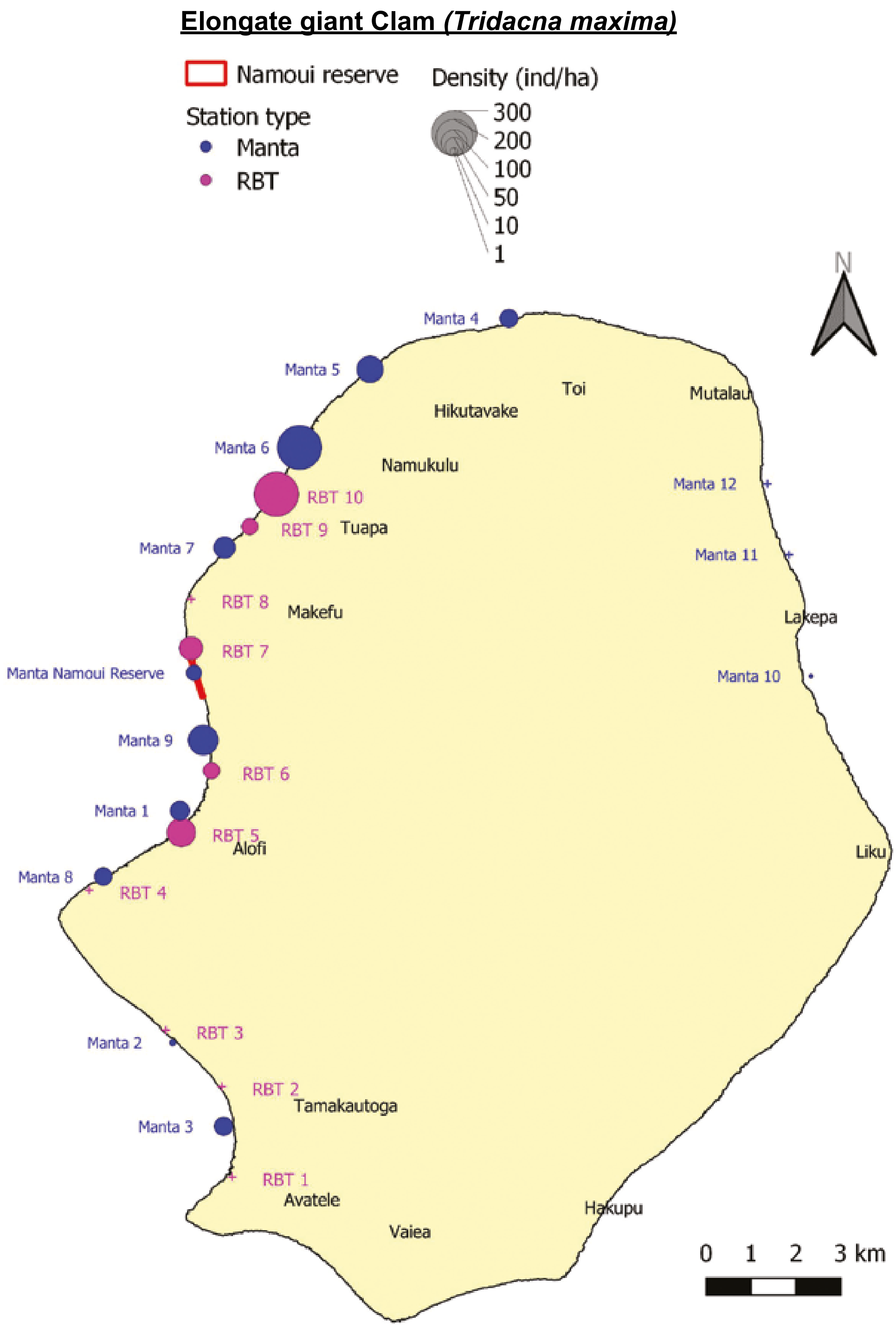


Figure 17. Elongate giant clam density (ind. ha^{-1}) at manta tow and reef benthos transect stations around Niue (2016 and 2017). The '+' symbols correspond to stations where the species was not observed.

Turban snails

Turban snails are of local importance as a seafood. *Turbo setosus* was the only species of the genus seen during surveys, and only during reef front searches at night after low tide. There were two stations (RFS 3 and RFS 7) where *T. setosus* was not observed. Among the other stations, estimated densities ranged from 4 ± 4 ind. ha^{-1} (RFS 11) to 116 ± 72 ind. ha^{-1} (RFS 2). Stations with the highest densities were located on Niue's north and southwest coasts. Two stations adjacent to each other – RFS 11 and RFS 5 – had very different densities, which we attribute to harvesting at RFS 11 where a large amount of crushed turban snail shells were found.

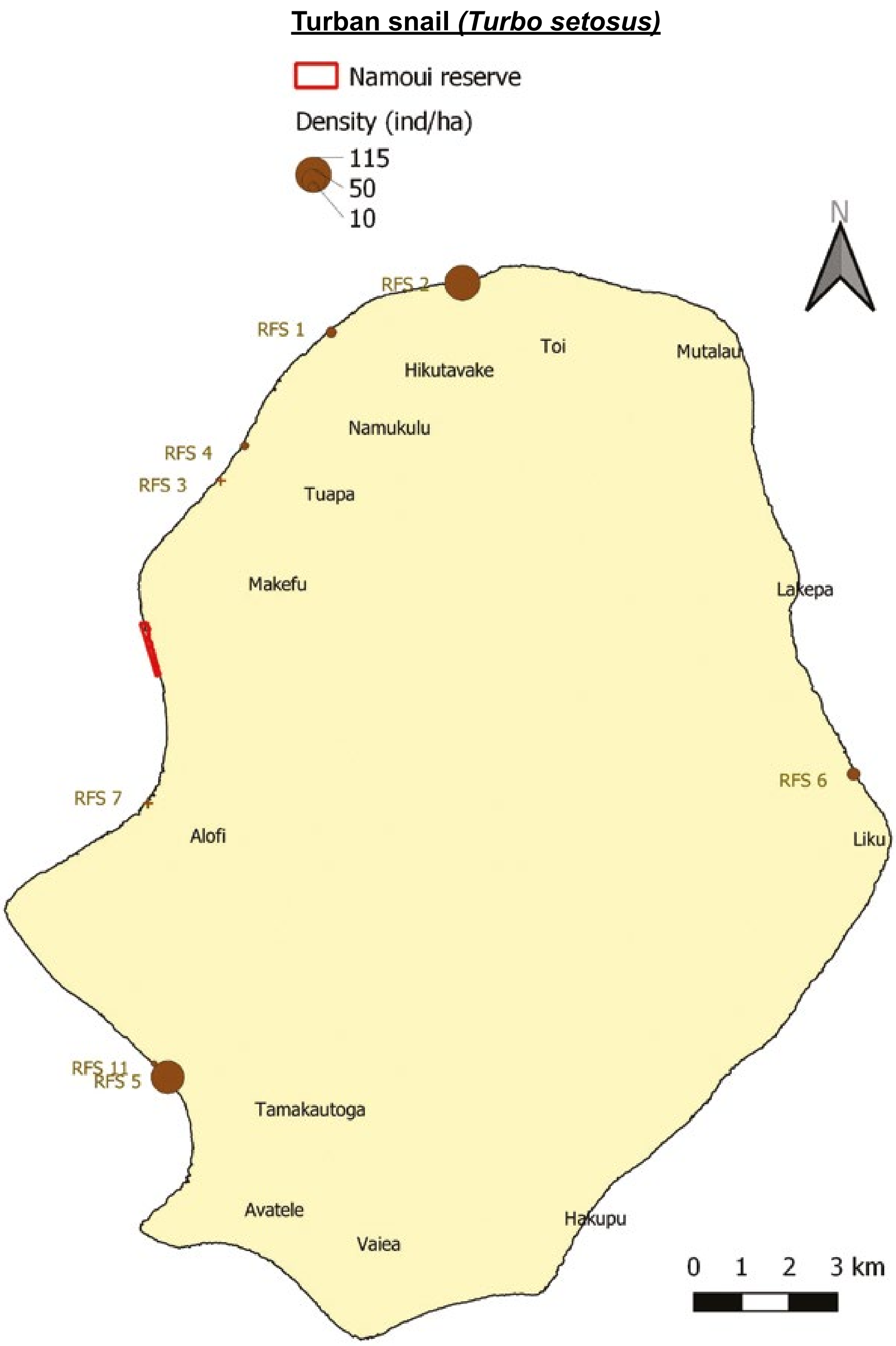


Figure 18. Estimated density (ind. ha^{-1}) for *Turbo setosus* from reef front searches around Niue (2016 and 2017). The '+' symbols correspond to stations where the species was not observed.

Crustaceans

Spiny lobsters and slipper lobsters, which are a local seafood delicacy in Niue, can be found on the reef flat at night when they come out of reef crevices, ledges, nooks and crannies to forage.

Pronghorn spiny lobsters (*Panulirus penicillatus*) were counted at two stations (RFS 6 and 11), with the highest density of (29 ± 7 ind. ha^{-1}) measured at RFS 6 on the east coast, and the lowest density (15 ± 11 ind. ha^{-1}) was recorded at site RFS 11 on the southwest coast.

Slipper lobsters were counted at only one station (RFS 3) on Niue, on the islands northwest coast. At this station, the red-spotted mitten lobster (*Parribacus holthuisi*) was the most common species, at a density of 20 ± 16 ind. ha^{-1}. A few other individuals were observed in the vicinity of other stations on the west coast, but not during the surveys and, therefore, they were not counted.

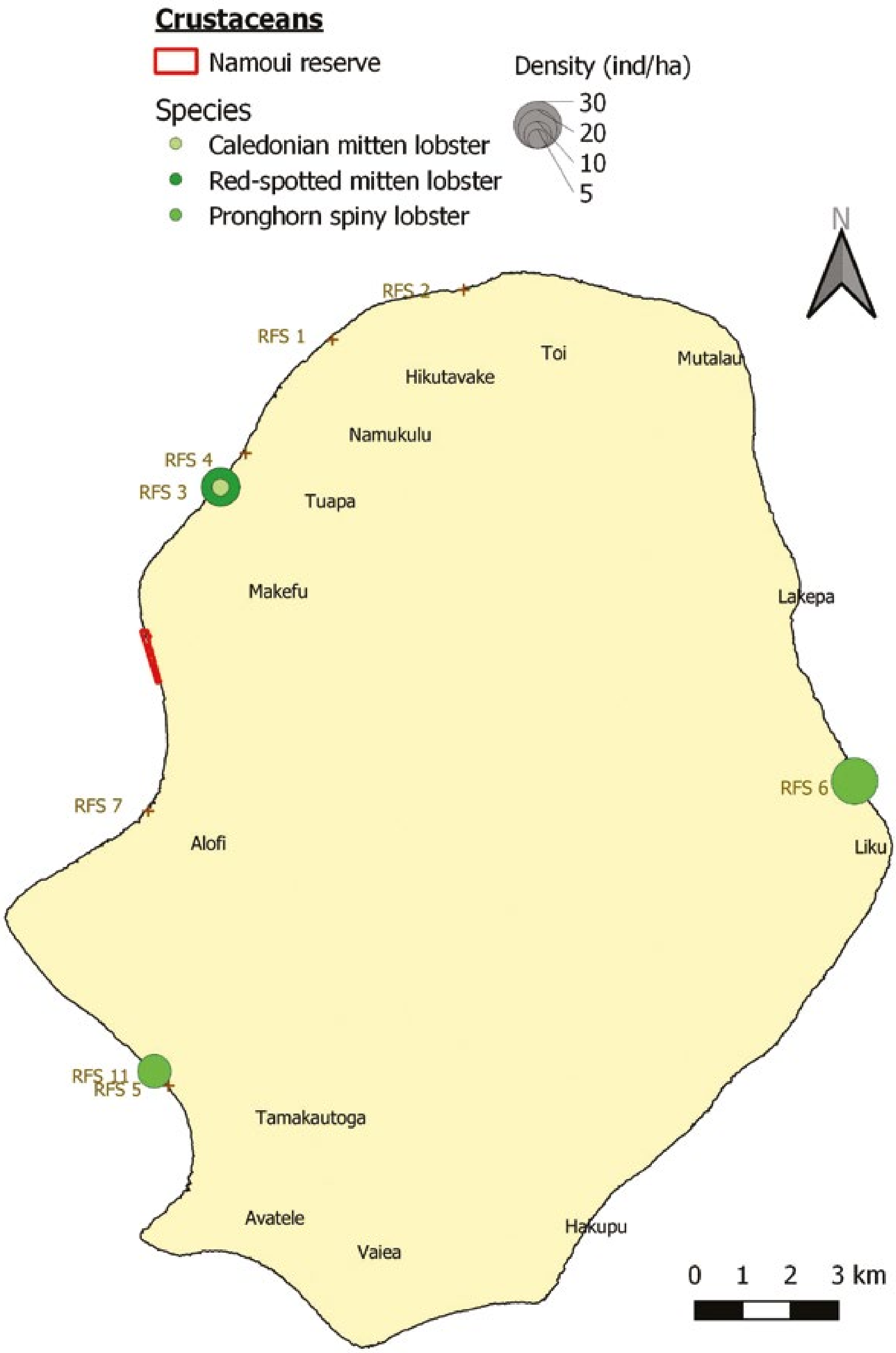


Figure 19. Spiny lobster and slipper lobster densities (ind. ha^{-1}) for reef front searches around Niue (2016 and 2017). The '+' symbols correspond to stations where lobsters were not observed.

Size structure

Mean length was calculated for any species where at least three individuals were measured, with the results presented in Figure 20. All sizes are presented in table form in Appendix 6.

Mean size of all sea cucumber species ranged between 220.00 ± 46.19 mm (dragonfish) to 303.75 ± 26.57 mm (black teatfish). In Niue, sea cucumbers are not generally harvested for food or for commercial purposes and this corresponds with the mean sizes, which were generally above the regional common size. The mean size for white threadfish and dragonfish was found to be below the regional means, however, because only a few individuals were encountered and the measured results may not accurately represent the average size of the local population.

Mean total length was calculated for the three species of crustaceans recorded during the survey: pronghorn spiny lobster, 197.25 ± 22.43 mm and red-spotted mitten lobster 167.00 ± 8.00 mm. All three lobster species are regulated in Niue, and it is not allowed to collect individual spiny lobsters that are less than 130 mm in tail length, or slipper lobsters that are 80 mm total length. The mean size of slipper lobsters was more than the minimum harvest size, although the mean size of spiny lobsters was 67 mm greater than the minimum harvest tail length. Mean tail length of measured individuals would have been relatively close to the harvest minimum size as it is usually considered that the tail represents approximately two-thirds of the body length.

For bivalves, measurements of the elongate giant clam were only made on the reef flat during the reef benthos transect surveys. All individuals were small, with an average length of 44.29 ± 4.70 mm, which is well below the 180 mm minimum harvest size. When compared to the 2005 survey (Kronen et al. 2008), where the mean size was 133.86 ± 9.00 mm (n=21 individuals) and the 1990 survey (Dalzell 1993), where the mean size was 120 mm (n=150), there appears to have been a significant drop in the size of harvestable clams. However, larger clams are found mostly on the shallow reef slope where conditions are not so harsh although measurements were not made on individuals in this zone. The mean size of reef oysters, *Chama* sp, was calculated to be 65.00 ± 4.16 mm.

Within the gastropod group, the belligerent rock shell, *Mancinella armigera*, had a mean size of 62.84 ± 1.96 mm and the turban snail, *Turbo setosus,* had a mean size of 61.56 ± 1.58 mm.

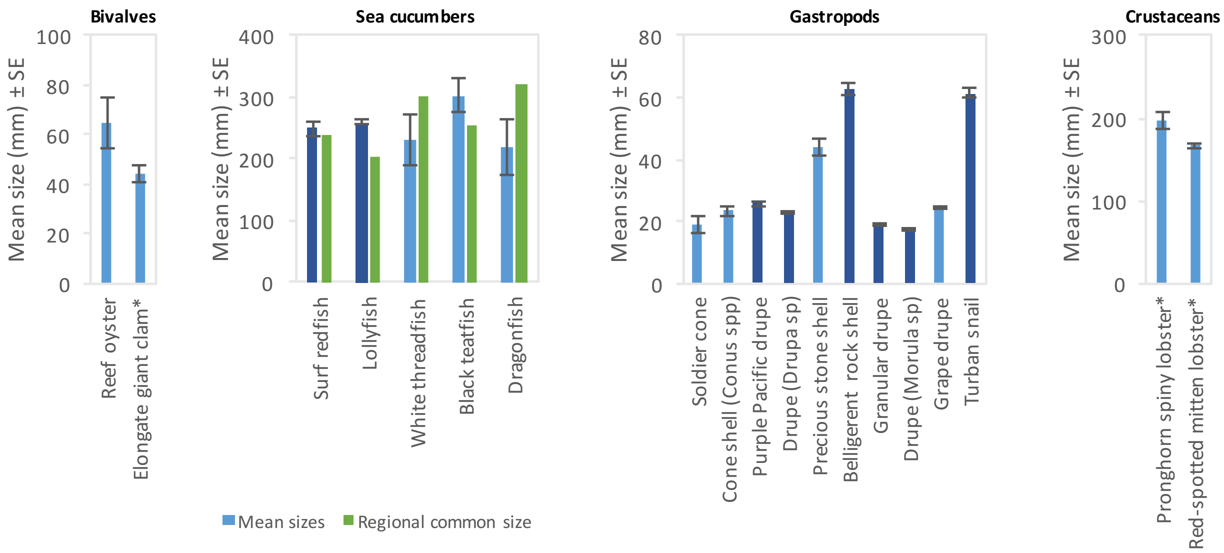


Figure 20. Mean size of invertebrate species (with at least three measurements) recorded for all methods in Niue (2016 and 2017).
* Species under specific management regulation in Niue.
Bar plots coloured dark blue indicate species for which length-frequency plots are displayed.

Length frequencies

For those species where at least 30 individuals were measured, length-frequencies were plotted (Fig. 20). These plots provide information on the mean size of a population and indicate how variable individual sizes are around that mean. These data are a necessary first step in understanding the population structure of species.

Sea cucumbers

- Lollyfish (*Holothuria atra*)

We obtained extensive measurements of lollyfish individuals (n=428), which enabled us to make an estimate of the population structure. The length-frequency analysis shows that the Niue lollyfish population is normally distributed, with a mean size of 259.08 ± 3.57 mm and modal length class of 221–240 mm. The population is considered to be unexploited relative to the regional mean.

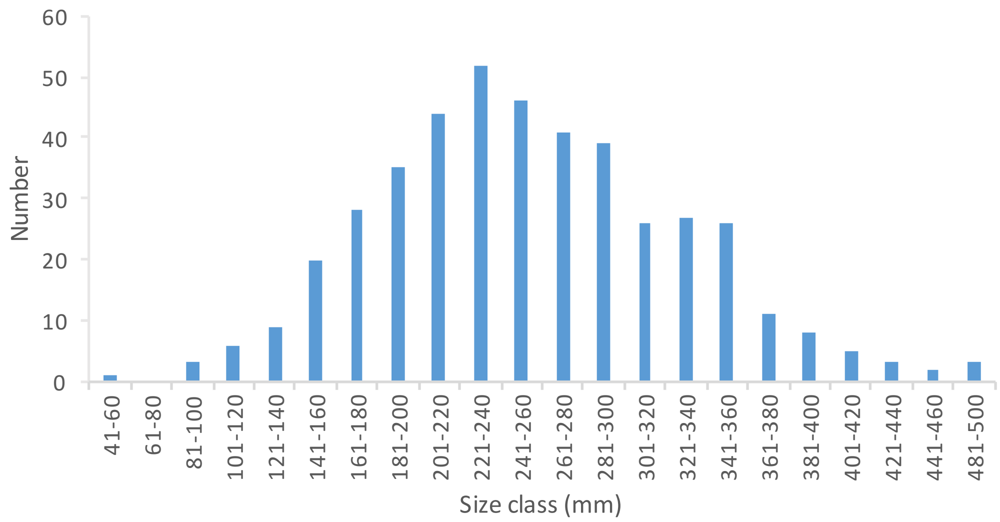


Figure 21. Length frequencies of lollyfish (*Holothuria atra*) at Niue during the 2016 and 2017 surveys.

- Surf redfish (*Actinopyga mauritiana*)

Only 30 individuals were sampled during the surveys and this is reflected in the length -requency plot, which is left skewed and has patchy representation across size classes. The mean size of individuals was 249.17 ± 10.53 mm with a modal length class of 261–281 mm. There is an under-representation of larger animals in the frequency distribution, which likely represents insufficient sampling given that the calculated mean size is comparable to the regional estimate.

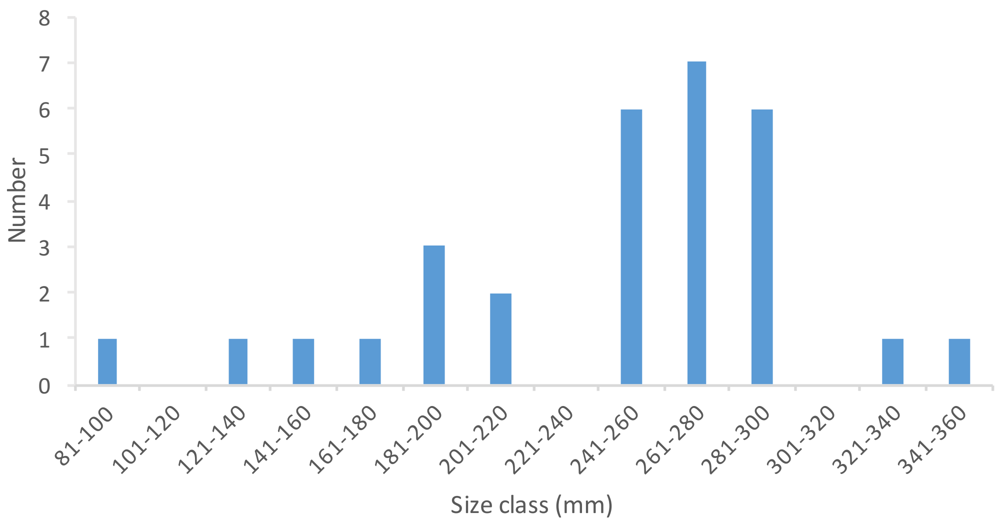


Figure 22. Length frequencies of surf redfish (*Actinopyga mauritiana*) at Niue during the 2016 and 2017 surveys.

Gastropods

- Turban snail (*Turbo setosus*)

For the turban snail, 32 individuals were measured. Similar to the surf redfish, the length-frequency plot has patchy representation across size classes, which is indicative of insufficient sampling effort. The two larger individuals were in the 71–75 mm size class.

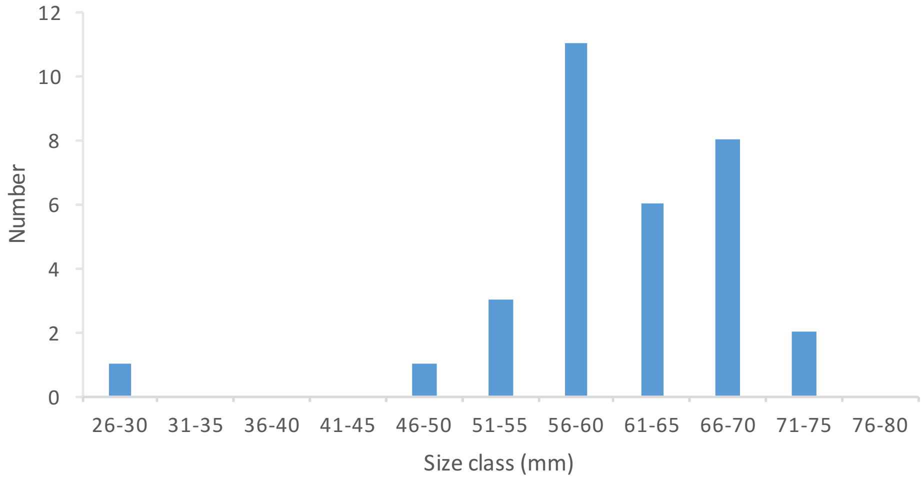


Figure 23. Length frequencies of turban snail (*Turbo setosus*) at Niue during the 2016 and 2017 assessments.

Mean size was calculated at 61.56 ± 1.58 mm with a modal length class of 56–60 mm. While there are no reference values for this species, the species has been recorded and measured in a number of surveys in the past. The following table presents turban snail mean lengths in past surveys. The mean size recorded for Niue is similar to those of Wallis and Futuna and Tikehau (French Polynesia), but slightly greater than those from Nauru and Tonga.

Table 7. Mean length (mm) of the turban snail in Niue and four past surveys within the region where over 30 individuals were measured.

	Year	Mean length (mm)	SE	n
Niue (this report)	2016 and 2017	61.56	1.58	32
Wallis and Futuna	2016	63.89	0.88	73
Nauru	2015	50.02	1.65	54
French Polynesia (Tikehau)	2003	60.15	0.75	60
Tonga (Ha'atufu)	2002	56.72	1.10	36

- Belligerent rock shell (*Mancinella armigera*)

Lengths of belligerent rock shells were taken from 35 individuals. The length-frequency distribution was patchy, with only a few individuals recorded across a wide range of size classes. Only two size classes, 61–65 mm and 66–70 mm, were well represented with 19 and 9 individuals, respectively. Mean size was 62.94 ± 1.96 mm with a modal length class of 60–65 mm. There are no reference values for this species.

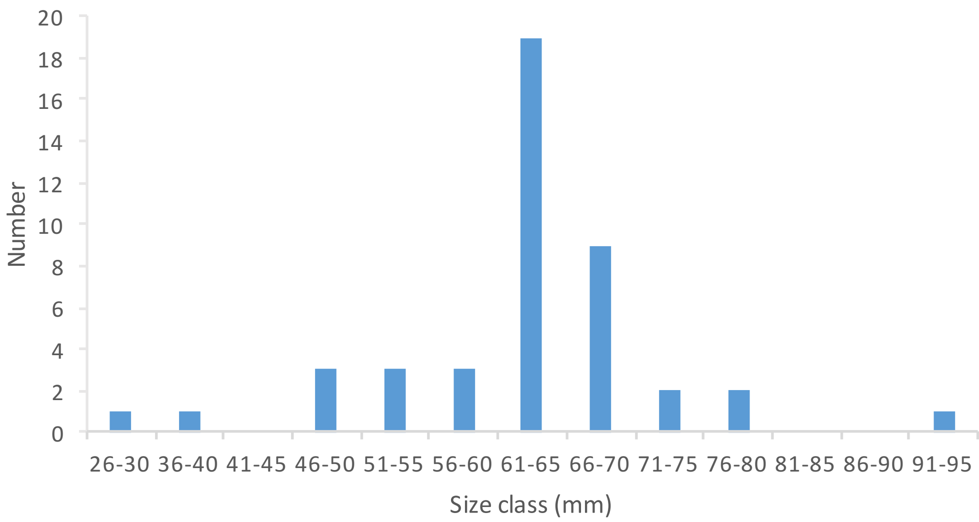


Figure 24. Length frequencies of belligerent rock shell (*Mancinella armigera*) in Niue during the 2016 and 2017 surveys.

○ Drupe (*Drupa* sp.)

Lengths were measured on 146 individuals of the genera *Drupa* (unidentified to species level) and 51 purple Pacific drupe (*Drupa morum*). The length-frequency distribution of *Drupa* sp. was normally distributed with a mean of 22.75 ± 0.30 mm, and a modal class of 24–25 mm. In contrast, the length-frequency of the purple Pacific drupe was more patchy, with many missing size classes, although there were likely to have been identification issues with drupe species during the survey and this would influence the length-frequency distributions shown in Figure 25. Mean size of Purple Pacific Drupe was calculated at 25.92 ± 0.74 mm with a modal class of 28 mm.

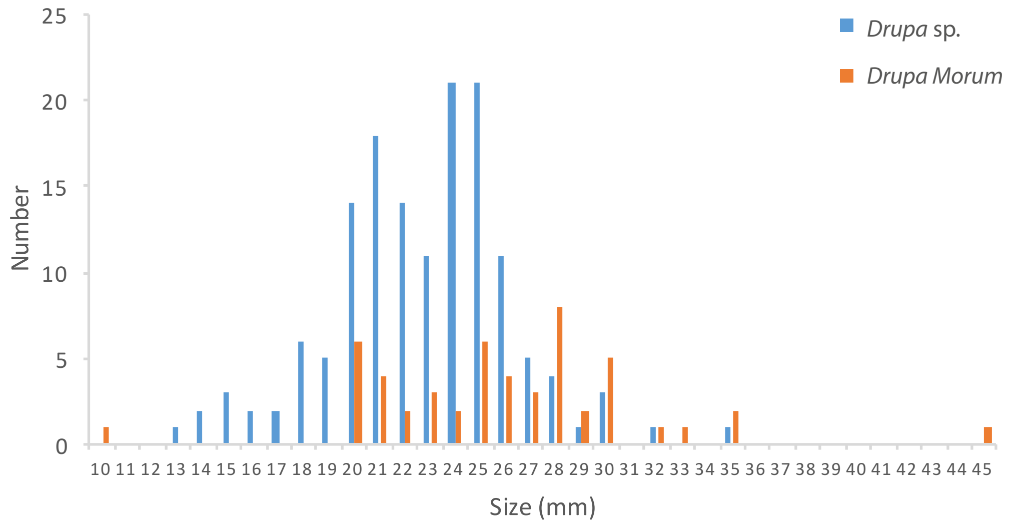


Figure 25. Length frequencies of drupe of the *Drupa* genus (purple Pacific drupe and other drupe of the genus *Drupa*) observed during the 2016 and 2017 Niue Marine Ecological Surveys.

○ Drupe (*Morula* spp.)

Length measurements were taken of 96 *Morula* spp. (drupe unidentified to species level) and 77 granular drupe (*Morula granullata*). The length-frequency distribution of granular drupe was concentrated on a few size classes while *Morula* sp. was distributed across a wider size range, although only a few individuals were recorded in the larger size classes. The mean size of granular drupe was 19.12 ± 0.29 mm, with a modal length of 20 mm. The mean size of *Morula* sp. was 17.55 ± 0.51 mm, with a modal length of 18 mm. Similar to *Drupa* spp. measurements, there was a high possibility of identification issues with species of *Morula* spp., which may have influenced length-frequency distributions.

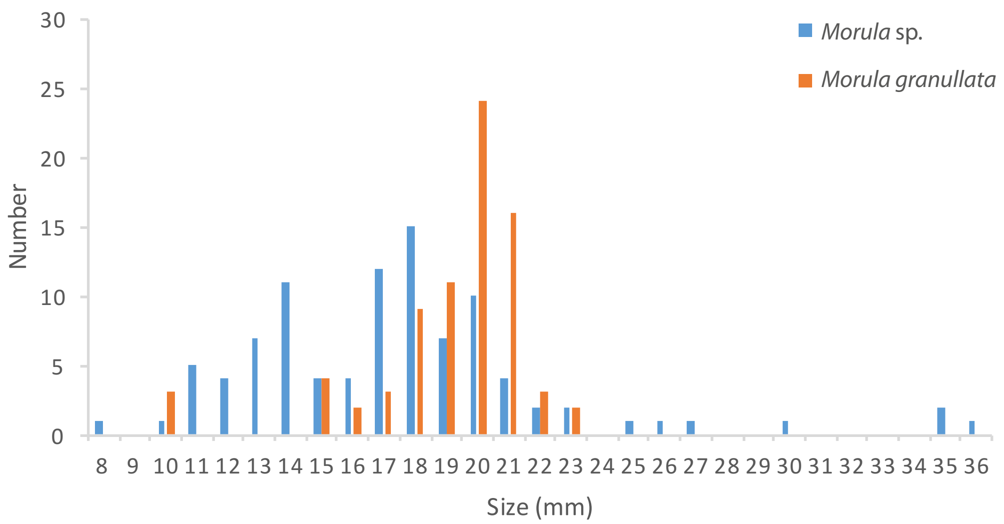


Figure 26. Length frequencies of drupe snails (*Morula* sp. and *M. granullata*) at Niue during the 2016 and 2017 surveys.

Finfish

All stations combined

In total, 1,942 fishes were counted across the 16 D-UVC stations around Niue. These fishes belonged to 18 families and 43 genera and 86 species. There was a mean abundance of 121 fish per station, with an average richness of 27 species from 9 families and 17 genera.

Table 8. Average number of finfish families, genera, species and fish per station, and total for the surveys in 2016 and 2017 in Niue.

	Station mean	Standard error	Total
# Family	9.31	0.45	18
# Genera	16.50	0.77	43
# Species	27.25	1.42	86
# Fish	121.00	14.65	1,942

For all stations combined, the mean density of finfish was 20.41 ± 2.86 fish 100 m^{-2}. Mean fish biomass was observed to be approximately 2,295 ± 264 g 100 m^{-2}.

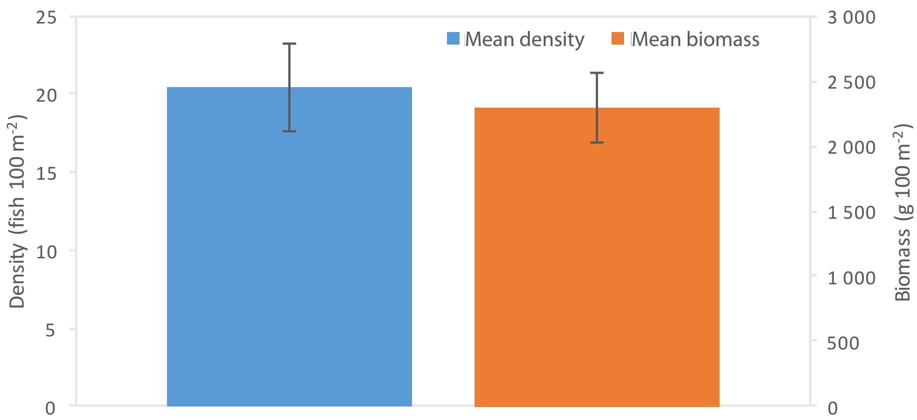


Figure 27. Overall mean density (fish 100 m^{-2}) and mean biomass (g 100 m^{-2}) of finfish for the 2017 survey.

Acanthurids (surgeonfish) were the most abundant finfish family, with a recorded density of 14.01 ± 2.56 fish 100 m^{-2}, which was over eight times greater than the next highest density. Apart from the acanthurids, all other finfish family densities were < 2 fish 100 m^{-2}. Chaetodontidae (butterflyfish) had the second highest density at 1.68 ± 0.25 fish 100 m^{-2}, followed by Balistidae (triggerfish), which had a density of 1.18 ± 0.18 fish 100 m^{-2}. Scaridae (parrotfish) and Serranidae (grouper) densities were similar at < 1 fish 100 m^{-2}.

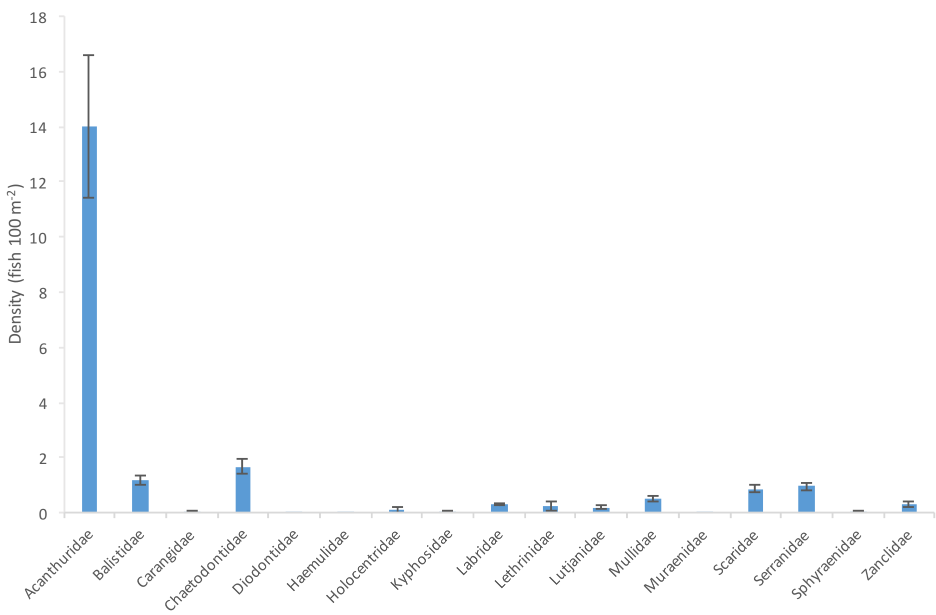


Figure 28. Mean finfish family densities (fish 100 m^{-2}), all stations combined.

The Acanthuridae family accounted for the highest finfish biomass at 1,209 ± 170 g 100 m^{-2}, which was about four times higher than for the Scaridae family, which accounted for the next highest finfish biomass at 302 ± 52 g 100 m^{-2}, and higher still than for the Serranidae family at 199 ± 41 g 100 m^{-2}. Biomass for the remaining finfish families was <200 g 100 m^{-2} (Fig. 29).

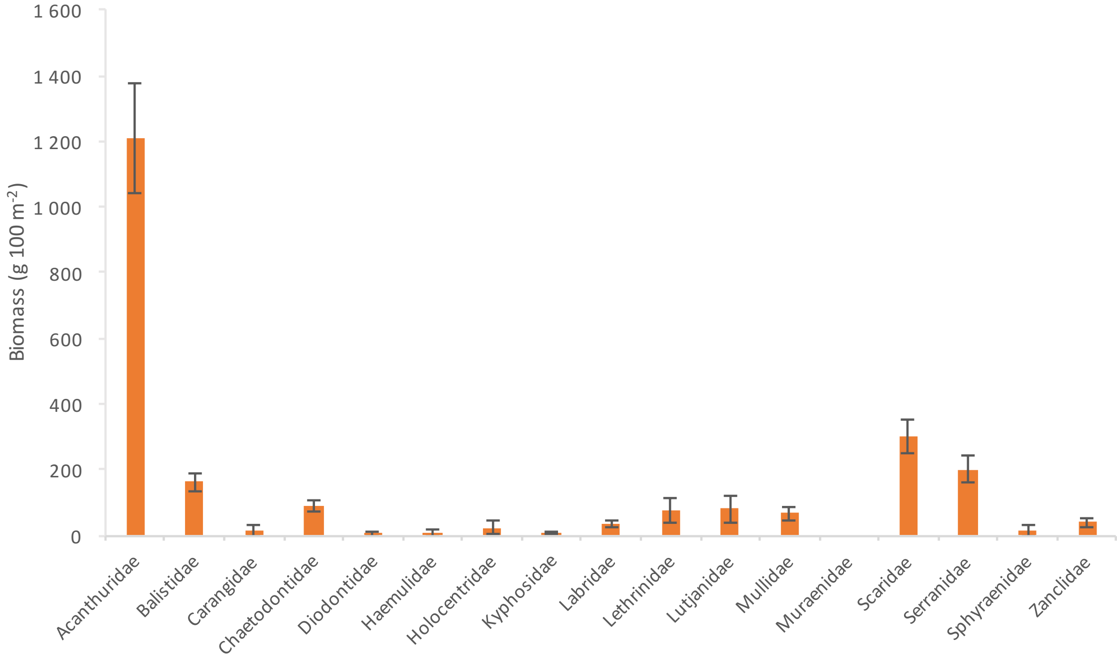


Figure 29. Mean finfish family biomass (g 100 m^{-2}) for all Niue stations combined.

When sorted by trophic category[5], herbivores[6] (e.g. most surgeonfish and parrotfish) were found in significantly higher densities (14.60 ± 2.48 fish 100 m^{-2}) and biomass (1,489 ± 177 g 100 m^{-2}) than other trophic levels. Invertivores[6] (e.g. butterflyfish, triggerfish, goatfish, emperorfish and wrasses) had the second highest density (3.38 ± 0.42 fish 100 m^{-2}) and biomass (338 ± 52 g 100 m^{-2}) followed by piscivores[6] (e.g. groupers, snappers) and planktivores[6] (e.g. some surgeonfish, triggerfish and soldierfish). There was no significant difference in the densities of piscivores and planktivores and in the biomass of carnivores and piscivores. No detritivores[6] (e.g. mullets and bonefish) were recorded during the survey. Diet preferences were set to a specific type for each species into the database when it was created, however fish diets are not always well defined and diet preferences of one species can be set as a different type than this database in other sources.

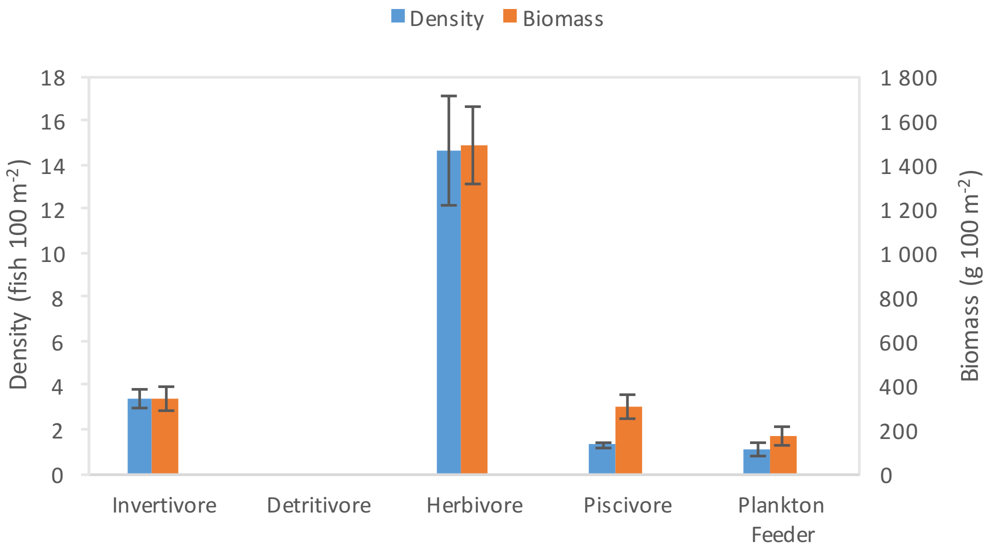


Figure 30. Overall finfish density (fish 100 m^{-2}) and biomass (g 100 m^{-2}) by diet preference.

5 Diet preferences as set into SPC database (RFID).

6 Invertivore: main portion of diet consists of a mix of invertebrates and algae; detritivore: main portion of diet consists of dead animals or plants; herbivore: main portion of diet consists of algae; piscivore: main portion of diet consists of fish; planktivore: main portion of diet consists of zooplankton and/or phytoplankton.

A comparison of abundance and biomass for 14 species was made across the different trophic categories (Fig. 31). Surgeonfishes *Acanthurus nigrofuscus* and *Ctenochaetus striatus* had the highest densities at 2.81 ± 0.56 fish 100 m^{-2} and 2.75 ± 0.56 fish 100 m^{-2}, respectively, followed by another herbivorous acanthurid, *Naso lituratus*, at a density of 1.16 ± 0.56 fish 100 m^{-2}, which although significantly lower than that of *A. nigrofuscus* and *C. striatus* was still significantly higher than for other species for which densities were all <1 fish 100 m^{-2}.

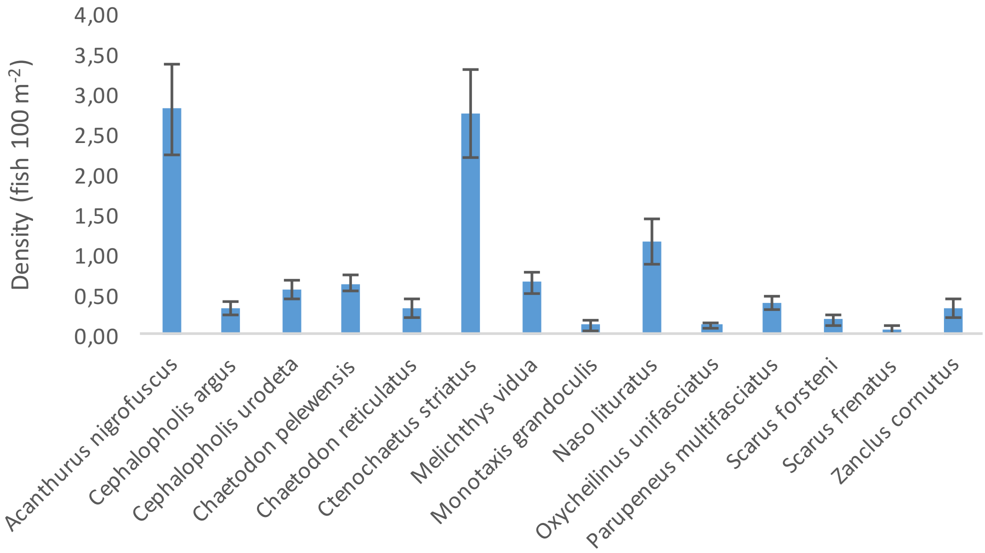


Figure 31. Density (fish 100 m^{-2}) of 14 selected finfish, all stations combined.

While *A. nigrofuscus* had the highest density, *C. striatus* had the highest biomass at 358 ± 81 g 100 m^{-2}, followed by *Naso lituratus* at 237 ± 58 g 100 m^{-2} (Fig. 32). These differences reflect the bigger size of the latter two species. Biomass among the other species was < 110 g 100 m^{-2}.

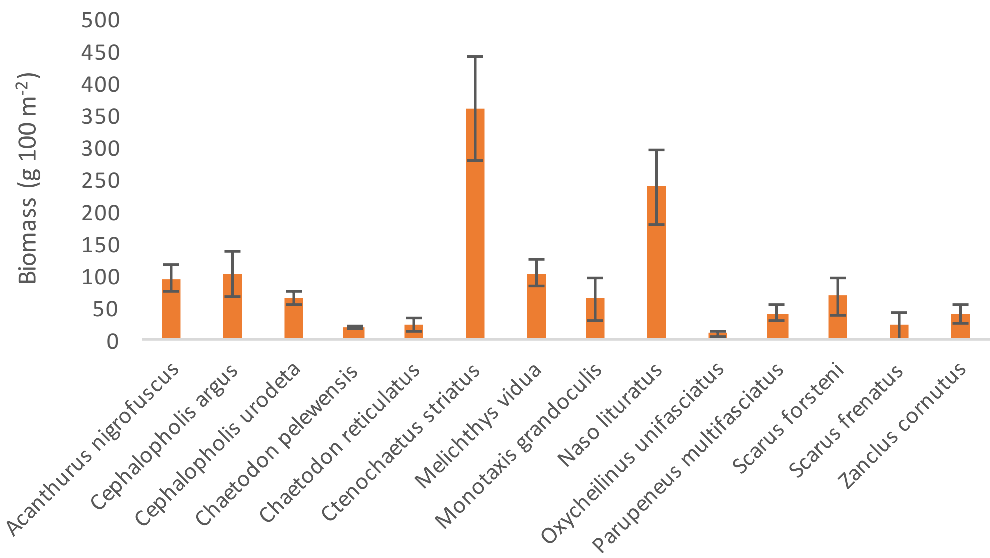


Figure 32. Biomass (g 100 m^{-2}) of 14 selected finfish, all stations combined.

Density by station

Figure 33 presents the combined density of all finfish recorded at survey stations, along with the density of the most abundant finfish family, Acanthuridae. Density was highly variable across stations with only two stations having >40 fish 100 m^{-2}. The majority of stations had densities of 10–30 fish 100 m^{-2}, including stations within the Namoui marine reserve.

Acanthurids were the most common finfishes recorded, and were plotted on the map to illustrate their distribution. At many stations, surgeonfish represented greatest density of finfish recorded, as can be seen at stations 1, 44, 18, 19, 4, 48 and 38. At other stations, acanthurids still represented a great proportion of the overall density (see stations 3, 46, 11 and 50). Only at four stations (22, 26, 30, 5 and 48) were acanthurids a minor proportion of the total density.

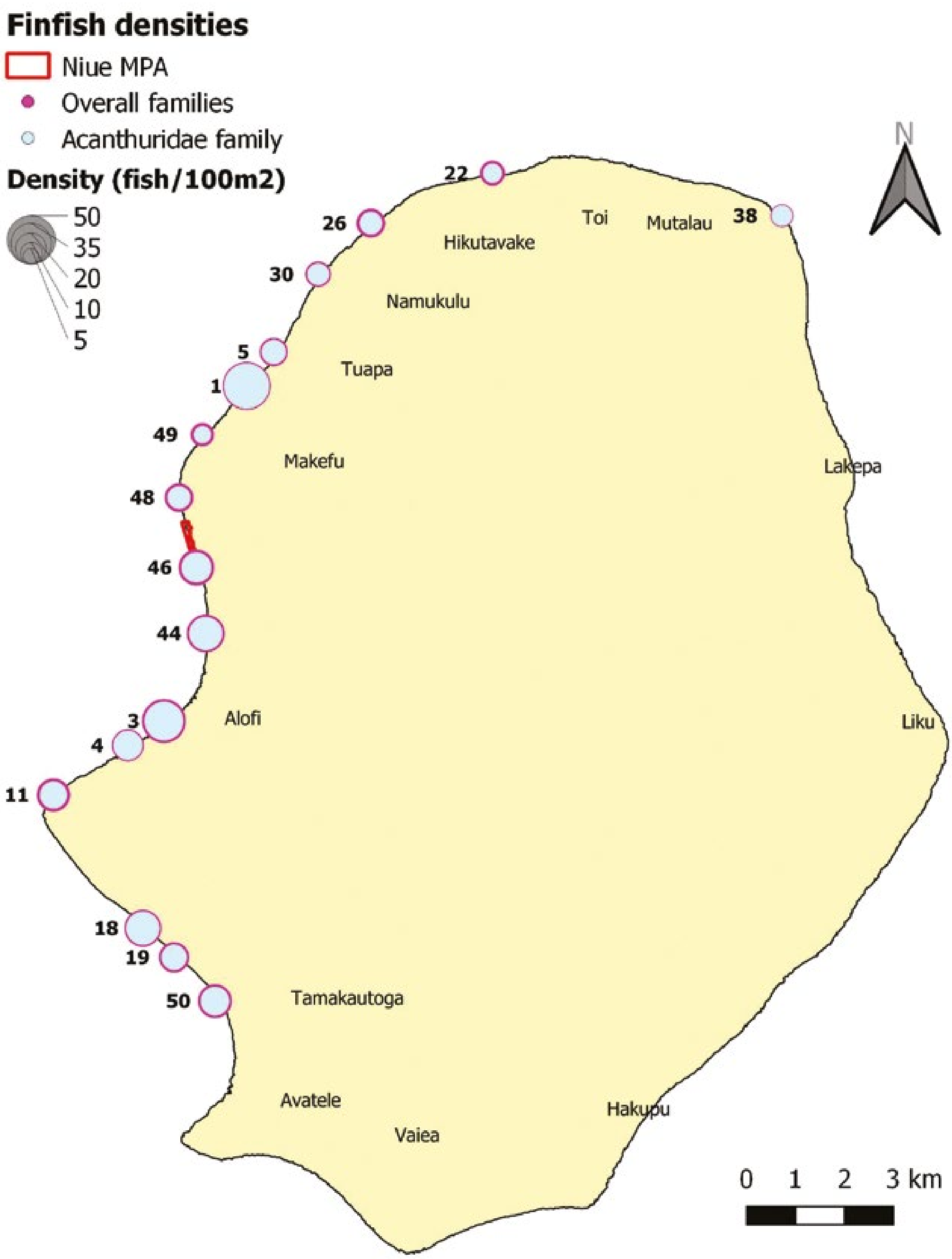


Figure 33. Overall finfish family density (fish 100 m^{-2}) and Acanthuridae density (fish 100 m^{-2}) per station.

Biomass by station

Biomass was recorded at the different stations but not to the same extent as density. The majority of stations (12) had 1,000 – 3,000 g 100 m^{-2}, with only three stations holding more biomass. The greatest biomass was recorded at station 3 (4,869 g 100 m^{-2}) and the lowest at station 49 (742 g 100 m^{-2}).

With the exception of station 22, acanthurids accounted for more than one-third of the total biomass in all cases, and over two-thirds of the biomass for two stations (stations 3 and 38).

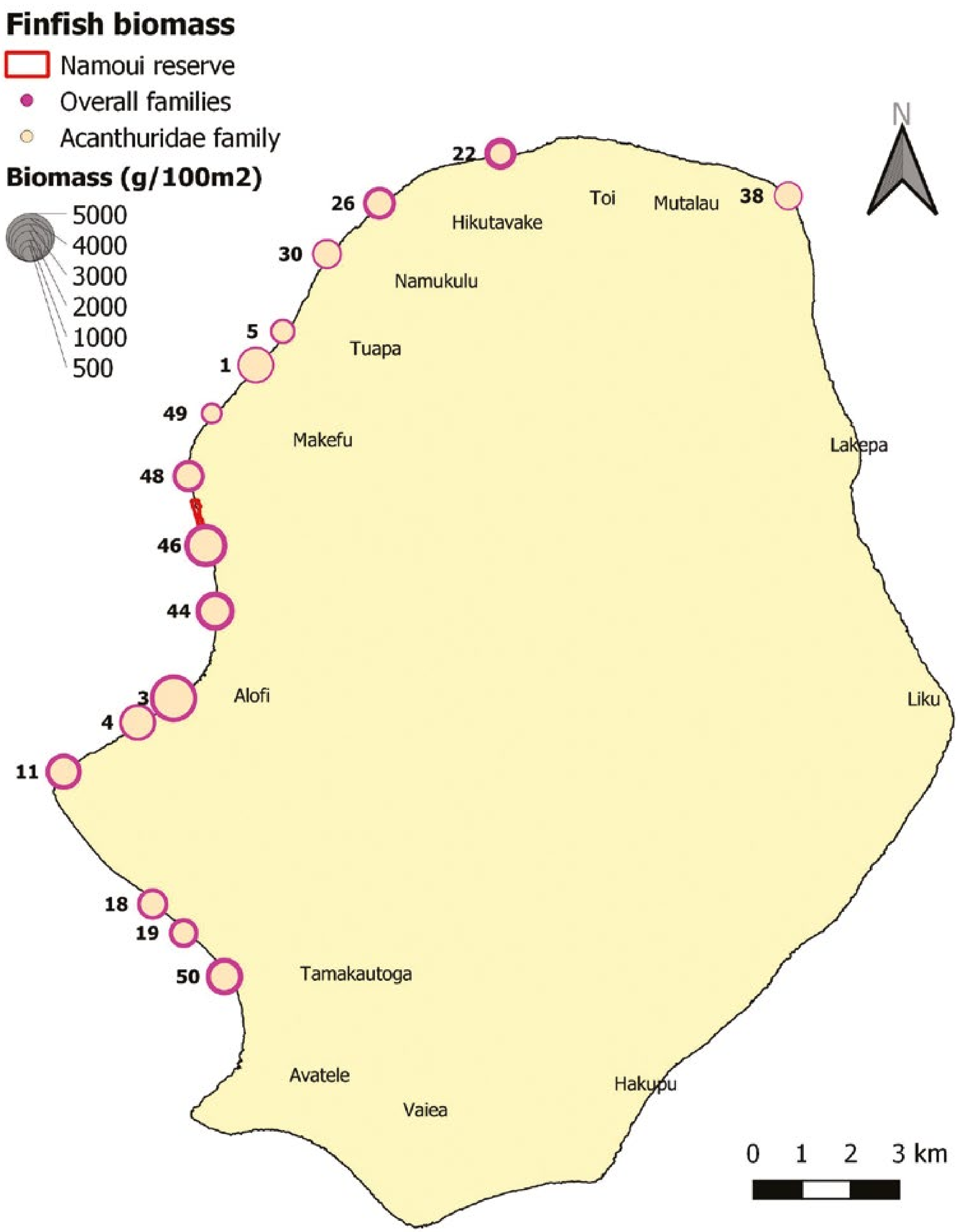


Figure 34. Overall finfish family biomass (g 100m^{-2}) and Acanthuridae biomass (g 100m^{-2}) per station.

Finfish comparison with previous surveys

The PROCFish/C survey conducted in 2005 was used as a reference study for the 2017 survey. All stations surveyed in 2017 matched a stations that were surveyed in 2005. The exact same survey methods and techniques were used for both surveys allowing for good comparisons.

The National Geographic Pristine Seas survey took place in September and October 2016 with a different methodology (1 station is composed of three 25 m replicate transects) and different station locations. However they surveyed the same number of stations at a similar depth to this 2017 survey and can therefore provide some opportunities to compare the results with this survey.

Densities and biomass of the most common finfish families

Important variabilities in the overall densities of the most common fish families were recorded between the surveys, with 46.71 ± 7.89 ind. ha^{-1} for the 2005 PROCFish/C survey, 33.85 ± 5.21 ind. ha^{-1} for the 2016 National Geographic Pristine Seas survey, and 20.40 ± 3.85 ind. ha^{-1} for the 2017 survey. For all surveys, the highest densities were for the family Acanthuridae, with the 2005 PROCFish/C recording significantly higher densities than the other two surveys. For all other families, density trends were relatively consistent among surveys.

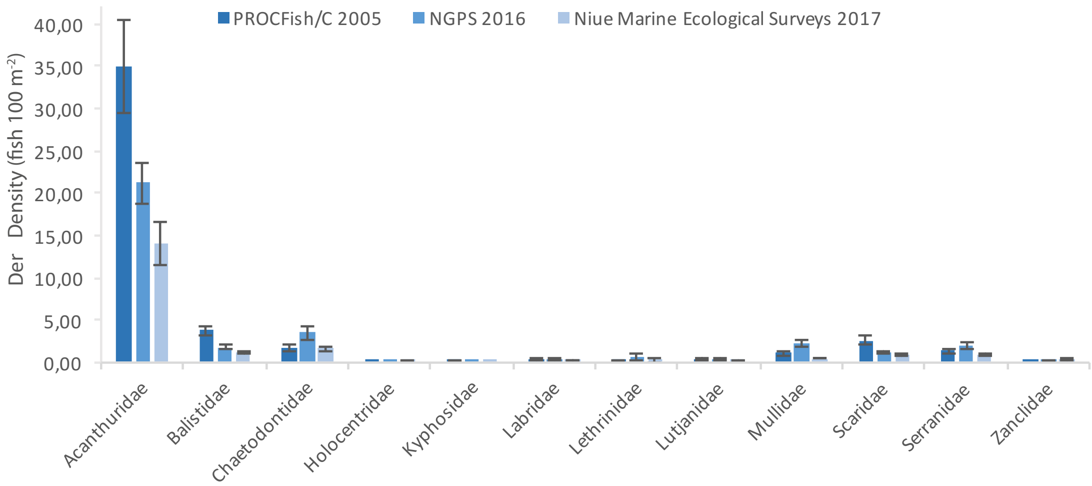


Figure 35. Mean finfish family densities (fish 100 m^{-2}) for the 2017 Niue Marine Ecological Survey and the 2005 PROCFish/C survey for the same station surveyed (16 stations). The 2016 National Geographic Pristine Seas (NGPS) survey is also represented here but the 16 stations were surveyed in other locations around Niue.

Similar to the density results, the biomass for the Acanthuridae family was highest among all finfish families across all three surveys, with the PROCFish/C survey recording significantly higher densities than the other two surveys. There was more variability among the surveys for biomass, with obvious differences in the Scaridae family, with 2017 densities being much lower than for the other surveys.

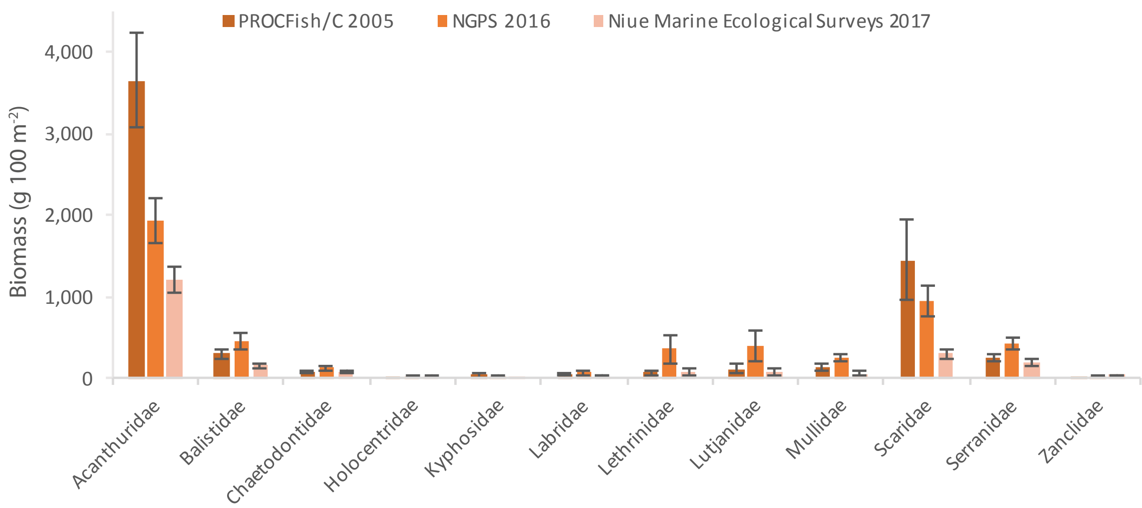


Figure 36. Mean finfish family biomass (g 100 m^{-2}) for the 2017 Niue Marine Ecological Survey and the 2005 PROCFish/C survey for the same surveyed stations (16 stations). The 2016 National Geographic Pristine Seas (NGPS) survey is also represented in this but their 16 stations were surveyed in other locations around Niue.

Density and biomass by trophic category

Herbivores are the overwhelmingly abundant trophic group on the reefs around Niue, and this pattern is consistent across all three different surveys. However, the 2005 PROCFish/C survey recorded significantly greater density and biomass of herbivores than the more recent surveys (Figs. 37 and 38). This difference between the PROCFish/C survey and the other surveys was not replicated across any other trophic group where differences were negligible and/or uncertain.

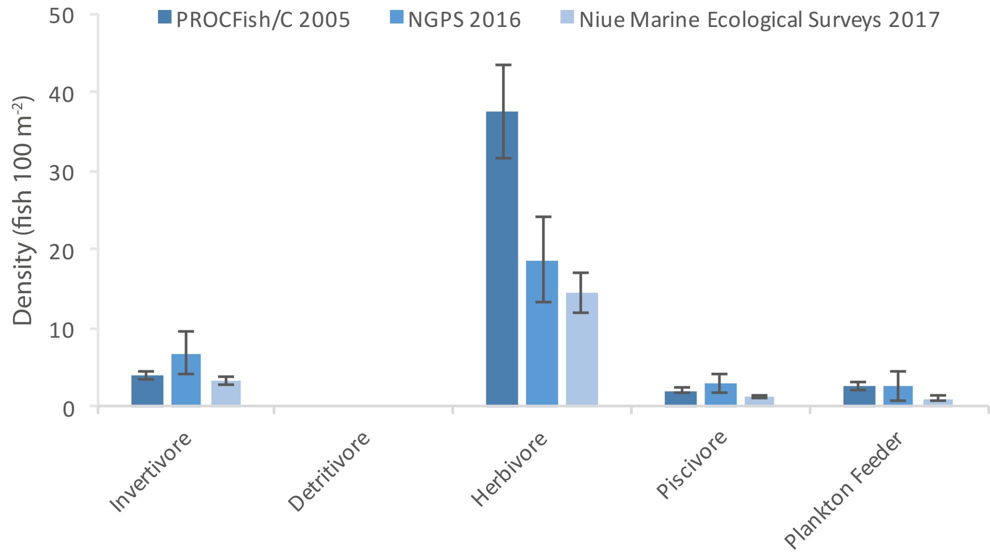


Figure 37. Finfish density (fish 100 m^{-2}) by diet preference for the 2017 Niue Marine Ecological Survey and the 2005 PROCFish/C survey for the same surveyed stations (16 stations). The 2016 National Geographic Pristine Seas (NGPS) survey is also represented in this but their 16 stations were surveyed in other locations around Niue.

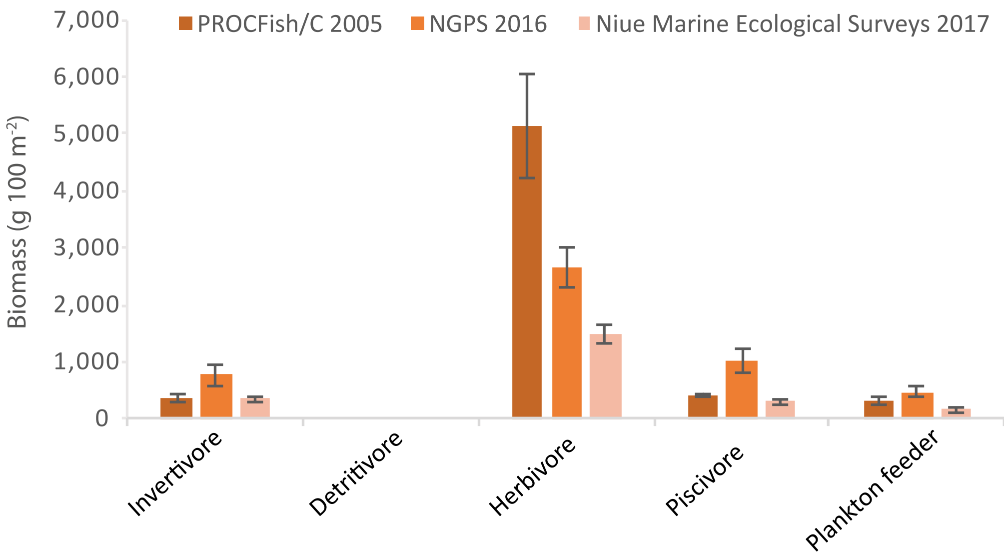


Figure 38. Finfish biomass (g 100 m^{-2}) by diet preference for the 2017 Niue Marine Ecological Survey and the 2005 PROCFish/C survey for the same surveyed stations (16 stations). The 2016 National Geographic Pristine Seas (NGPS) survey is also represented in this but their 16 stations were surveyed in other locations around Niue.

Supporting habitat (benthos)

All stations combined

For the benthos surveys, 16 stations were covered, representing an analysis of 800 x 0.25 m^2 quadrats.

Mean hard coral cover was relatively low at 16%, with turf and macroalgae occupying a greater area at 25%. The majority of benthic habitats consisted of hard rock or pavement, occupying 44%, along with crustose coralline algae at 8%. The abundance of hard substrate is a reflection of the narrow reef flats and their exposure to prevailing winds and swell.

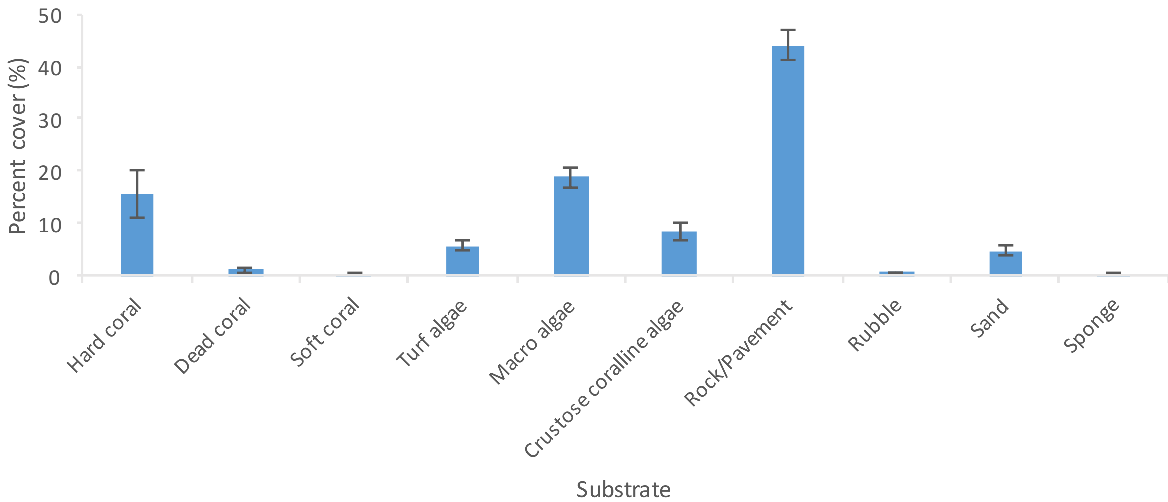


Figure 39. Main substrate cover categories recorded in Niue during the 2017 survey.

In total, 22 hard coral genera were identified during the quadrat analysis (see Appendix 9), with Acropora being the overwhelmingly dominant genus, representing 70% of all recorded corals. Percentage cover distribution of the main families illustrates this dominance (Fig. 40).

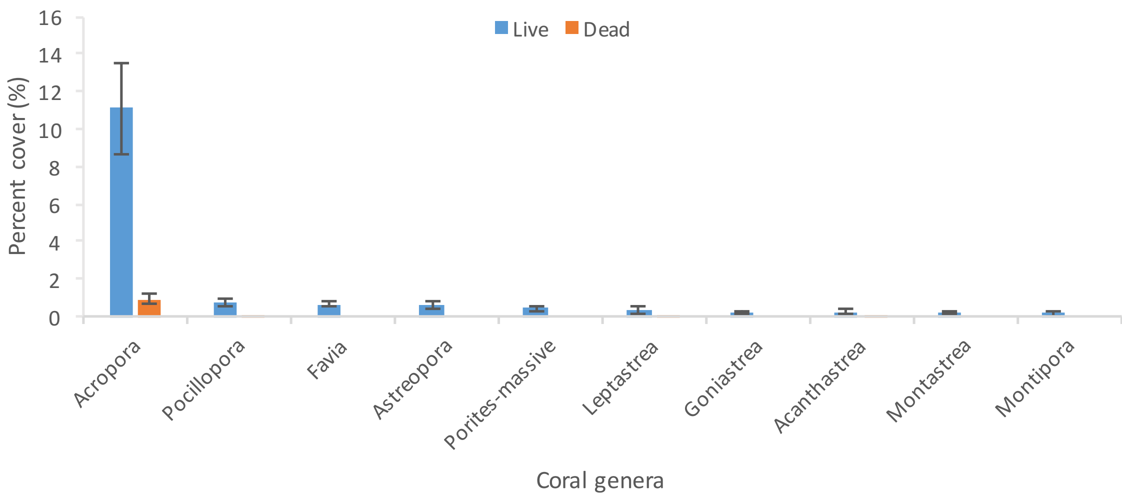


Figure 40. Main hard coral genera represented in Niue during the 2017 survey.

Relative abundance of main substrate categories by station

The benthic community structure varied across sites, with pavement and macroalgae being the only two types to be well represented across all stations (Fig. 41). The amount of pavement ranged from 24.4% at station 19 to 58.8% at station 11, while the percentage cover of macroalgae ranged from 6.4% to 28.8%; crustose coralline algae cover was minimal at most sites except in the southwest (sites 18, 19 and 50) where cover was as high as 28% at station 18.

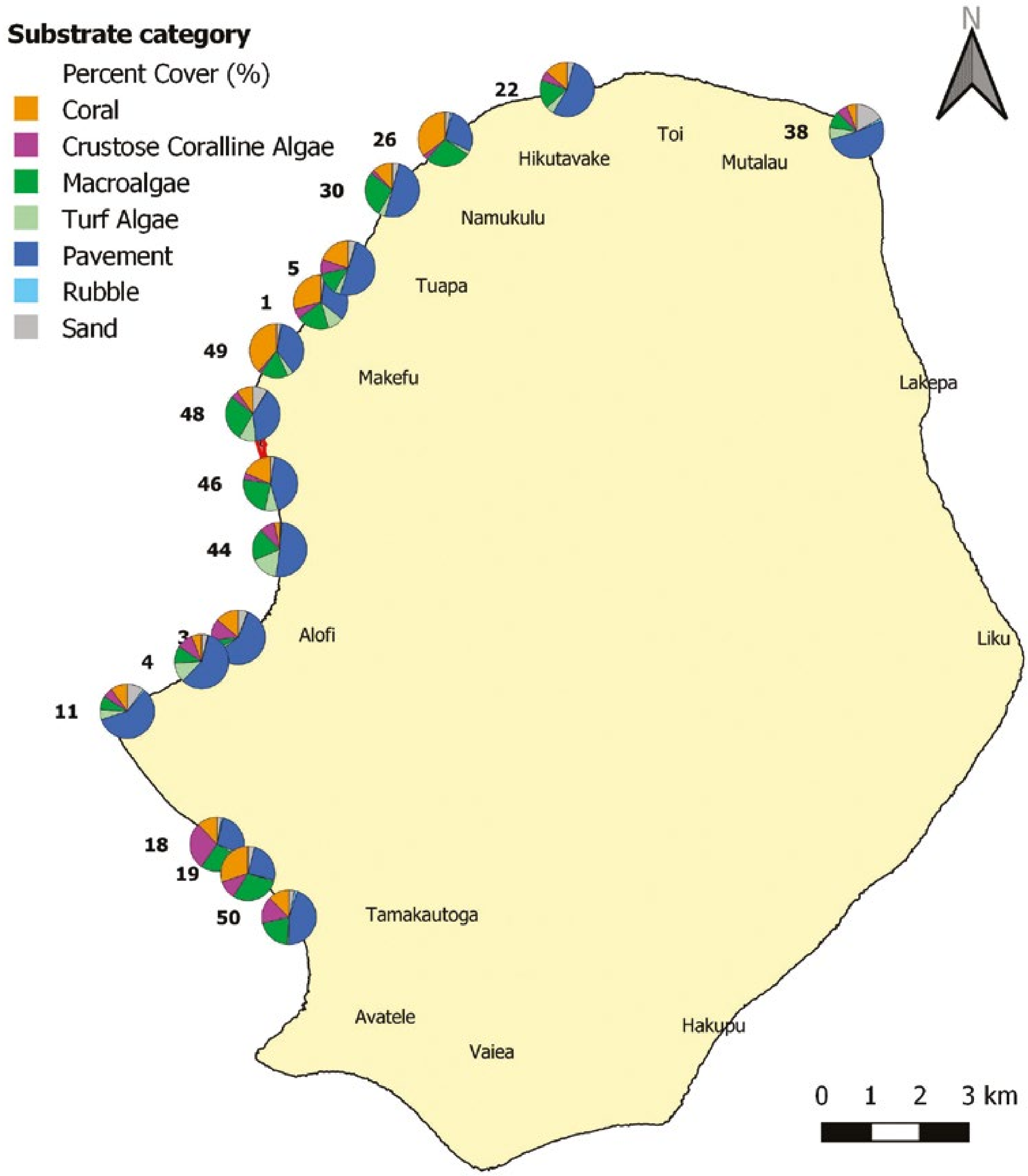


Figure 41. Substrate cover composition (category %) per station around Niue in 2017.

Coral cover by station

Coral cover (including dead coral) varied greatly among stations, from 3.2% at station 44 (in the west) to 37.6% at station 49 (in the northwest). Overall, coral cover was highest along the northwest coast, although site 19 in the southwest also had relatively good coral cover.

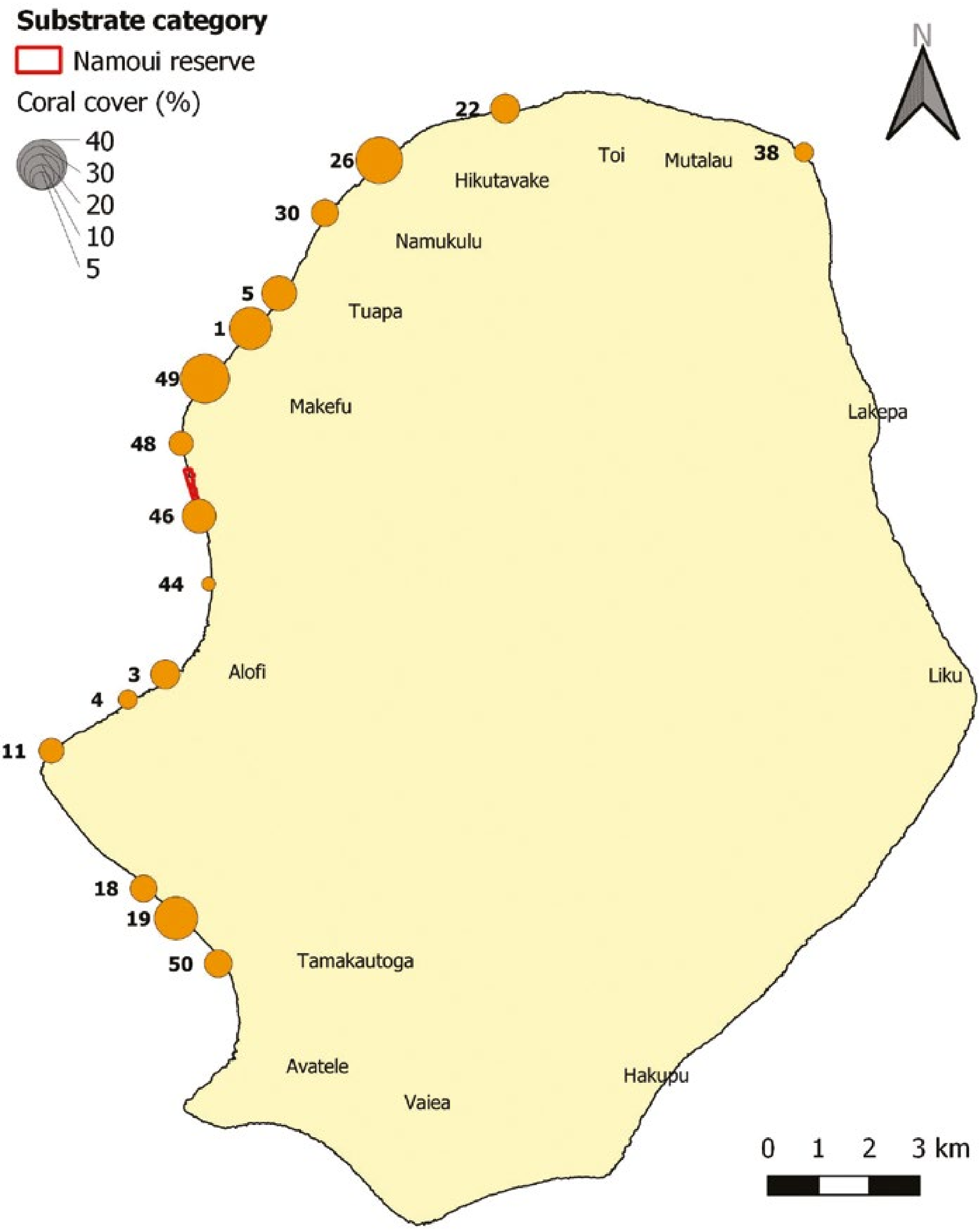


Figure 42. Percent coral cover at each station around Niue in 2017.

Substrate comparison with previous surveys

The 2005 PROCFish/C survey was used as a reference study for the 2017 Niue Marine Ecological Survey. Estimated substrate cover for all stations surveyed was divided into five categories (live coral, soft coral, hard bottom, rubble and boulder, and soft bottom) for the PROCFish/C report (Kronen et al. 2008). In order to compare the results of the 2017 survey with the 2005 survey, we pooled some categories to match:

- live coral corresponds to hard coral;
- soft coral was already a category in both surveys;
- hard bottom comprised rock and/or pavement, dead coral, turf algae, coralline crustose algae, macroalgae (all algae types tend to grow on hard surfaces) and sponges;
- rubble and boulder corresponds to rubble;
- soft bottom corresponds to sand.

A comparison of the two surveys shows an increase in live coral cover from 8.10 ± 0.80% in 2005 to 15.77 ± 4.47% in 2017 (Fig. 43). There was also a slight decrease in the area identified as hard bottom between the two surveys, which can be partly attributed to the live coral increase. Other categories were too low to reliably compare between surveys.

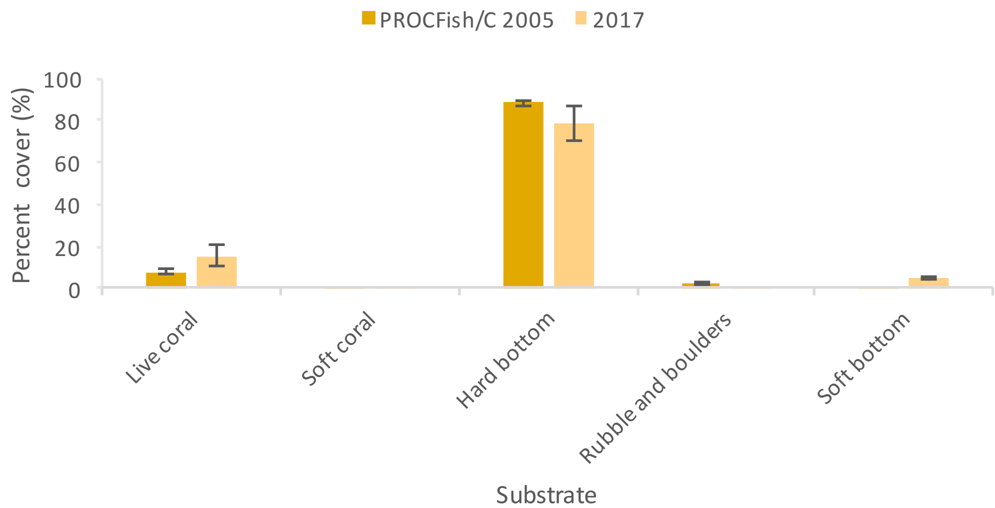


Figure 43. Comparison of substrate composition between the 2005 PROCFish/C survey and the 2017 Niue Marine Ecological Survey.

Live coral results were also compared to the National Geographic Pristine Seas survey (Friedlander et al. 2017). Hard coral cover was estimated at 19% all around Niue for the three depths (5 m, 10 m, 20 m) surveyed, which was slightly higher than the 2017 survey. However considering the different methodologies used and stations surveyed, and the occurrence of some bleaching in early 2017 (Nadia Helagi Kavisi, DAFF Fisheries Development Officer, pers. comm.), the results seem relatively comparable and suggest an increase in coral cover since 2005.

Discussion and recommendations

Although reef conditions seem to have improved slightly since the 2005 PROCFish/C survey as indicated by improved coral cover, there are concerns about the sustainability of current levels of harvesting marine resources, especially finfish and invertebrates. There are also concerns about the changing climate and how it will impact local fisheries. In Niue, the Pacific Climate Change Science Program predicted an increase in sea surface temperature (0.3–1.1 °C by 2030 according to projected scenarios), sea level and ocean acidification (PCCSP 2011). Rainfall is also expected to increase during the wet season and less-frequent cyclones are forecasted, however an increase in their intensity is expected by the end of the 21st century (PCCSP 2011). Oceanic fisheries may be impacted through lower productivity (primary production and zooplankton biomass), and catches of bigeye tuna is expected to decrease (Bell et al. 2011). The impact on coastal fisheries is expected to be variable: the increase in catches of nearshore pelagic fish is projected to counter balance the decrease in reef-associated fishes and invertebrates. In addition to the effects of climate change, Niue has limited reef habitat for fish and invertebrates and its remoteness makes it very unlikely that other reef systems could supply new recruits to replenish existing stocks. Recent genetics work on two invertebrate species (*Tridacna maxima* and *Echinometra mathaei*) and three reef fish species (*Acanthurus nigrofuscus*, *A. triostegus* and *Cephalopholis argus*) from Niue and Beveridge Reef (Liggins and Arranz-Martinez 2018) has confirmed the minimal connectivity between Niue and other reef systems. Species sampled in Niue and Beveridge Reef shared genetic diversity with other Indo-Pacific locations, but both locations had higher genetic diversity and uniqueness, indicating restricted gene flow with wider locations. Even between Niue and Beveridge Reef, patterns of gene flow were species-specific and inconsistent; hence, very low connectivity capacity is expected between the two reef systems. Stock self-recruitment is likely the main means of replenishment of local stocks, which makes it crucial that these stocks are well managed.

Invertebrates

There was significant variability in invertebrate densities between sites and within taxa. While most of this variability reflects patchiness in the local environment, some differences could be attributed to observer bias and to survey timing, with some stations surveyed in 2016 and others in 2017. Many of the invertebrates recorded during the surveys are consumed locally, with harvest effort a function of the quality and/or popularity of the species as seafood. Giant clams, turban snails and great worm shells are among the most harvested species on reef flats.

Giant clams were recorded in low densities around Niue, with the population consisting almost entirely of the elongate giant clam, with very few individuals of the fluted giant clam observed. While there was an increase in density of giant clams between 2005 (Cyclone Heta struck in 2004) and 2016–2017, density was still lower than the density measured after Cyclone Ofa in 1990 (Dalzell et al. 1993). This is despite the existence of specific regulations governing minimum size limits and catch limits per person per day.

Turban snails were recorded during night reef searches and most of the time in low densities. Species presence was recorded in 2005 but no density could be estimated due to the scarcity of the species at that time.

While this survey found significant densities of drupe, most other gastropods were recorded at relatively low densities. Further survey work may be required to evaluate the status of specific species of importance for Niuean people.

Spiny lobsters and slipper lobsters were observed at a small number of stations surveyed at night. While this result is likely affected by the timing of the survey (e.g. year, moon phase, tide) it could also reflect the low abundance of these species around the island. Further investigations would be required to clarify their status. No observations of lobster were made during the 2005 PROCFish/C survey, and only the presence and/or absence of species was evaluated in the 1990 survey (Dalzell et al. 1993).

Based on the results of our survey, which demonstrated low natural densities around the island, it is recommended that there be no commercial harvesting of any sea cucumber species.

Recommendations

When surveys are widely spaced apart in terms of time (>10 years in the case of Niue), it is difficult to know the causes of any recorded changes or to be able to make management recommendations in a timely manner. We therefore suggest that invertebrate surveys should be carried out more regularly, every three to five years. The methods used and stations surveyed to be used should match this survey in order to make comparisons, although extra stations could be included to increase the accuracy of surveys (Appendix 12). Any occurrence of invertebrate die-off should also be recorded as accurately as possible and this could be a collaboration with communities (Appendix 13).

Given Niue's isolation, there is a need for sufficient levels of local of invertebrate stocks to ensure that enough recruits are available for replenishing the population each year. Effectively managed, marine protected areas will serve as nursery grounds where existing stocks can grow to their maximum size and reproductive capacity. These protected areas will become seed areas for the rest of the island's reefs and also help to reduce overall fishing pressure around Niue. Any marine reserve should be located in an area that promotes the dispersion of larvae to the rest of the island and should encompass the outer slope, crest and reef flat. Suggested locations for marine reserves are:

- Tamakautoga, in the surrounding areas of stations RFS 11 and RFS 5 and RBT 2 and RBT 3;
- Tuapa, in the surroundings areas of stations RBT 9 and RBT 10, RFS 3 and manta tow 6;
- Toi, in the surrounding area of station RFS 2.

These three areas are proposed as preliminary locations and are based on species diversity and density and relative resilience to climatic extremes compared with other areas of Niue. A precise study of the literature regarding the establishment of a marine reserve should be done in order determine the most suitable locations with regard to Niuean conservation ideals and the most efficient way based on scientific recommendations.

Establishing an awareness programme for the marine reserves is necessary as it would provide an opportunity for local people to become involved in the design and implementation. Part of this process would include explaining the purpose of such reserves and generating sufficient will among Niueans to respect them and the rules governing them.

In addition to marine reserve implementation, we suggest that a socioeconomic survey be conducted to update catch and consumption figures, and enable comparisons with the 2005 PROCFish/C survey. Such a survey would also update the list of invertebrate species that are most important to Niuean people and clarify whether further species-specific studies and/or management measures are necessary.

Finfish

The finfish resource assessment confirmed that fish diversity, density and biomass are relatively low around Niue. A comparison with the two earlier surveys (2005 PROCFish/C and 2016 NGPS) revealed significant variations in biomass and densities. While there were differences between the 2016 NGPS survey and the 2017 Niue Marine Ecological Survey, the major differences were between the 2005 PROCFish/C survey and the NGPS survey and the 2017 survey, with the 2005 survey recording far greater numbers of fish. There was a more general pattern consistent between all surveys with lower density and biomass usually found on the windward side of the island.

Observed differences in this study compared with the two previous surveys could result from various factors, such as:

- The experience of the surveyors;
- changes in the environment through time; and
- fishing effort.

While all of these factors will have had some influence on the results, it is very difficult to attribute results directly due to the length of the time between surveys after 2005. We make some recommendations to help address these issues in the future.

By way of comparison, it is pertinent to mention that PROCFish/C data from other Pacific Island countries also showed significant differences with later climate change finfish surveys (e.g. Moore et al. 2012a, b; Siaosi et al. 2012a, b). Climate change surveys conducted in the Marshall Islands, Kiribati, Papua New Guinea and Tuvalu often demonstrated lower finfish density and biomass than the PROCFish/C surveys. In several sites in Kiribati (Abemama) and Papua New Guinea (Andra), finfish densities and biomass measured on the outer reefs were almost as low as the 2017 Niue Marine Ecological Survey.

Recommendations

As is the case for the invertebrate surveys, when finfish surveys are done at very long intervals (>10 years in this case), it is difficult to know the causes of any observed changes, or to make management recommendations in a timely manner. We suggest that finfish surveys be carried out more regularly, every three to five years. The stations surveyed in the future should match the 2017 survey, with extra stations included where greater accuracy is required.

Due to the scarcity of information on local catch, especially of reef species, it is strongly recommended that DAFF continue the data collection of artisanal catch and have a particular focus on reef fish.

To supplement this data collection, it is also suggested that a socio-economic survey should be carried out for both invertebrates and fish. Results could be compared to the 2005 survey and catch and consumption figures could be updated. It will also provide useful information on reef fish catch quantity and species composition around the island.

Supporting habitat

Coral cover has improved slightly since 2005, but remains relatively low, which is indicative of a disturbed reef system rather than a healthy one. Recovery following major disturbance can take at least a decade and even longer for isolated reefs, especially when coral cover has been depleted in all areas and results in reduced recruitment. In 2005, the Tamakautoga area and the east coast had the highest coral cover (40% and 29%, respectively) and diversity, while the rest of the western side of the island had critically low coral cover. In 2017, both the northwest and Tamakautoga areas had the highest live coral cover (from 12% up to 38% in the northwest and from 11% up to 26% in the Tamakautoga area).

While coral cover has slowly increased, coral communities around Niue remain under stress from recurrent storms and coral bleaching.

Recommendations

We recommend more regular benthic habitat monitoring in line with our recommendations for invertebrates and fish. Reef fish and invertebrates need healthy reef systems to survive so it is critical to understand changes in the health of the benthos. These surveys should be done at the same time as the finfish surveys. A temperature logger, which was placed in Niuean water in 2016 (first year of record in Appendix 10) should help understand some of the benthic processes providing that it is replaced regularly, ideally on a two-year basis.

While there are data on cyclone events in Niue, there is a lack of information on other disturbances that may also affect reefs. Therefore, we recommended that records be kept on all severe disturbances, such as cyclones, bleaching, mass die-offs or pollution events, which could impact the reef. Local departments involved in resource management (e.g. DAFF and Environment Department) could work with communities to collect information when a disturbance occurs (Appendix 13).

References

Anon. 2017. Annual report to the commission – Part 1: information on fisheries, research, and statistics: Niue. [Rarotonga, Cook Islands]: Western and Central Pacific Fisheries Commission. Scientific Committee, 13th Regular Session, Rarotonga, Cook Islands, 9–17 August 2017.

Barnett B., Brock M. and Gregor K. 2008. Stock assessment of the coconut crab (*Birgus latro*) on Niue Island. Unpublished report. Bay of Plenty Polytechnic, New Zealand: Marine Studies Department. 40 p.

Bell J.D., Johnson J.E., Ganachaud A.S., Gehrke P.C., Hobday A.J., Hoegh-Guldberg O., Le Borgne R., Lehodey P., Lough J.M., Pickering T., Pratchett M.S. and Waycott M. 2011. Vulnerability of tropical Pacific fisheries and aquaculture to climate change: Summary for Pacific Island countries and territories. Secretariat of the Pacific Community, Noumea, New Caledonia. 386 p.

Borsa P., Fauvelot C., Tiavouane J., Grulois D., Wabnitz C., Abdon Naguit and Andréfouët S. 2014. Distribution of Noah's giant clam, *Tridacna noae*. Marine Biodiversity 45: 339-344. Available at: https://doi.org/10.1007/s12526-014-0265-9

Dalzell P., Lindsay S. and Patiale H. 1990. Niue Fisheries Resources Survey, 11–25 July 1990. SPC Fisheries Newsletter 54:31–35.

Dalzell P.J., Lindsay S. and Patiale H. 1993. Fisheries resources survey of the island of Niue. Noumea, New Caledonia: South Pacific Commission. XIII, 68 p.

Fisk D. 2007. Niue sustainable coastal fisheries: Marine baseline survey and monitoring programme. International Waters Programme Pacific Technical Report. Secretariat of the Pacific Islands Regional Environment Programme, Apia, Samoa.

Friedlander A.M., Arribas J., Ballesteros E., Betz J., Bosserelle P., Brown E., Caselle J.E., Cramp J.E., Gataua L., Helagi N., Mayorga J., McAloney D., Myers D., Pasisi B., Richmond'Rex A., Rose P., Salinas-de-León P., San Félix M., Thompson C., Turchik A. and Sala E. 2017. Exploring the marine ecosystems of Niue and Beveridge Reef. Report to the Government of Niue. National Geographic Pristine Seas. 79 p.

Gillett R. 1993. The August 1992 transplantation of trochus to Tonga and Niue. SPC Trochus Information Bulletin 2:10–12.

Gillett R. 2002. Pacific Islands trochus introductions 1927–1998. SPC Trochus Information Bulletin 9: 9–13.

Gillett R. 2015. Fisheries in the economies of Pacific Island countries and territories. Noumea, New Caledonia: Pacific Community. 684 p.

Helagi N., Tafatu J., Bertram I., Moore B., Linawak M. and Pakoa K. 2015. Status of the coconut crab, *Birgus latro*, in Niue. Noumea, New Caledonia: Pacific Community. 48 p.

Kohler K.E and Gill S.M. 2006. Coral point count with Excel extensions (CPCe): A visual basic program for the determination of coral and substrate coverage using random point count methodology. Computers and Geosciences 32:1259–1269. Available at: https://doi.org/10.1016/j.cageo.2005.11.009

Kronen M., Fisk D., Pinca S., Magron F., Friedman K.J., Boblin P., Awira R. and Chapman L.B. 2008. Niue country report: Profile and results from in-country survey work (May to June 2005). Pacific Regional Oceanic and Coastal Fisheries Development Programme (PROCFish/C/CoFish). Noumea, New Caledonia: Secretariat of the Pacific Community. 189 p.

Labrosse P., Yeeting B. and Pasisi B. 1999. Survey of the Namoui fisheries reserve in Niue. SPC Fisheries Newsletter Information Bulletin 90:29–36.

Labrosse P., Kulbicki M. and Ferraris J. 2002. Underwater visual fish census surveys proper use and implementation. Noumea, New Caledonia: Secretariat of the Pacific Community. REAT: Reef Resources Assessment Tools, VI. 54 p.

Liggins L. and Arranz-Martinez V. 2018. Genetic diversity and connectivity of Beveridge Reef's marine biodiversity in an Indo-Pacific wide context. Report for the Department of Agriculture, Forestry and Fisheries of Niue. 37 p.

Moore B., Sapatu M., Yeeting B., Pakoa K., Magron F., Bertram I. and Chapman L. 2012. Climate change baseline assessment – Majuro Atoll, Republic of the Marshall Islands. Noumea, New Caledonia: Secretariat of the Pacific Community. 110 p.

Moore B., Siaosi F., Lalavanua W., Simpson R., Magron F., Bertram I. and Chapman L. 2012b. Climate change baseline assessment – northern Manus outer islands, Papua New Guinea. Noumea, New Caledonia: Secretariat of the Pacific Community. 117 p.

Pakoa K., Friedman K., Moore B., Tardy E. and Bertram I. 2014. Assessing tropical marine invertebrates: A manual for Pacific Island resource managers. Noumea, New Caledonia: Secretariat of the Pacific Community. 118 p.

Pasisi B. 1995. Country statement – Niue Island [CP 9]. Noumea, New Caledonia: South Pacific Commission. South Pacific Commission and Forum Fisheries Agency Workshop on the Management of South Pacific Inshore Fisheries, Noumea, New Caledonia, 1995. 4 p.

PCCSP (Pacific Climate Change Scientific Program). 2011. Climate change in the Pacific: Scientific assessments and new research. Volume 2, country reports, chapter 9, Niue.

Schiller C.B. 1992. Assessment of the status of the coconut crab, *Birgus latro*, on Niue Island, with recommendations regarding an appropriate resource management strategy. South Pacific Aquaculture Development Project, consultancy report. Rome, Italy: Food and Agriculture Organization of the United Nations. 152 p.

Siaosi F., Sapatu M., Lalavanua W., Yeeting B., Pakoa K., Magron F., Moore B., Bertram I. and Chapman L. 2012a. Climate change baseline assessment – Abemama Atoll, Kiribati. Noumea, New Caledonia: Secretariat of the Pacific Community. 115 p.

Siaosi F., Sapatu M., Lalavanua W., Pakoa K., Yeeting B., Magron F., Moore B., Bertram I. and Chapman L. 2012b. Climate change baseline assessment – Funafuti Atoll, Tuvalu. Noumea, New Caledonia: Secretariat of the Pacific Community. 107 p.

Statistics Niue. 2010. Agriculture census of Niue 2009. Statistics Niue and the Department of Agriculture, Forestry and Fisheries. Government of Niue.

Vaha K. 2012. Niue census of population and households 2011. Statistics Niue, Department of Finance, Planning and Statistics, Government of Niue, Alofi.

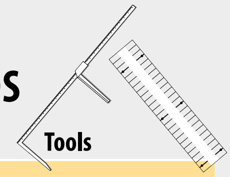
Yeeting B.M. 2001. Densities of *Gambierdiscus toxicus* obtained from some algae samples collected from Niue in November 2001. Report submitted to the Niue Fisheries Department. Secretariat of the Pacific Community, Noumea, New Caledonia.

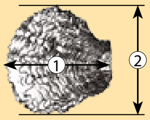
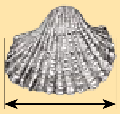
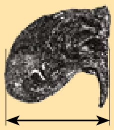
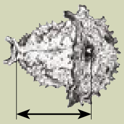
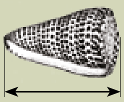
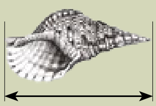
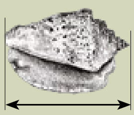
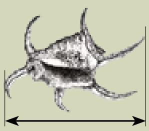
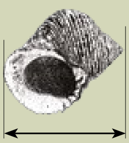
Yeeting B.M. 2003. A preliminary investigation of ciguatera fish poisoning in Niue. Draft report submitted to the Niue Fisheries Department. Secretariat of the Pacific Community, Noumea, New Caledonia.

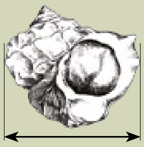
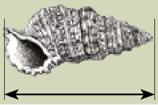
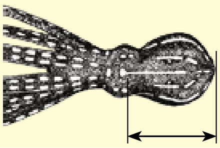
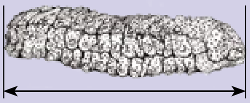
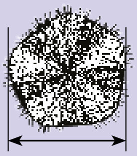
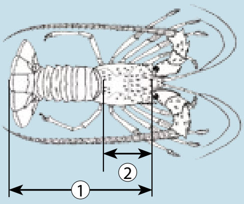
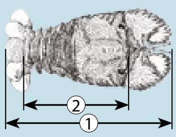
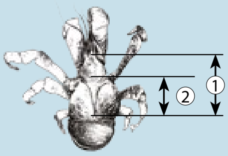
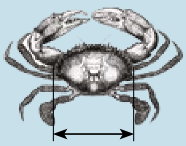
Appendix

Appendix 1. Methodology for measuring invertebrates.

IDENTIFICATION CARDS FOR MARINE INVERTEBRATE SURVEYS IN THE PACIFIC ISLANDS



		Measurements	Tools
Bivalves			
Giant clam		Longest length	Caliper Ruler
Oyster		1: Distance from hinge to opposite edge 2: Shell width	Caliper Ruler
Ark shell (*Anadara* sp.)		Shell width	Caliper Ruler
Penguin's wing (*Pteria penguin*)		Umbo-ventral length	Caliper Ruler
Gastropods			
Sea hare		Total length	Caliper Ruler
Trochus		Basal diameter (measure across the base of the shell)	Caliper Ruler
Cone shell		Total length	Caliper Ruler
Triton shell		Total length	Caliper Ruler
Strombus shell		Total length	Caliper Ruler
Conch shell (*Lambis chiragra*)		Total length (end of shell to end of furtherest spike)	Caliper Ruler
Turban snail (*Turbo setosus*)		Longest width (end of apex to end of outer edge of whorl opening)	Caliper Ruler

		Measurements	Tools
Gastropods			
Green snail		Longest width	Caliper Ruler
Cowry shell		Total length	Caliper Ruler
Cerith (*Cerithium* sp.)		Total length	Caliper Ruler
Cephalopods			
Octopus		Mantle height	Ruler
Echinoderms			
Sea cucumber		Length	Ruler
Sea urchin		Length without spines	Caliper Ruler
Crustaceans			
Spiny lobster		1: Length from front edge of carapace to rear edge of telson 2: Carapace length	Caliper Ruler
Slipper lobster		1: Total length 2: Length from eyeline to front of telson	Caliper Ruler
Coconut crab		1: Cephalo-thoracic length (CL) 2: Thoracic length (TL)	Caliper Ruler
Mangrove crab		Carapace width	Ruler

Appendix 2. Station position (in decimal degrees) by survey method

Manta tow (Manta)

Station name	N°	Start latitude	Start longitude	End latitude	End L longitude
Manta 1	1	-19.0598	190.0699	-19.0586	190.0727
	2	-19.0585	190.0728	-19.0566	190.075
	3	-19.0565	190.0756	-19.0543	190.0774
	4	-19.0542	190.0774	-19.052	190.0791
	5	-19.0519	190.0792	-19.0494	190.0802
	6	-19.0491	190.0802	-19.0465	190.0809
Manta 2	1	-19.1047	190.0798	-19.1028	190.0776
	2	-19.1029	190.0777	-19.101	190.0756
	3	-19.1011	190.0758	-19.1005	190.0751
	4	-19.0993	190.0735	-19.0973	190.0713
	5	-19.0975	190.0715	-19.095	190.0686
Manta 3	1	-19.1241	190.0863	-19.1218	190.0868
	2	-19.1219	190.0867	-19.1194	190.0872
	3	-19.1196	190.087	-19.1167	190.0869
	4	-19.1169	190.087	-19.1141	190.0863
	5	-19.114	190.0863	-19.1115	190.0856
	6	-19.1115	190.0855	-19.1091	190.0839
Manta 4	1	-18.9557	190.1374	-18.9552	190.1402
	2	-18.9551	190.1402	-18.9545	190.143
	3	-18.9542	190.1431	-18.9531	190.1457
	4	-18.953	190.1457	-18.9523	190.1484
	5	-18.9521	190.1485	-18.9519	190.1513
Manta 5	1	-18.9695	190.1081	-18.9676	190.1102
	2	-18.9676	190.1103	-18.9658	190.1125
	3	-18.9657	190.1126	-18.964	190.1148
	4	-18.9639	190.1149	-18.9621	190.117
	5	-18.962	190.1171	-18.9604	190.1194
	6	-18.9603	190.1195	-18.9589	190.122
Manta 6	1	-18.9876	190.0956	-18.9852	190.097
	2	-18.9848	190.0969	-18.9825	190.0983
	3	-18.9821	190.0984	-18.9797	190.0997
	4	-18.9792	190.0999	-18.977	190.1014
	5	-18.9767	190.1016	-18.9744	190.1031
	6	-18.9744	190.1031	-18.9724	190.105

Station name	N°	Start latitude	Start longitude	End latitude	End L longitude
Manta 7	1	-19.0069	190.0782	-19.0049	190.0801
	2	-19.0047	190.0804	-19.0028	190.0824
	3	-19.0026	190.0824	-19.0005	190.0842
	4	-19.0003	190.0846	-18.9983	190.0865
	5	-18.9982	190.0866	-18.996	190.0886
	6	-18.9958	190.0888	-18.9937	190.0909
Manta 8	1	-19.0713	190.0518	-19.0694	190.0541
	2	-19.0694	190.0542	-19.0677	190.0566
	3	-19.0677	190.0567	-19.0665	190.0592
	4	-19.0664	190.0595	-19.0651	190.062
	5	-19.065	190.0621	-19.0635	190.0644
	6	-19.0635	190.0645	-19.0619	190.0668
Manta 9	1	-19.0475	190.0806	-19.0449	190.0812
	2	-19.0446	190.0812	-19.0418	190.0815
	3	-19.0416	190.0815	-19.0388	190.0814
	4	-19.0386	190.0814	-19.0361	190.081
	5	-19.0359	190.0811	-19.0331	190.0808
	6	-19.033	190.0808	-19.0306	190.08
Manta 10	1	-19.0174	190.2061	-19.0201	190.2063
	2	-19.0202	190.2063	-19.0204	190.2063
	3	-19.0229	190.2065	-19.0255	190.2072
	4	-19.0257	190.2073	-19.0281	190.2086
	5	-19.0282	190.2087	-19.0307	190.2097
	6	-19.0308	190.2098	-19.0332	190.2112
Manta 11	1	-19.0086	190.2072	-19.0061	190.2062
	2	-19.006	190.2062	-19.0036	190.2047
	3	-19.0035	190.2046	-19.0011	190.2033
	4	-19.001	190.2033	-18.9985	190.2022
	5	-18.9984	190.2022	-18.9959	190.2011
	6	-18.9958	190.2012	-18.9932	190.2004
Manta 12	1	-18.9914	190.1999	-18.9888	190.1992
	2	-18.9885	190.1991	-18.9858	190.1986
	3	-18.9854	190.1986	-18.9819	190.1983
Manta Namoui marine reserve	1	-19.0303	190.0799	-19.028	190.0791
	2	-19.0278	190.0791	-19.0253	190.0782
	3	-19.025	190.0781	-19.0226	190.0775
	4	-19.0224	190.0774	-19.0206	190.0768

Reef front night searches (RFS)

Station name	N°	Start latitude	Start longitude	End latitude	End longitude
RFS 1	1	-18.9648	190.1147	-18.9652	190.1144
	2	-18.9653	190.1143	-18.9657	190.1140
	3	-18.9658	190.1140	-18.9662	190.1136
	4	-18.9648	190.1147	-18.9652	190.1144
	5	-18.9653	190.1143	-18.9657	190.1140
	6	-18.9658	190.1140	-18.9662	190.1136
RFS 2	1	-18.9562	190.1393	-18.9561	190.1400
	2	-18.9561	190.1400	-18.9558	190.1410
	3	-18.9562	190.1393	-18.9561	190.1400
	4	-18.9561	190.1400	-18.9558	190.1410
RFS 3	1	-18.9944	190.0914	-18.9937	190.0919
	2	-18.9936	190.0920	-18.9930	190.0926
	3	-18.9930	190.0926	-18.9927	190.0931
	4	-18.9944	190.0914	-18.9937	190.0919
	5	-18.9936	190.0920	-18.9930	190.0926
	6	-18.9930	190.0926	-18.9927	190.0931
RFS 4	1	-18.9883	190.0964	-18.9874	190.0970
	2	-18.9873	190.0970	-18.9865	190.0973
	3	-18.9865	190.0974	-18.9857	190.0978
	4	-18.9883	190.0964	-18.9874	190.0970
	5	-18.9873	190.0970	-18.9865	190.0973
	6	-18.9865	190.0974	-18.9857	190.0978
RFS 5	1	-19.1071	190.0831	-19.1063	190.0825
	2	-19.1062	190.0825	-19.1057	190.0819
	3	-19.1056	190.0819		
	4	-19.1071	190.0831	-19.1063	190.0825
	5	-19.1062	190.0825	-19.1057	190.0819
	6	-19.1056	190.0819		
RFS 6	1	-19.0493	190.219	-19.0486	190.2185
	2	-19.0485	190.2185	-19.0478	190.2182
	3	-19.0478	190.2182	-19.0471	190.2178
	4	-19.0493	190.219	-19.0486	190.2185
	5	-19.0485	190.2185	-19.0478	190.2182
	6	-19.0478	190.2182	-19.0471	190.2178
RFS 7	1	-19.0536	190.0789	-19.0543	190.0784
	2	-19.0543	190.0783	-19.0551	190.0780
	3	-19.0551	190.0780	-19.0556	190.0775
	4	-19.0536	190.0789	-19.0543	190.0784
	5	-19.0543	190.0783	-19.0551	190.0780
	6	-19.0551	190.0780	-19.0556	190.0775
RFS 11	1	-19.1046	190.0808	-19.1041	190.0804
	2	-19.1041	190.0804	-19.1036	190.0797
	3	-19.1036	190.0796	-19.1030	190.0789
	4	-19.1046	190.0808	-19.1041	190.0804
	5	-19.1041	190.0804	-19.1036	190.0797
	6	-19.1036	190.0796	-19.1030	190.0789

Reef benthos transect (RBT)

Station name	Start latitude	Start longitude
RBT 1	-19.1267	-169.913
RBT 2	-19.1085	-169.915
RBT 3	-19.0973	-169.927
RBT 4	-19.0692	-169.944
RBT 5	-19.0575	-169.924
RBT 6	-19.0451	-169.918
RBT 7	-19.0205	-169.922
RBT 8	-19.0106	-169.923
RBT 9	-18.996	-169.91
RBT 10	-18.9895	-169.905

Fish transects and substrate quadrats (D-UVC)

Station name[7]	Start latitude	Start longitude
D-UVC 01	-169.911	-18.9954
D-UVC 03	-169.927	-19.0574
D-UVC 04	-169.934	-19.0619
D-UVC 05	-169.906	-18.9891
D-UVC 11	-169.948	-19.0712
D-UVC 18	-169.931	-19.0957
D-UVC 19	-169.924	-19.1011
D-UVC 22	-169.863	-18.9558
D-UVC 26	-169.887	-18.9651
D-UVC 30	-169.897	-18.9746
D-UVC 38	-169.807	-18.9633
D-UVC 44	-169.919	-19.0412
D-UVC 46	-169.921	-19.029
D-UVC 48	-169.924	-19.0161
D-UVC 49	-169.92	-19.0044
D-UVC 50	-169.916	-19.1091

7 Station name based on the selection of the 2005 PROCfish\C stations resurveyed in 2017.

Appendix 3. Densities of invertebrate species observed during manta tow surveys in Niue in 2016.

Invertebrate group	English common name or scientific name	Overall mean density (ind. ha^{-1})	SE	n	Present mean density (ind. ha^{-1})	SE_P	n_P
Sea cucumber	Surf redfish	1.03	0.59	13	4.46	1.12	3
	Lollyfish	5.06	1.6	13	6.58	1.83	10
	Black teatfish	4.18	1.61	13	6.04	2.05	9
	Prickly redfish	8.33	2.03	13	10.83	2.03	10
	Amberfish	0.42	0.29	13	2.76	0.02	2
Urchin	Blue-black sea urchin	0.43	0.43	13	5.56		1
	Echinothrix sp.	396.84	123.89	13	644.86	141.09	8
	Red pencil urchin	0.25	0.25	13	3.29		1
Bivalve	Elongate giant clam	66.28	22.09	13	78.35	24.45	11
	Fluted giant clam	1.55	0.77	13	5.05	1.35	4
Gastropod	Seba's spider conch	0.21	0.21	13	2.76		1
Octopus	*Octopus* sp.	0.47	0.32	13	3.03	0.26	2
Turtle	Green turtle	0.52	0.36	13	3.4	0.63	2

Appendix 4. Densities of invertebrate species observed during reef benthos transects in Niue in 2016 and 2017.

Invertebrate group	English common name or scientific name	Overall mean density (ind. ha^{-1})	SE	n	Present mean density (ind. ha^{-1})	SE_P	n_P
Sea cucumber	Surf redfish	29.17	15.28	10	97.22	13.89	3
	Lollyfish	1179.17	503.19	10	1310.19	543.18	9
	White threadfish	316.67	277.51	10	1583.33	1208.33	2
	Black teatfish	16.67	12.73	10	83.33	41.67	2
Urchin	Rock-boring urchin	991.67	475.71	10	1652.78	678.51	6
	Needle-spined urchin	54.17	45.66	10	270.83	187.5	2
	Echinostrephus sp.	325	173.78	10	650	288.25	5
	Black banded sea urchin	8.33	8.33	10	83.33		1
	Blue-black sea urchin	1412.5	1389.42	10	4708.33	4604.18	3
	Echinothrix sp.	12.5	12.5	10	125		1
Sea star	*Linckia multifora*	16.67	12.73	10	83.33	41.67	2
Bivalve	Jewel box (reef oyster)	125	72.44	10	312.5	140.79	4
	Elongate giant clam	58.33	29.27	10	116.67	46.4	5
Gastropod	*Astralium* sp.	4.17	4.17	10	41.67		1
	Great worm shell	212.5	86.39	10	354.17	111.15	6
	Soldier cone	125	98.6	10	312.5	231.05	4
	Cone shell (*Conus* sp.)	683.33	295.82	10	854.17	346.11	8
	Purple pacific drupe	387.5	213.1	10	775	359.54	5
	Other drupe (*Drupa* sp.)	3212.5	1819.85	10	4015.63	2204.97	8
	Precious stone shell	25	11.11	10	62.5	12.03	4
	Belligerent rock shell	162.5	79.41	10	325	123.18	5
	Serpent's head cowrie	12.5	6.36	10	41.67	0	3
	Money cowrie	4.17	4.17	10	41.67		1
	Granular drupe	1854.17	1382.47	10	4635.42	3168.1	4
	Other drupe (*Morula* sp.)	2291.67	965.29	10	3273.81	1208.64	7
	Grape drupe	295.83	295.83	10	2958.33		1
	Star-shaped limpet	4.17	4.17	10	41.67		1
	Thais sp.	225	225	10	2250		1
Octopus	*Octopus* sp.	4.17	4.17	10	41.67		1

Appendix 5. Densities of invertebrate species observed during night reef front walks in Niue in 2016 and 2017.

Invertebrate group	English common name or scientific name	Overall mean density (ind. ha^{-1})	SE	n	Present mean density (ind. ha^{-1})	SE_P	n_P
Sea cucumber	Surf redfish	13.06	3.39	8	17.41	2.52	6
	Lollyfish	512.82	238.22	8	512.82	238.22	8
	White teatfish	1.01	1.01	8	8.06		1
	White threadfish	335.74	305.89	8	895.3	789.17	3
	Dragonfish	1.67	0.83	8	4.46	0.52	3
Urchin	Black banded sea urchin	4.74	2	8	9.48	1.91	4
	Blue-black sea urchin	9.94	4.24	8	13.46	4.97	6
	Echinothrix sp.	9.65	9.65	8	77.17		1
Gastropod	Great worm shell	1.34	0.97	8	8.24	2.75	2
	Belligerent rock shell	3.25	1.76	8	8.67	2.32	3
	Turban snail	31.46	16.84	8	41.94	21.01	6
Crustacean	Pronghorn spiny lobster	5.55	3.85	8	22.21	6.77	2
	Caledonian mitten lobster	0.5	0.5	8	4.03		1
	Red-spotted mitten lobster	2.52	2.52	8	20.16		1

Appendix 6. Invertebrate sizes.

Invertebrate group	English common name or scientific name	Mean length (mm)	SE	Individual with length measured	Individuals counted
Sea cucumber	Surf redfish	249.17	10.53	30	34
	Lollyfish	258.95	3.55	435	1367
	White teatfish	215	65	2	2
	White threadfish	230	40.91	10	762
	Black teatfish	303.75	26.57	4	22
	Dragonfish	220	46.19	3	3
	Prickly redfish			0	34
	Amberfish			0	2
Urchin	Rock-boring urchin			0	238
	Needle-spined urchin			0	13
	Echinostrephus sp.				78
	Black banded sea urchin			0	11
	Blue-black sea urchin			0	362
	Echinothrix sp.			0	1765
	Red pencil urchin			0	1
Sea star	*Linckia multifora*			0	4
Bivalve	Jewel box (reef oyster)	65	4.16	6	30
	Elongate giant clam	44.29	4.7	14	318
	Fluted giant clam			0	6
Gastropod	*Astralium* sp.	28		1	1
	Great worm shell			0	54
	Soldier cone	19.43	2.78	7	30
	Cone shell	22.81	1.56	31	164
	Purple Pacific drupe	25.59	0.72	54	93
	Other drupe (*Drupa* sp.)	22.49	0.26	173	771
	Seba's spider conch			0	1
	Precious stone shell	43.75	2.78	4	6
	Belligerent rock shell	63.48	1.57	44	44
	Serpent's head cowrie	32	5	2	3
	Granular drupe	19.12	0.29	77	445
	Other drupe (*Morula* sp.)	17.35	0.46	108	550
	Grape drupe	24.86	0.4	7	71
	Star-shaped limpet			0	1
	Thais sp.			0	54
	Turban snail	61.56	1.58	32	50
Octopus	*Octopus* sp.			0	3
Crustacean	Pronghorn spiny lobster	197.5	22.43	6	12
	Caledonian mitten lobster	160		1	1
	Red-spotted mitten lobster	167	8	5	5
Turtle	Green turtle			0	2

Appendix 7. Fish species counted within 5 m on either side of a transect from the Distance Underwater Visual Census method.

Only commercial fish families and indicator species (e.g. Chaetodontidae) were recorded. The preferred diet[8] of each species is provided.

Family	Species	Diet
Acanthuridae	*Acanthurus achilles*	H
Acanthuridae	*Acanthurus blochii*	H
Acanthuridae	*Acanthurus leucopareius*	H
Acanthuridae	*Acanthurus lineatus*	H
Acanthuridae	*Acanthurus nigricans*	H
Acanthuridae	*Acanthurus nigrofuscus*	H
Acanthuridae	*Acanthurus nigroris*	H
Acanthuridae	*Acanthurus olivaceus*	H
Acanthuridae	*Acanthurus pyroferus*	H
Acanthuridae	*Acanthurus* sp.	
Acanthuridae	*Acanthurus thompsoni*	Z
Acanthuridae	*Ctenochaetus cyanocheilus*	H
Acanthuridae	*Ctenochaetus flavicauda*	H
Acanthuridae	*Ctenochaetus hawaiiensis*	H
Acanthuridae	*Ctenochaetus striatus*	H
Acanthuridae	*Naso lituratus*	H
Acanthuridae	*Naso unicornis*	H
Acanthuridae	*Naso vlamingii*	Z
Acanthuridae	*Zebrasoma scopas*	H
Acanthuridae	*Zebrasoma veliferum*	H
Balistidae	*Balistapus undulatus*	I
Balistidae	*Melichthys niger*	Z
Balistidae	*Melichthys vidua*	H
Balistidae	*Sufflamen bursa*	I
Carangidae	*Caranx* sp.	
Chaetodontidae	*Chaetodon auriga*	I
Chaetodontidae	*Chaetodon ephippium*	I
Chaetodontidae	*Chaetodon flavirostris*	I
Chaetodontidae	*Chaetodon lunula*	I
Chaetodontidae	*Chaetodon mertensii*	I
Chaetodontidae	*Chaetodon ornatissimus*	I
Chaetodontidae	*Chaetodon pelewensis*	I
Chaetodontidae	*Chaetodon quadrimaculatus*	I
Chaetodontidae	*Chaetodon reticulatus*	I
Chaetodontidae	*Chaetodon* sp.	
Chaetodontidae	*Chaetodon trifascialis*	I
Chaetodontidae	*Chaetodon unimaculatus*	I
Chaetodontidae	*Forcipiger flavissimus*	I
Chaetodontidae	*Forcipiger longirostris*	I
Diodontidae	*Diodon holocanthus*	I
Haemulidae	*Plectorhinchus chaetodonoides*	I OU P

Family	Species	Diet
Holocentridae	*Myripristis berndti*	I
Holocentridae	*Neoniphon opercularis*	I
Holocentridae	*Sargocentron spiniferum*	I
Kyphosidae	*Kyphosus vaigiensis*	H
Labridae	*Bodianus loxozonus*	I
Labridae	*Coris aygula*	I
Labridae	*Coris gaimard*	I
Labridae	*Hemigymnus fasciatus*	I
Labridae	*Oxycheilinus unifasciatus*	I
Lethrinidae	*Gnathodentex aureolineatus*	I
Lethrinidae	*Monotaxis grandoculis*	I
Lutjanidae	*Aphareus furca*	P
Lutjanidae	*Lutjanus bohar*	I
Lutjanidae	*Macolor niger*	I
Malacanthidae	*Malacanthus latovittatus*	I
Monacanthidae	*Amanses scopas*	I
Mullidae	*Parupeneus cyclostomus*	P
Mullidae	*Parupeneus multifasciatus*	I
Mullidae	*Parupeneus* sp.	
Mullidae	*Parupeneus crassilabris*	I
Muraenidae	*Gymnothorax javanicus*	P
Scaridae	*Calotomus carolinus*	H
Scaridae	*Cetoscarus ocellatus*	H
Scaridae	*Chlorurus sordidus*	H
Scaridae	*Scarus chameleon*	H
Scaridae	*Scarus forsteni*	H
Scaridae	*Scarus frenatus*	H
Scaridae	*Scarus ghobban*	H
Scaridae	*Scarus longipinnis*	H
Scaridae	*Scarus niger*	H
Scaridae	*Scarus oviceps*	H
Scaridae	*Scarus rubroviolaceus*	H
Scaridae	*Scarus schlegeli*	H
Scaridae	*Scarus* sp.	
Serranidae	*Cephalopholis argus*	P
Serranidae	*Cephalopholis urodeta*	P
Serranidae	*Epinephelus* sp.	
Serranidae	*Gracila albomarginata*	P
Serranidae	*Variola louti*	P
Sphyraenidae	*Sphyraena barracuda*	P
Zanclidae	*Zanclus cornutus*	I

[8] Invertivore: consumes mainly invertebrates and algae; detritivore: consumes mainly dead animals or plants; Herbivore: consumes mainly algae; piscivore: consumes mainly fish; Plankton feeder: consumes mainly zooplankton and/or phytoplankton.

Appendix 8. Fish species observed during swims, including fish species from Appendix 7 and Distance Underwater Visual Census.

All types of fish (i.e. not just commercial) were recorded.

Family	Species	2016	2017
Acanthuridae	*Acanthurus achilles*	x	x
Acanthuridae	*Acanthurus albipectoralis*	x	x
Acanthuridae	*Acanthurus blochii*	x	x
Acanthuridae	*Acanthurus guttatus*	x	x
Acanthuridae	*Acanthurus lineatus*	x	x
Acanthuridae	*Acanthurus nigricans*	x	x
Acanthuridae	*Acanthurus nigricauda*	x	
Acanthuridae	*Acanthurus nigrofuscus*	x	x
Acanthuridae	*Acanthurus nigros*	x	
Acanthuridae	*Acanthurus olivaceus*	x	x
Acanthuridae	*Acanthurus pyroferus*	x	x
Acanthuridae	*Acanthurus thompsoni*	x	x
Acanthuridae	*Acanthurus triostegus*	x	x
Acanthuridae	*Acanthurus xanthopterus*	x	x
Acanthuridae	*Ctenochaetus binotatus*	x	
Acanthuridae	*Ctenochaetus flavicauda*	x	x
Acanthuridae	*Ctenochaetus striatus*	x	x
Acanthuridae	*Naso brevicornis*	x	
Acanthuridae	*Naso lituratus*	x	x
Acanthuridae	*Naso unicornis*	x	x
Acanthuridae	*Zebrasoma scopas*	x	x
Acanthuridae	*Zebrasoma velifer*	x	x
Balistidae	*Balistapus unduladus*	x	x
Balistidae	*Balistoides flavipectoralis*	x	
Balistidae	*Balistoides viridescens*	x	x
Balistidae	*Melichthys niger*	x	x
Balistidae	*Melichthys vidua*	x	x
Balistidae	*Rhinecanthus rectangulus*	x	x
Balistidae	*Sufflamen bursa*	x	x
Blenniidae	*Plagiostremus tapeinosoma*	x	x
Blenniidae	*Plagiotremus rhinorhynchos*	x	
Caracanthidae	*Caracanthus maculatus*	x	
Carangidae	*Caranx lugubris*		x
Carangidae	*Caranx melampygus*	x	x
Carangidae	*Trachinotus balloni*		x
Chaetodontidae	*Chaetodon auriga*	x	x
Chaetodontidae	*Chaetodon benetti*	x	
Chaetodontidae	*Chaetodon citrinellus*	x	x
Chaetodontidae	*Chaetodon flavirostris*		x
Chaetodontidae	*Chaetodon lunula*	x	x
Chaetodontidae	*Chaetodon mertensii*	x	x
Chaetodontidae	*Chaetodon ornatissimus*	x	x
Chaetodontidae	*Chaetodon pelewensis*	x	x
Chaetodontidae	*Chaetodon quadrimaculatus*	x	x
Chaetodontidae	*Chaetodon reticulatus*	x	x
Chaetodontidae	*Chaetodon trifascialis*	x	x
Chaetodontidae	*Chaetodon ulietensis*	x	
Chaetodontidae	*Chatodon unimaculatus*	x	x
Chaetodontidae	*Forciper flavissima*	x	x
Chaetodontidae	*Forcipiger longirostris*	x	x
Chaetodontidae	*Hemniochus chrysostomus*	x	x
Cirrhitidae	*Cirrhitichthys falco*	x	x
Cirrhitidae	*Cirrhitus pinnulatus*	x	
Cirrhitidae	*Neocirrhitus armatus*	x	
Cirrhitidae	*Paracirrhites arcatus*	x	x
Cirrhitidae	*Paracirrhites forsteri*	x	x
Cirrhitidae	*Paracirrhites hemistictus*	x	x
Diodontidae	*Diodon holocanthus*		x
Diodontidae	*Diodon hystrix*	x	
Echeneidae	*Echeneis naucrates*	x	
Fistulariidae	*Fistularia commersonii*	x	x
Holocentridae	*Sargocentron caudimaculatum*	x	
Holocentridae	*Sargocentron spiniferum*	x	x
Holocentridae	*Sargocentron tiere*	x	x
Kuhliidae	*Kuhlia mugil*	x	x
Kyphosidae	*Kyphosus biggibus*		x
Kyphosidae	*Kyphosus cinerascens*	x	x
Kyphosidae	*Kyphosus vaigensis*	x	x
Labridae	*Anampses caeruleopunctatus*		x
Labridae	*Bodianus axillaris*	x	
Labridae	*Bodianus loxozonus*	x	x
Labridae	*Cheilinus trilobatus*	x	
Labridae	*Cheilinus undulatus*	x	x
Labridae	*Coris aygula*	x	x
Labridae	*Coris gaimard*	x	x
Labridae	*Gomphosus varius*	x	x
Labridae	*Halichoeres hortulanus*	x	x
Labridae	*Halichoeres melasmapomus*	x	
Labridae	*Halichoeres ornatissimus*	x	x
Labridae	*Hemigymnus fasciatus*	x	x
Labridae	*Hologymnosus annulatus*	x	x
Labridae	*Labroides bicolor*	x	x
Labridae	*Labroides dimidiatus*	x	x
Labridae	*Macropharygodon meleagris*	x	x

Family	Species	2016	2017
Labridae	*Novaculichthys tanieorous*	x	x
Labridae	*Oxycheilinus unifasciatus*	x	x
Labridae	*Pseudocheilinus hexataenia*	x	x
Labridae	*Pseudocheilinus octotaenia*	x	x
Labridae	*Pseudocheilinus tetrataenia*	x	x
Labridae	*Stethojulis bandanensis*	x	x
Labridae	*Thalassoma amblycephalum*	x	x
Labridae	*Thalassoma hardwicke*	x	x
Labridae	*Thalassoma lutescens*	x	x
Labridae	*Thalassoma purpureum*		x
Labridae	*Thalassoma quiquevittatum*	x	x
Labridae	*Thalassoma trilobatum*		x
Lethrinidae	*Gnatodentex aureolineatus*	x	x
Lethrinidae	*Monotaxis grandoculis*	x	x
Lutjanidae	*Afareus furca*	x	x
Lutjanidae	*Lutjanus bohar*	x	x
Lutjanidae	*Macolor macularis*	x	
Lutjanidae	*Macolor niger*	x	x
Malacanthidae	*Malacanthus latovittatus*	x	x
Monacanthidae	*Aluterus scriptus*	x	
Monacanthidae	*Cantherhines dumerilii*	x	x
Monacanthidae	*Oxymonacanthus longirostris*	x	
Mullidae	*Parupeneus crassilabris*	x	x
Mullidae	*Parupeneus cyclostomus*	x	x
Mullidae	*Parupeneus multifasciatus*	x	x
Muraenidae	*Gymnothorax javanicus*	x	x
Muraenidae	*Rhinomuraena quaesita*	x	
Ostraciidae	*Ostracion meleagris*	x	x
Pempheridae	*Pempheris* sp.	x	x
Pinguipedidae	*Parapercis clathrata*	x	
Pomacanthidae	*Centropyge bispinosa*	x	x
Pomacanthidae	*Centropyge flavissima*	x	x
Pomacanthidae	*Centropyge heraldi*	x	x
Pomacanthidae	*Centropyge loriculus*	x	x
Pomacanthidae	*Pomacanthus imperator*	x	x
Pomacentridae	*Abdefduf septemfasciatus*		x
Pomacentridae	*Abdefduf sordidus*	x	x
Pomacentridae	*Amphiprion clarkii/chrysopterus*	x	
Pomacentridae	*Chromis acares*	x	x
Pomacentridae	*Chromis agilis*	x	x
Pomacentridae	*Chromis iomelas*	x	x
Pomacentridae	*Chromis margaritifer*	x	x
Pomacentridae	*Chromis vanderbilti*	x	x
Pomacentridae	*Chromis xanthura*	x	x

Family	Species	2016	2017
Pomacentridae	*Chrysiptera taupou*	x	x
Pomacentridae	*Dascyllus reticulatus*	x	x
Pomacentridae	*Dascyllus trimaculatus*	x	x
Pomacentridae	*Lepidozygus tapeinosoma*	x	x
Pomacentridae	*Plectroglyphidodon dickii*	x	x
Pomacentridae	*Plectroglyphidodon imparipennis*	x	x
Pomacentridae	*Plectroglyphidodon johnstonianus*	x	x
Pomacentridae	*Plectroglyphidodon lacrymatus*	x	x
Pomacentridae	*Plectroglyphidodon phoenixensis*	x	
Pomacentridae	*Pomacentrus vaiuli*	x	x
Pomacentridae	*Pomachromis fuscidorsalis*	x	x
Pomacentridae	*Stegastes albifasciatus*	x	x
Ptereleotridae	*Nemateleotris magnifica*	x	x
Ptereleotridae	*Ptereleotris evides*	x	
Scaridae	*Calotomus carolinus*	x	x
Scaridae	*Cetoscarus ocellatus*		x
Scaridae	*Chlorurus microrhinos*	x	x
Scaridae	*Chlorurus sordidus*		x
Scaridae	*Hyposcarus longiceps*		
Scaridae	*Scarus altipinnis*		x
Scaridae	*Scarus chameleon*	x	x
Scaridae	*Scarus forsteni*	x	x
Scaridae	*Scarus frenatus*	x	x
Scaridae	*Scarus globiceps*		x
Scaridae	*Scarus niger*	x	
Scaridae	*Scarus oviceps*	x	
Scaridae	*Scarus psittacus*		x
Scaridae	*Scarus rivulatus*		
Scaridae	*Scarus rubroviolaceus*	x	x
Scorpionidae	*Pterois volitans*		x
Serranidae	*Cephalopholis argus*	x	x
Serranidae	*Cephalopholis hexagonatus*	x	x
Serranidae	*Cephalopholis urodeta*	x	x
Serranidae	*Epinephelus polyphekadion*		x
Serranidae	*Gracilaria albomarginata*	x	x
Serranidae	*Plectropomus laevis*	x	x
Serranidae	*Pseudanthias olivaceus*	x	
Serranidae	*Pseudanthias pascalus*		x
Serranidae	*Variola louti*	x	x
Tetraodontidae	*Arothron meleagris*	x	x
Tetraodontidae	*Canthigaster amboinensis*	x	
Tetraodontidae	*Canthigaster solandri*	x	
Tetraodontidae	*Canthigaster valentini*	x	
Zanclidae	*Zanclus cornutus*	x	x

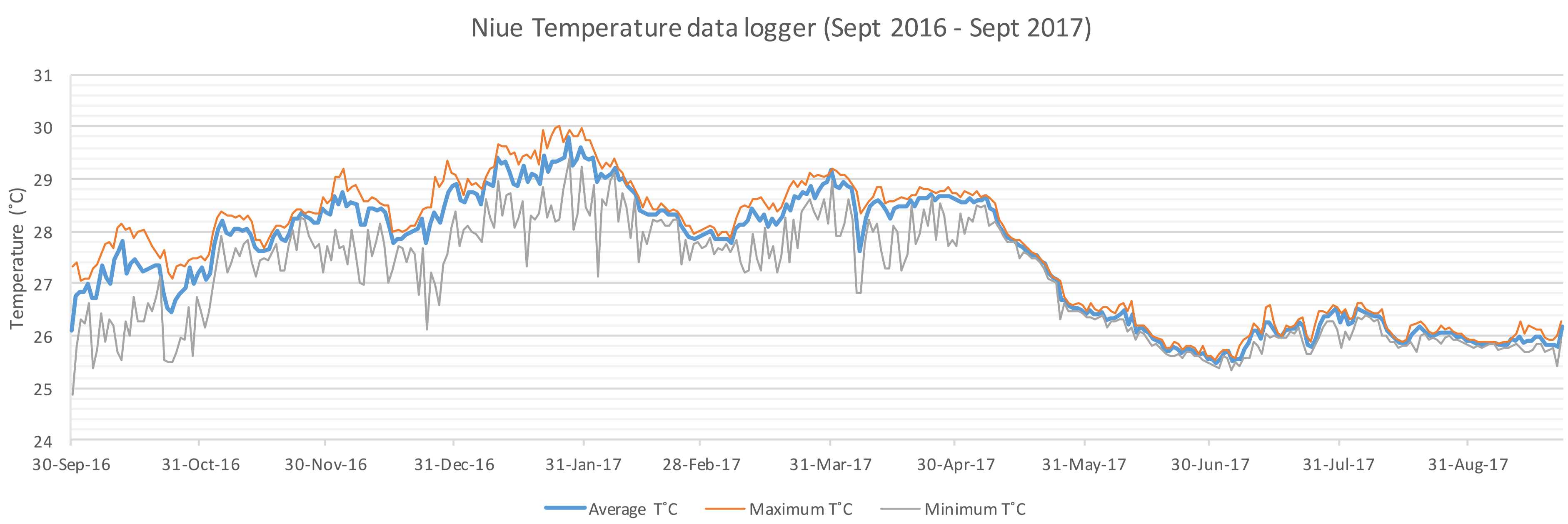
Appendix 9. Percent cover of substrate component by station.

Station	Live coral cover	Dead coral	Soft coral	Turf algae	macro algae	Coralline crustose algae	Rock/ pavement	Rubble	Sand	Sponge
1	27.20	2.00	0.00	9.60	19.20	6.00	32.80	0.80	2.00	0.40
3	12.15	2.02	0.00	2.02	6.48	12.96	58.30	0.40	5.67	0.00
4	6.00	0.00	0.00	11.60	10.00	9.60	57.60	0.40	3.60	1.20
5	19.18	1.22	0.00	3.67	13.06	8.57	48.98	0.82	4.49	0.00
11	8.80	1.20	0.00	6.00	8.00	6.00	58.80	1.20	10.00	0.00
18	12.10	0.00	0.00	2.02	26.61	28.23	27.42	0.81	2.82	0.00
19	26.40	3.20	1.60	0.80	28.80	10.80	24.40	0.00	4.00	0.00
22	12.85	0.80	0.00	4.82	17.27	5.62	54.22	0.00	4.02	0.40
26	31.85	3.23	0.00	2.42	27.02	2.82	27.82	1.21	3.23	0.40
30	11.60	0.00	0.00	4.00	27.60	2.40	50.40	0.00	4.00	0.00
38	6.00	0.40	0.40	7.20	10.00	6.40	51.20	1.60	16.80	0.00
44	3.20	0.40	0.00	16.40	18.80	9.20	50.80	0.40	0.80	0.00
46	17.27	0.80	0.00	7.63	24.50	3.61	42.57	0.00	2.41	1.20
48	8.91	0.40	0.00	10.12	27.53	4.45	39.27	0.40	8.50	0.40
49	37.60	0.80	0.00	3.60	16.40	1.60	36.40	0.80	2.40	0.40
50	11.24	1.20	2.01	0.80	20.08	15.66	44.18	1.61	3.21	0.00
Average	**15.77**	**1.11**	**0.25**	**5.79**	**18.83**	**8.37**	**44.07**	**0.65**	**4.87**	**0.28**
SE	**4.47**	**0.34**	**0.15**	**1.10**	**1.92**	**1.65**	**2.89**	**0.14**	**0.99**	**0.10**

Appendix 10. Percent cover of live coral by genus and station.

Station	Acanthastrea	Acropora	Astreopora	Cyphastrea	Echinphyllia	Favia	Favites	Fungia	Galaxea	Goniastrea	Leptastrea	Leptoria	Leptoseris	Lobophyllia	Millepora	Montastrea	Montipora	Nold	Pavona	Platygyra	Pocillopora	Porites-massive	Stylophora
1	0.00	22.40	0.40	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40	1.20	0.00	0.00
3	0.00	4.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	2.83	0.00	0.00	0.00	0.00	0.00	0.00	0.40	1.62	0.00	2.02	0.00	0.00
4	2.80	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.80	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.40	0.00
5	0.00	9.80	0.41	0.41	0.41	0.82	0.00	0.00	0.00	0.00	2.04	0.00	0.00	0.00	0.00	1.22	1.22	0.82	0.00	0.41	1.63	0.00	0.00
11	0.00	8.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00
18	0.00	6.85	0.81	0.00	0.00	0.81	0.40	0.00	0.40	0.00	0.00	0.40	0.00	0.00	0.81	0.40	0.00	0.00	0.00	0.00	0.00	1.21	0.00
19	0.00	17.20	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.80	0.80	1.20	0.00	0.00	0.40	0.00	0.80	0.80
22	0.00	7.63	0.00	0.00	0.00	2.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.81	0.00	0.40
26	0.40	28.23	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.02	0.00	0.00
30	0.00	7.20	0.80	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.40	0.00
38	0.00	3.20	0.40	0.00	0.00	0.40	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.40	0.00	0.00	0.00	0.40	0.00
44	0.00	1.60	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.40	0.00
46	0.00	12.85	1.20	0.00	0.00	0.80	0.00	0.40	0.00	0.40	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.40	0.40	0.40	0.00
48	0.00	8.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	0.00	35.20	0.40	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40	0.80
50	1.20	4.02	2.01	0.00	0.00	0.40	0.00	0.00	0.40	0.80	0.00	0.00	0.00	0.00	0.00	0.80	0.40	0.00	0.00	0.00	0.00	0.80	0.40
Average	**0.28**	**11.10**	**0.60**	**0.03**	**0.03**	**0.68**	**0.03**	**0.05**	**0.05**	**0.28**	**0.38**	**0.03**	**0.03**	**0.03**	**0.15**	**0.20**	**0.18**	**0.13**	**0.13**	**0.10**	**0.73**	**0.45**	**0.15**
SE	**0.19**	**2.48**	**0.16**	**0.03**	**0.03**	**0.19**	**0.03**	**0.03**	**0.03**	**0.08**	**0.21**	**0.03**	**0.03**	**0.03**	**0.08**	**0.10**	**0.10**	**0.06**	**0.10**	**0.04**	**0.23**	**0.16**	**0.07**

Appendix 11. Temperature data logger placed from the 30 September 2016 until 23 September 2017.



Appendix 12. Proposed methodology for future invertebrate and fish surveys in Niue.

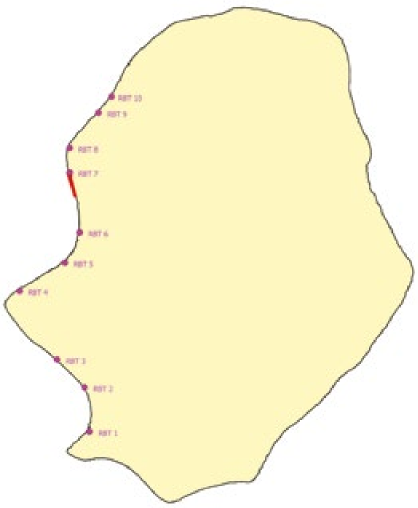
Invertebrates

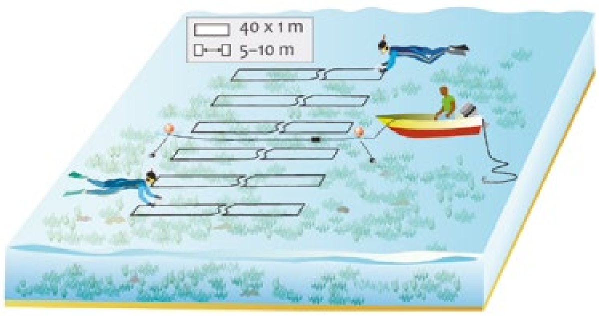
Apply the same methodologies as the 2016 and 2017 surveys (see the Methodology section in the main body of this report for more details) and repeat them at the same stations (Appendix 2).

Manta tow

- **1 station** → six 300-m (2-m swath) replicates – Use GPS odometer function to measure distance;
- **Minimum staff required**: 2 surveyors (1 GPS navigator + 1 underwater surveyor) + 1 boat captain;
- **Task**:
  - Attach the 25-m rope to the boat and manta board
  - Count targeted species
  - Conduct a brief assessment of the habitat at the end of each replicate tow
- **Equipment needed**:
  - 1 boat
  - 1 25-m, 12–16 mm diameter floating rope
  - 1 GPS
  - 1 manta tow board
  - datasheets (1 type for the boat and 1 type for the board) + pencils
  - 1 set of snorkelling equipment
  - 1 camera
- **Timing:**
  - Any time of the day, any tide
  - Avoid rainy periods, which can affect visibility
  - Avoid surveying in rough weather and sea conditions
  - Try to survey in September/October in order to match the survey period presented in this report
- **Duration:** ≈ 1 hour per station, up to 6 stations per day
- **Targeted invertebrates:**
  - All sea cucumber species (identified to species level)
  - Giant clams (Tridacna maxima and T. squamosa)
  - Large urchins (genus Diadema and Heterocentrotus)
  - Other macroinvertebrates size >10 cm (e.g. Lambis truncata)
- **12 stations to resurvey:** all but manta station 12 (too deep to survey accurately); manta 10 and 11 can only be done in calm weather;
- **New stations**: some new stations can be added, especially on the south and east coasts, depending on weather conditions, and reconnaissance is required to ensure the depth is appropriate.

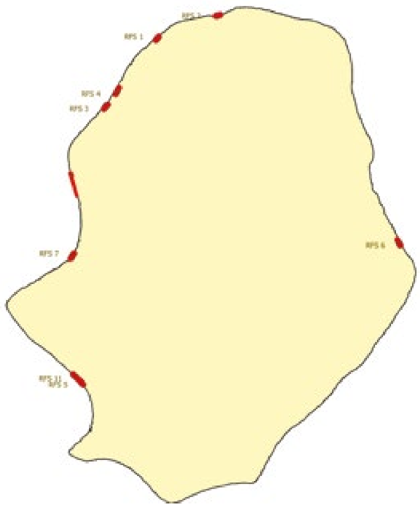
Reef benthos transect

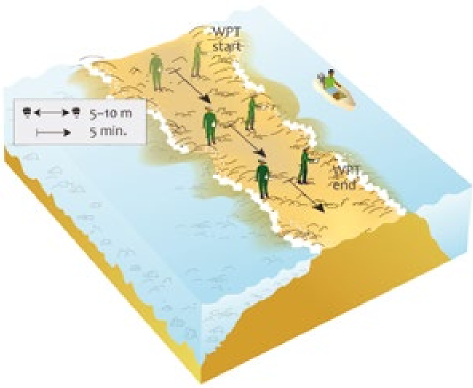




- **1 station** → six 40-m (1 m swath) replicates, perpendicular to the shore
- **Minimum staff required**: 2 surveyors (each surveyor completes three replicates for each station)
- **Task**:
  - Lay down 40-m reference rope with floats
  - Count targeted species
  - Measure targeted species in mm (excluding urchins), and try to measure as many specimens as possible
  - Conduct a brief assessment of the habitat at the end of each replicate
- **Equipment needed**:
  - 1 vehicle
  - 1 45-m rope with float or marker to deliniate the 40 m
  - 1 GPS
  - 2 writing slates with ruler
  - datasheets + pencil
  - a set of reef boots and snorkelling equipment for each surveyor
- **Timing**:
  - Around low tide (2 hours before and after)
  - Avoid rainy periods, which can affect visibility
  - Avoid surveying in rough weather and sea conditions
  - Try to survey in September/October in order to match the survey period presented in this report
- **Duration**: ≈ 1 hour/station; two to three stations can be surveyed in one day
- **Targeted Invertebrates**:
  - Molluscs (bivalves, gastropods, cephalopods) of local importance (see Table 4 in the main body of this report)
  - Echinoderms (all sea cucumbers, all urchins, and all sea stars)
- **10 stations to resurvey**: all
- **New stations**: some new stations can be added anywhere where the reef flat extends more than 40 m, but prior reconnaissance is recommended.

Reef front walk at night



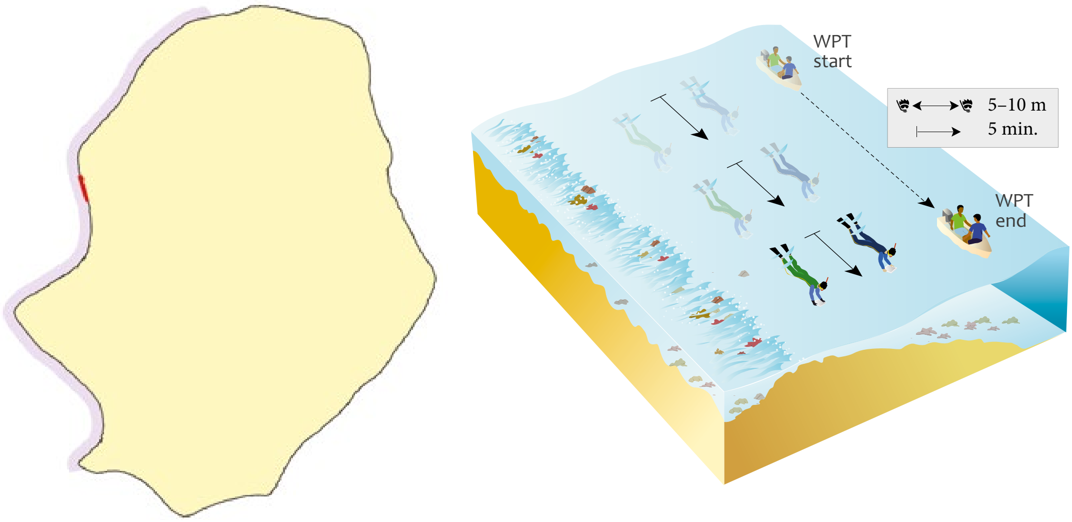


- **1 station** → six 5-minute walks (2–5 m swath);
- **Minimum staff required**: 2 surveyors (walking in parallel 20 m away from each other, along the reef crest) + 1 navigator (GPS and timing).
- **Task**:
    - Count targeted species
    - Measure targeted species in mm (excluding urchins), and try to measure as many specimens as possible
    - Conduct a brief assessment of the habitat at the end of each replicate

A bucket or bag can be used to collect invertebrates to be measured at the end of each replicate. All collected individuals must be released at the end of each transect.

- **Equipment needed**:
    - 1 GPS
    - 2 writing slates with ruler
    - 3 head torches + spare batteries
    - datasheets + pencil
    - a set of reef boots, snorkelling equipment and a torch for each surveyor
    - 1 camera
- **Timing**:
    - Start at least one hour after dark
    - Start about one hour after low tide
    - Avoid rainy period, which can affect visibility
    - Avoid surveying in rough weather and sea conditions
    - Try to survey in September/October in order to match the survey period presented in this report;
- **Duration**: ≈ 40 minutes/station; two to three stations can be surveyed in one night
- **Targeted invertebrates**:
    - Large molluscs (e.g. turban snail) size > 5 cm
    - Echinoderms (all sea cucumbers and large urchins)
    - Crustaceans of local importance (large crabs, slipper lobsters, and spiny lobsters)
- **8 stations to resurvey**: all
- **New stations**: some new stations can be added anywhere where the reef flat extends more than 40 m, but prior reconnaissance in daylight is required.

Reef front swims – night (optional)



- **1 station → six, 10-minute swim (5–10 m swath) in the shallows**
- **Minimum staff required: 2 surveyors (swimming in parallel 20 m away from each other along the reef crest) + 1 navigator (GPS, measurement and timing) + 1 boat captain**
- **Task:**
  - Count targeted species
  - Measure targeted species in mm (excluding urchins)
  - Conduct a brief assessment of the habitat at the end of each replicate

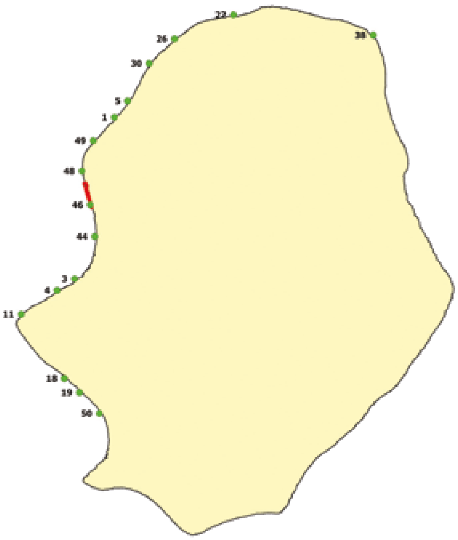
A bag can be used to collect invertebrates to be measured with the help of the boat surveyor at the end of each replicate or station. All collected individuals must be released at the end of each transect.

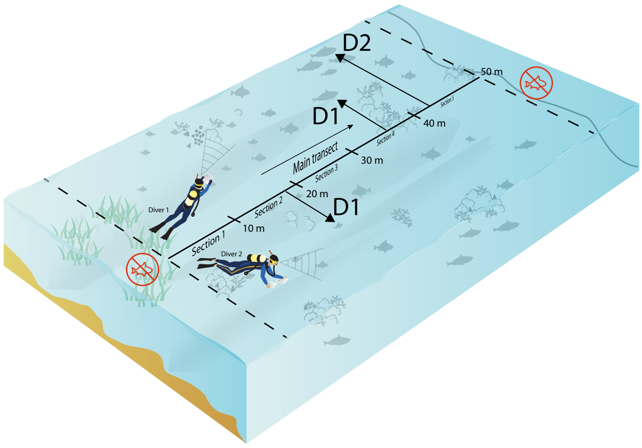
- **Equipment needed:**
  - 1 boat
  - 1 GPS
  - 2 writing slates (with ruler)
  - 2 dive torches + 1 head torch + spare batteries
  - datasheets + pencil
  - a set of reef boots, snorkelling equipment and a torch for each surveyor
  - 1 camera
- **Timing:**
  - At least one hour after dark
  - Survey can be done during a new moon or after the full moon period (before moon rise)
  - Avoid rainy periods, which can affect visibility
  - Weather should be very calm for this type of survey
- **Duration**: ≈ 45 minutes/station, only two to three stations can be surveyed in one night
- **Targeted invertebrates**:
  - Large crustaceans (large crabs, slipper lobsters and spiny lobsters)
  - Any large invertebrates with nocturnal behaviour
- **Stations to survey (new)**: stations are recommended to be restricted to the west coast.

Finfish

Apply the same methodology used in the 2017 Niue Marine Ecological Survey (see the Methodology section of this report for more details) and repeat them at the same stations (Appendix 2).

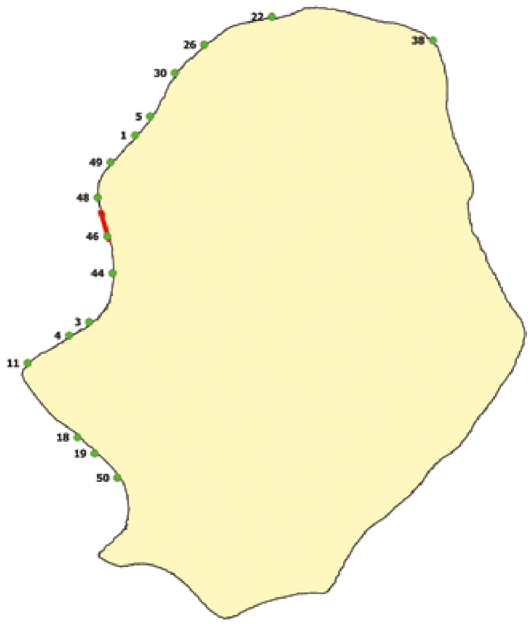
Fish transects





- **1 station** → 50-m-long transect X 10 m wide (5 m each side of the transect) at 10 m depth, and parallel to the reef crest
- **Minimum staff required**: 2 surveyors (one on each side of the transect) + 1 boat captain
- **Task**:
  - Lay down transect as you start the survey
  - Count and estimate the size of fish (using 5-cm size class) on the transect
  - Conduct a brief assessment of the habitat at the end of each replicate
  - Collect the transect tape
- **Equipment needed**:
  - 1 boat
  - 1 GPS
  - 2 writing slates
  - Datasheets + pencil
  - a set of diving equipment for each surveyor
  - 1 camera
- **Timing**:
  - Avoid rainy periods, which can affect visibility
  - Avoid surveying in rough weather and sea conditions
  - Try to survey in September/October in order to match the survey period presented in this report
- **Duration**: ≈ 1 hour/station; only two to three stations can be surveyed in one day due to diving constraints
- **Targeted fish**:
  - Commercial reef fish (see Table 2 in the main body of this report)
- **16 stations to resurvey**: all
- **New stations**: any extra stations from the 2005 PROCFish/C survey can be surveyed; try to survey the Avatele area, which was not surveyed in 2017

Fish swims (optional)

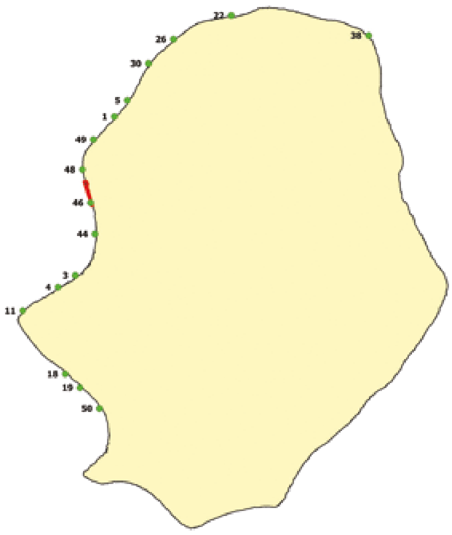


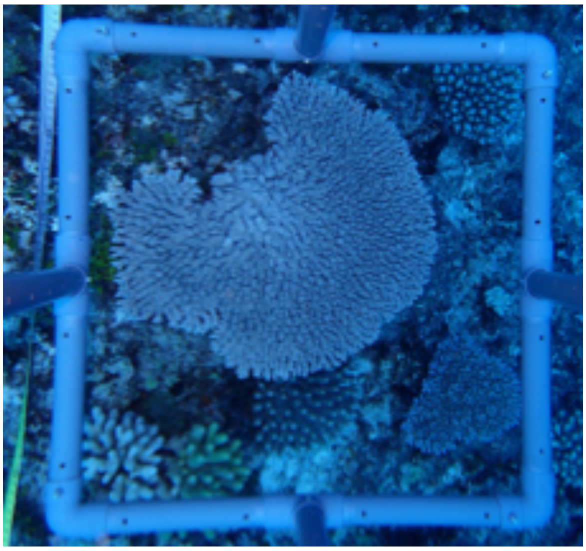
- **1 station Three, 10-minute swims along the reef slope at same stations as fish transects**
- **Minimum staff required: 1 surveyor + 1 boat captain**
- **Task:**
  - Tie a float with a GPS behind the surveyor
  - Count and estimate the size of large commercial fish species during the 10 minute swims
  - Conduct a brief assessment of the habitat at the end of each replicate
- **Equipment needed**:
  - 1 boat
  - 1 GPS
  - 1 float, with a GPS
  - 1 writing slate
  - datasheets + pencil
  - one set of snorkelling gear
  - 1 camera
- **Timing**:
  - Avoid rainy periods, which can affect visibility
- **Duration**: ≈ 40 minutes/station
- **Targeted fish**:
  - Large commercial reef fish species (see Table 2 in the main body of this report), such as emperorfish and snappers
- 16 stations to survey
- **New stations**: use any extra stations chosen for fish transects (from the 2005 PROCFish/C survey and Avatele area).

Supporting habitat

Apply the same methodology that was used in the 2017 Niue Marine Ecological Survey (see the Methodology section in the main body of this report for more details) and repeat them at the same stations (Appendix 2).

Photoquadrat





- **1 station** → 50 quadrats along a 50-m transect at 10-m depth, parallel to the reef crest (space quadrat every 1 m)
- **Minimum staff required**: 2 surveyors + 1 boat captain
- **Task**:
    - Lay down transect
    - One diver places the quadrat along the transect tape, one diver takes photographs (the bottom frame needs to be visible in each picture)
    - Take close-up photos of corals and macroalgae within the transect to help with coral identification
    - Collect the transect tape
    - Analyse quadrats (office work)
- **Equipment needed**:
    - 1 boat
    - 1 GPS
    - 1 transect tape
    - 1 frame quadrat
    - 1 camera
    - 2 sets of diving gear
- **Timing**:
    - Avoid rainy periods, which can affect visibility.
- **Duration**: ≈ 1 hour/station (when combined with finfish survey), only two to three stations can be surveyed in one day due to diving constraints
- **Recommendation**: place one stake at the beginning and end of each transect. Try to resurvey the same area during future surveys
- **16 stations to resurvey**: all
- **New stations**: any extra stations from the 2005 PROCFish/C survey can be surveyed, try to survey the Avatele area, which was not surveyed in 2017

Data entry, analysis, interpretation and reporting

Data entry

Data entry needs to be done in an appropriate database and format. SPC has designed a database that can be made available for use by the country. Databases used for the 2016–2017 surveys were:

- Invertebrates → Reef Fisheries Integrated Database (RFID)
- Fish → Reef Fisheries Integrated Database (RFID)
- Supporting habitats → SPC Coral Monitoring Portal, online access at: https://www.spc.int/CoastalFisheries/FieldSurveys/FieldSurveysHome

Analysis and reporting

Analysis and reporting could follow the same plan as this report, with specific items to be used by the different components:

- Invertebrates:
    - Richness
        - Species richness + comparison with prior survey
    - Relative abundance
        - General group composition by method
    - Densities
        - By species per method
        - Comparison with previous surveys
        - Map by species or group of species
    - Size structure
        - By species of local importance where enough measurements are available
- Fish:
    - Richness
    - Density and biomass, all stations pooled
        - By family,
        - By diet
        - By species (selection of species)
        - Comparisons with previous surveys
    - Density and Biomass , by station using maps
        - Selection by families or any other valuable variable
- Supporting habitat:
    - Percent cover
        - All components, all stations pooled
        - All components, by station (as a map)
    - Coral diversity
        - To genus level, all stations pooled
    - Algae diversity
        - To genus level, all stations pooled

Adaptability

Considering the reduced number of staff that may be available in Niue and funding constraints, narrowing down the number of stations (to one-third or a half) of each survey method could be a solution to allow more frequent resurveying. Another option would be to select certain in-water survey methods as described in Appendix 12 that capture the main species of interest for Niue.

Appendix 13. Proposed community-based monitoring activities

Identify the top 10 species of importance to each community

- Conduct small workshops in each village
    - Provide workshop participants with tools (such as pictures for species identification, paper pads, etc.) to record the species of highest value (both finfish and invertebrates) within their community
    - Record all local names for specific species

Monitoring community catch of the top 10 species

- Measure catch and effort
    - Once species of high value have been identified by a community, propose that the community monitor their catches. Information to collect include date, fishing location, type of fishing method, catch by species, length and/or weight of individual specimens
    - Regular visit from the administration that initiated community consultations + collection of data
    - Provide tool (scales, measuring board, if needed)
    - Develop visual tools that help the community to visualise summaries of the information collected

Identify spawning periods of targeted fish

- Members of communities have valuable information on species biology that can be useful for management discussions
    - Encourage communities to identify and provide information on their fishing grounds:
        - Spawning periods or areas of fish (and crustacean, if meaningful) that area valuable to the community
        - Identify recruitment seasons of species of interest
        - Include any other biological aspect of species that have an importance to Niueans (e.g. migration)

Monitor impact of disturbances through observations

- Provide the community with an opportunity to provide information following disturbances
    - Identification of a disturbance:
        - Disturbance can be identified by the community based on their day-to-day observations;
        - Contact communities when a disturbance occurs (e.g. information made available by local media, National Oceanic and Atmospheric Administration coral reef watch bleaching alerts (www.coralreefwatch.noaa.gov)
    - Provide each community with tools (pictures of invertebrates, basic datasheet) they can use for their reporting
    - If necessary, conduct small presentations with community members at the start of an event to explain possible consequences and what communities should keep an eye out for
    - Provide a system of two-way feedback, collect information from all communities and present them back to the communities.