RAPID BIODIVERSITY ASSESSMENT OF REPUBLIC OF NAURU

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The Pacific environment, sustaining our livelihoods and natural heritage in harmony with our cultures.

RAPID BIODIVERSITY ASSESSMENT OF REPUBLIC OF NAURU

SHEILA A. MCKENNA, DAVID J. BUTLER,
AND AMANDA WHEATLEY (EDITORS)

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ORGANISATIONAL PROFILES

BIRDLIFE PACIFIC PARTNERSHIP

BirdLife International is a global network of 117 national NGOs (Partners) – including seven in the Pacific - whose mission is "to conserve wild birds, their habitats and global biodiversity, working with people towards sustainability in the use of natural resources".

The BirdLife Partnership is supported by a Secretariat with headquarters in Cambridge, UK. A regional supporting Secretariat for the Pacific Partnership is based in Fiji, and includes a 'BirdLife Fiji Programme'. BirdLife's Pacific Partners are in Australia, Cook Islands, French Polynesia, New Caledonia, New Zealand, Palau and Samoa with a country programme managed by the Pacific Secretariat in Fiji.

For more information visit: http://www.birdlife.org

CONSERVATION INTERNATIONAL PACIFIC ISLANDS PROGRAM

The focus of the Conservation International Pacific Islands Program is to provide for the development of sustainable societies by the people of the Pacific Islands, through the preservation of natural capital and adaptation to climate change. CI's Pacific Islands Program covers 20 - 30,000 islands in the 22 countries and territories which make up the Polynesia-Micronesia and New Caledonia Biodiversity Hotspots, and Papua New Guinea. The total oceanic coverage of the program is around 40 million sq km (more than four times the size of the continental United States). The Pacific Islands Program is the only regional program within CI's Asia-Pacific Field Division. It consists of three sub-country/territory programs with linked national strategies for Fiji, Papua New Guinea and New Caledonia, and a regional Pacific Oceanscape field program.

For more information visit http://www.conservation.org/Pages/default.aspx

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The New Zealand Department of Conservation works nationally conserving natural and historic heritage and recreational opportunities on public conservation lands including national parks, world heritage areas, much mountain land and many islands along with some marine protected areas. The department has an official role advocating protection of wildlife including for example birds, freshwater and marine life. Active Maori relationships with natural heritage are respected under the principles of the Treaty of Waitangi. The Department partners many agencies and organisations in its work and provides some capacity to cooperate internationally in work such as pest eradication from islands and technical support for conservation management such as this BIORAP.

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SPREP's activities are guided by its Strategic Action Plan 2011-2015, which was developed through extensive consultations with Members, Secretariat programme staff and partner organisations. The Plan establishes four strategic priorities, which form the basis and focus of SPREP's work: Climate Change; Biodiversity and Ecosystem Management; Waste Management and Pollution Control; and Environmental Monitoring and Governance. SPREP is actively engaged as a partner in many environmental management and conservation projects in the region such as this biodiversity assessment of Upland Savai'i.

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As the United States' largest water, earth, and biological science and civilian mapping agency, the USGS collects, monitors, analyses, and provides scientific understanding about natural resource conditions, issues, and problems. The diversity of our scientific expertise enables us to carry out large-scale, multi-disciplinary investigations and provide impartial scientific information to resource managers, planners, and other customers at home and overseas.

For more information visit: http://www.usgs.gov/

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The Department of Commerce, Industries and Environment is the Nauruan government agency mandated to coordinate the planning and implementation of its national development and environmental policies. Its environmental work started formally with the development of a National Environment Strategy in the mid-90's which was followed by specific policies for selected environmental components mainly climate change, biodiversity, land degradation and droughts, water, hazardous chemicals, waste and pollution.

In addition it is the national environmental policy and technical focal point of the government to regional and international organizations and secretariats of Multinational Environmental Agreements and represents the government's environmental programs to the country's district communities and civil society organizations. It currently has national environmental programs and projects for: adaptation to climate change; biodiversity conservation; sustainable land management and water resources management.

For more information visit: http://www.naurugov.nr/

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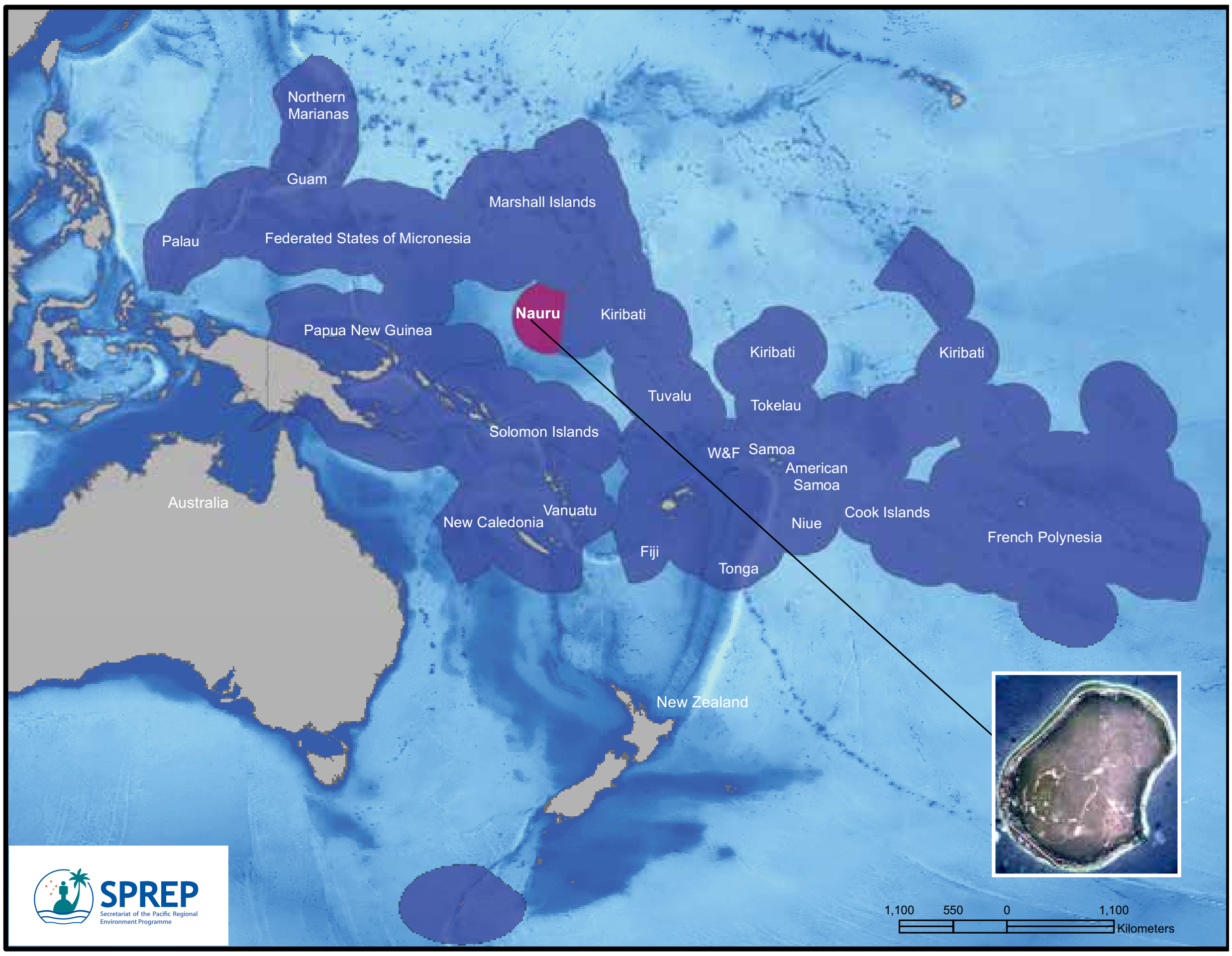
The BIORAP was designed and planned by the Secretariat of the Pacific Regional Environment Programme (SPREP), the Government of Nauru – Department of Commerce, Industries and Environment (DCIE) and Conservation International Pacific Islands Programme. The Secretary of DCIE was a key supporter as was Asterio Appi IIBP Coordinator.

Important Republic of Nauru (RON) partners included Nauru Rehabilitation Corporation (NRC), Nauru Island Association for Non-Government Organisations (NIANGO), Republic of Nauru Phosphate (RONPOS) and the University of the South Pacific (USP).

Key logistical associates included: Bruce Jefferies, Paul Anderson, Posa Skelton, and Easter Galuvao (SPREP). We also sincerely thank the following organisations who provided technical expertise to the BIORAP; New Zealand Department of Conservation, Birdlife International – Pacific Islands Programme, United States Geological Survey, Nauru Fisheries & Marine Resources Authority, Government of Samoa – Ministry of Natural Resources and Environment, Conservation International - Pacific Islands and Oceans Program.

The Nauru BIORAP was a success due to the outstanding contribution made by the following individuals most of whom are affiliated to the above institutions. Erana Aliklik, Asterio Appi, Adam R. Backlin, Timex Dabwido, Jali Baeden, Ransome Olsson, Jake Debao, O'Brien Aboubo, B'Jorn Detageowa, Jon Bill, Gideon Teabuge, Noah Teleni, Shasta Bill, Kay Brechtefeld, Mason Dick, Stella Daburiya, Shorona Ephraim, Eric Edwards, David Feary, Douglas Fenner, Fialelei Enoka, Robert N. Fisher, Maël Imirizaldu, Bruce Jefferies, Micah Jeremiah, Delvin Thoma, Sheila A. McKenna, Posa Skelton, Rebecca Stirnemann, Randy Thaman, Schannel van Dijken, Art Whistler.



FOREWORD

This report presents the results and recommendations of a rapid biodiversity assessment survey (BIORAP) carried out in the marine and terrestrial environments of the Republic of Nauru (June 17-27, 2013). Nauru lies within the Polynesia-Micronesia Biodiversity Hotspot defined by Conservation International that includes all the islands of Micronesia, Polynesia and Fiji. The overall purpose of the Nauru BIORAP was to improve the state of knowledge of marine and terrestrial ecosystems which, in turn, could be applied to provide a scientific basis for the conservation and management of nationally, regionally and globally important ecosystems and biodiversity, including threatened species. A particular focus of the BIORAP process was to identify areas of conservation value and to investigate opportunities for establishing marine and terrestrial protected areas.

This BIORAP was one of the activities for Nauru in the sub-regional project "*Implementing the Island Biodiversity Programme of Work by Integrating the Conservation Management of Island Biodiversity*" which is funded under the Global Environment Facility programme "Pacific Alliance for Sustainability" (fourth replenishment funding round). Other countries included in the project are Tonga, Cook Islands and Tuvalu. The United Nations Environment Programme (UNEP) and the Secretariat of the Pacific Regional Environment Programme (SPREP) are the Implementing and Executing Agencies respectively for this project.

Successful implementation of the BIORAP was made possible by establishing a strong partnership between the SPREP, the Government of Nauru Department of Commerce, Industries and Environment (DCIE) and the Conservation International Pacific Islands Programme. Partnership with local resource-owning communities which claim stewardship and ownership rights of much of the land and marine areas was also critical to BIORAP implementation. This partnership enabled a team of more than 19 specialists from a diverse range of institutions including Isle Botanica, New Zealand Department of Conservation, Samoa Ministry of Natural Resources and Environment, BirdLife International Pacific Programme, Massey University, U.S. Geological Survey, and Conservation International to work alongside government staff and civil society participants, including customary resource owners, to successfully complete the survey.

The challenge that faces the Government of the Republic of Nauru is to ensure that the outcomes of the BIORAP survey along with the recommendations put forward from globally, regionally and nationally recognised experts are translated into positive on-the-ground (and sea) action. Both SPREP and the Nauru DCIE believe this is key for future activities that will need serious commitment from other interventions and funding sources.

The findings of this BIORAP survey have identified or re-confirmed the critical importance of the biodiversity and ecosystems of Nauru's terrestrial and marine environments and the urgent need for follow-up activities to manage and mitigate threats for their conservation. This report provides a useful and pragmatic series of conclusions and recommendations that provide practical guidelines for the development of such follow-up activities to support and inform national planning processes such as the Nauru State of Environment Plan, and the review of the National Biodiversity Strategy and Action Plan.

We commend all of the individuals and organisations that collaborated to carry out the field survey work and who contributed to this report.

SPREP and the Government of Nauru are committed to continue to work together to ensure areas of significant biodiversity and ecosystem value are established, well managed and protected for the long-term.

Signed:

Mr Elkoga Gadabu
Secretary
Department of Commerce Industries and Environment
Government Buildings
Republic of Nauru

David Sheppard
Director-General
Secretariat for the Pacific Regional Environment Programme

EXECUTIVE SUMMARY AND SYNTHESIS

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Background

The Republic of Nauru, one of the world's smallest independent nations, is located approximately 50 kilometers south of the equator at the geographical coordinates 0°31'S and 166°56'E, and is one of the most unique by being a single raised phosphatic island with a maximum elevation of 71 m. The island is approximately 6 kilometers long by 4 kilometers wide with a land area of only 21 square kilometers. The Nauru volcanic base was presumably constructed by hotspot volcanism during the mid-Eocene to Oligocene period (29 to 47 Ma). It is estimated that the seamount is capped by about 500 meters of limestone, with uplift and sub-aerial exposure of the carbonate platform during the Pleistocene, 1.6 Ma (Jacobsen et al. 1997).

The majority of the land (70%) is utilized for phosphate mining. The remaining 30% of the land area is used for domestic, commercial, industrial and government purposes, with the international airport occupying a significant proportion of the island. A lack of land for urban development and an unsecured ground water supply are serious issues for Nauru. The lack of land is further exacerbated by the rise in population from 9,919 (1992 statistics) to 10,084 in 2011 (Nauru Bureau of Statistics).

Several plant communities can be distinguished on Nauru, but since the landscape has been so severely disturbed by mining, only remnants of these remain. Any forest is now largely confined to the coastal escarpment (Figure 1) with a few fragments in the interior, and much of the island is now covered with a secondary shrub community in areas where mining has ceased.

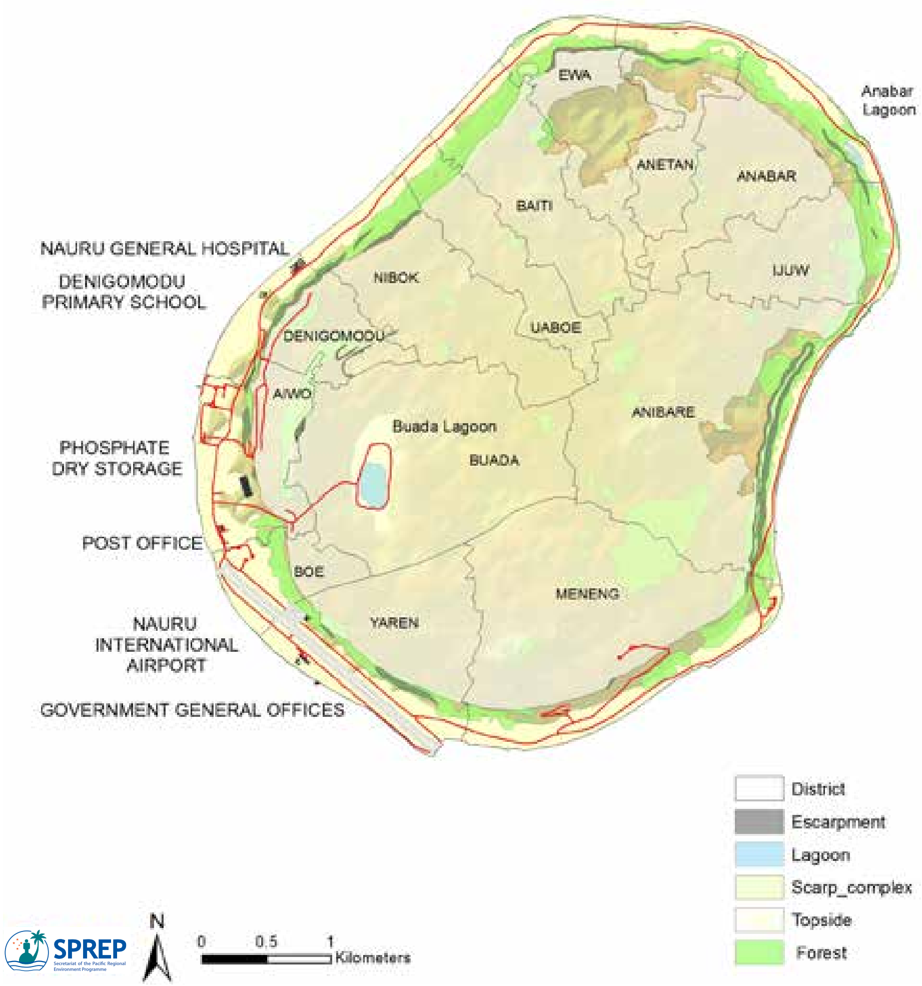

Figure 1. Districts and land forms of Nauru.

Nauru is located in the dry belt of the equatorial oceanic zone, with diurnal temperatures ranging from 26 degrees Celsius to 35 degrees Celsius, and night temperatures between 22 to 34 degrees Celsius. Annual rainfall is extremely variable, averaging 2126 millimeters per year, with a range of 280 to 4590 millimeters. Rains are more frequent between December and April. Prolonged droughts are common and cause severe stress on native ecosystems and species.

During the drier months of May to November, the prevailing wind direction is generally easterly at 5 to10 knots. During the wetter months, the winds are generally from the west at 10 to18 knots. Nauru does not experience tropical cyclones, although it is occasionally subject to strong winds and sea squalls. The only significant freshwater resource is a lens of often slightly brackish water hydrostatically 'floating' on high density sea water.

The country's small size, limited habitat diversity and physical isolation from other land masses has resulted in a low species richness compared with less isolated lands and shallow marine areas. However, the presence of distinctive assemblages of species and the provision of a haven for oceanic travelling marine and terrestrial biota are defining characters. There are only some 60 recorded indigenous species of vascular plants and although these constitute only approximately 16.5% of the total species, they are amongst the most culturally useful and ecologically important. Regenerated vegetation covers 63% of Nauru's land area. Nauru's main indigenous land animals are birds, lizards and invertebrates including land crabs. There are no indigenous land mammals. Nauru is surrounded by a fringing coral reef some 20 to 300 meters wide. This drops sharply on the seaward edge at an angle of 40 degrees to a depth of about 4000 meters. Nauru's 200 nautical mile Exclusive Economic Zone covers an area of approximately 320,000 kilometers square.

Purpose

The purpose of the Nauru BIORAP was to improve the state of knowledge of marine and terrestrial ecosystems, to provide a scientific basis for the conservation and management of nationally, regionally and globally important ecosystems and species. A particular focus was to identify areas of conservation value and to investigate opportunities for establishing marine and terrestrial protected areas. A fundamental principle is that decision-making should rest with resource owners and communities. The BIORAP provided opportunities for community members and Government staff to participate and receive training from the expert team.

Key findings – terrestrial

VEGETATION AND PLANTS

Seven plant communities were recognized: littoral strand; limestone forest; mangrove forest; freshwater marsh; managed land vegetation; secondary scrub; and secondary forest; and native plants still dominate most habitats. The majority of the island is covered in a secondary scrub community and very little native forest was found.

Nauru's flora comprises about 56 native species (no endemics) and only 42 were located during the survey. Most of the other 14 species are likely to be extinct, or on the verge of extinction. The remaining native species are considered of critical importance ecologically and culturally.

About 125 introduced species are known from Nauru and most were found during the survey. They include food plants such as coconut, breadfruit, pandanus and banana cultivars, many of which are endangered and are pivotal to food security on Nauru. Some of the introduced species are invasive weeds of which the red-bead tree *Adenanthera pavonina* is the most damaging, dominating some areas and preventing colonization by native species. Several new weed species were recorded include *Boerhavia coccinea* (Nyctaginaceae), *Acalypha indica* (Euphorbiaceae), *Ruellia tuberosa* (Acanthaceae), *Digitaria fuscescens* (Poaceae), and an unidentified species of grass, possibly *Dichanthium* sp. (Poaceae).

INVERTEBRATES

This was the first broad survey of Nauru's insect fauna. New records of moths, land snails and ants were reported, adding at least a second endemic species (a new moth) to the already known endemic Nauru tidal rock bug.

Moth richness was low and only 51 species (46 new records for Nauru) were detected but a reasonable richness of 19 moth families was recorded. Eleven out of 13 land snail species known from Nauru were located. Out of the three endemic land snail species, two may possibly be extinct as one was not found during the survey and another only represented by a single old empty shell.

Forty percent of both the moth and land snail fauna is native and 100% (all six) dragonflies are native. All 17 ant species recorded were exotic, including the highly destructive yellow crazy ant *Anoplolepis gracilipes* which was only detected at the port suggesting a recent incursion that could be eradicated.

Despite the strong representation of exotic moths, ants and snails, many of the most damaging pests present elsewhere in Micronesia have not yet arrived on Nauru, providing the opportunity to prevent the scale of biodiversity losses seen on the other pacific island, such as the Mariana Islands for example.

REPTILES

The reptile community appears intact despite major habitat alteration. A total of seven species of reptiles were detected including two species of ground skinks, four species of gecko (one of these invasive), and one snake species (invasive). Molecular data indicate that the Micronesian Black Skink *Emoia arnoensis nauru* is an undescribed species of *Emoia* that is not closely related to *E. a. arnoensis* from Micronesia.

BIRDS

Nauru contains only a moderate number of bird species, but these include significant populations of seabirds that are important from a biodiversity perspective, and also culturally as a traditional food.

A total of 36 bird species were recorded including two new records of seabirds. The endemic Nauru reed warbler (*Acrocephalus rehsei*) was found to be common over most of the island except for recently mined areas. The Micronesian pigeon (*Ducula oceanica*) exists on Nauru in very small numbers. Surveys of the black (*Anous minutus*) and brown noddy (*A. stolidus*) indicate that they are being harvested faster than they can breed.

Key findings – marine

CORAL REEFS

Nauru has many reefs with among the highest percentage cover by corals on the planet, and they are exceptionally healthy. No evidence of coral bleaching was seen and no outbreaks of the coral-eating crown of thorns starfish (*Acanthaster plancii*) recorded. The reefs contain globally significant species threatened with extinction including the humphead wrasse (*Chelinus undulates*), and many coral, fish and sea turtle species.

The reefs of Nauru have a low diversity of hard corals, though seven species were recorded that represented extensions of their known biogeographic range. All sites except one were heavily dominated by a single species of coral, *Porites rus*. There were five species of Acropora observed and colonies were rare. Acropora was reported to be more common in the past.

One coral species found *Pocillopora fungiformis*, was previously only known from one site in Madagascar. It is listed as Endangered (IUCN) and as one of the top 50 "EDGE" (Evolutionarily Distinct & Globally Endangered) coral species in the world. Three other threatened coral species were recorded.

INTERTIDAL REEF FLATS

The intertidal reef flat is fairly narrow with no lagoon and only a few shallow tidal pools. Algae (seaweeds) are the dominant organisms on the flats with 20 new species records for Nauru identified. Coral communities were rare. Introduced marine species associated with the fouling of wharves and ports were common including the bearded fire-worm (*Hermodice carunculata*) which has venom in its bristles that can cause a burning sensation.

INVERTEBRATES

The reefs of Nauru have a relatively low number of marine invertebrates. The total number of non-cryptic invertebrate species identified in this study was 79, representing 43 families, and including 41 new records for the country.

The invertebrate fauna is dominated by sea urchins (Diadematidae), molluscs (Muricidae), sea cucumbers (Holothuridae) and crabs (Trapeziidae). Soft corals were documented for the first time in Nauru.

Two giant clams (*Tridacna maxima*) known locally as "earinbawo" *were* found during the BIORAP. This was an important re-discovery as the species had previously been thought to be locally extinct as they had not been recorded since the 1980s.

There was limited diversity and number of marine invertebrates that are targeted for harvesting. Only five species of sea cucumber were observed and in very low densities. Very few *Turbo* spp were found and no *Trochus* despite suitable habitat being available, which warrants further assessment as it may suggest over-exploitation.

FISH

Nauru has a relatively depauperate reef fish fauna, consisting of at least 407 species of which 231 (56%) were observed during the BIORAP including many new species records for Nauru.

The reef fish fauna within Nauru is dominated by Labridae (34 spp), Pomacentridae (30 species), Acanthuridae (21 spp), Chaetodontidae (21 spp), Balistidae (12 spp), Serranidae (11 spp) and Scaridae (10 spp). Mobile invertebrate feeders were the most common group (23.8%), while plankton eaters (19.2%), those with a diet of both invertebrates and fishes (12.8%) and fish eaters (10.3%) were also relatively diverse.

Although the abundance of the reef fish fauna within Nauruan reefs was high relative to other nations, there were significant signs of overfishing. Several usually common groups of fish were under-represented, and the overall fish community structure was unbalanced with a high proportion of herbivorous species and a very low proportion of predators. There was a lack of large sized fishes like groupers and snappers. For five species most individuals were below the size at which they could breed, which was of concern. Whitetip reef sharks (*Triaenodon obesus*) were abundant at almost all sites.

Few early life stages were observed for the majority of reef fishes suggesting that the reefs may be distinctly isolated from source habitats.

Key Conservation Recommendations

Life in Nauru supported by Nature – Act now to secure the future

Focusing on the conservation of Nauru's plant and animal resources would have significant benefits for long-term food security, health, and the economy. There are a range of actions that are recommended as priorities to be addressed by stakeholders and communities. Further recommendations are included in the individual chapters.

SPECIES AND HABITAT CONSERVATION

- Conserve and manage key priority sites to protect the full range of Nauru's terrestrial and marine biodiversity. Eight sites together with scattered coastal trees are identified in detail in the following section.
- Develop a list of threatened, rare or endangered plants on Nauru. Protect nine locally rare plants (see Chapter 1).
- Carry out replanting programmes using rare and endangered trees that are culturally-useful to provide coastal protection and serve as a basis for food and livelihood security. Ensure that planting programmes include *Pisonia*, which is a cultural icon and critical to maintaining the number of noddies which use it for nesting.
- Review replanting plans for rehabilitation of mined land to maximize utilization of native species.
- Develop protected areas for the endemic Nauru skink species to establish long-term preservation of the species.
- Conduct a study of basic biology of the vulnerable endemic Nauru reed warbler.
- Seek advice to address the industrial light pollution that negatively impacts on bird and insect populations.
- Identify and protect fish breeding and spawning aggregation sites.
- Institute seasonal or temporary closures in sites known for fish spawning or nurseries, and bird breeding, during the relevant time period.
- Establish a system of village reserves and nurseries, including household gardens, alongside the conservation of key sites.

MONITORING AND ASSESSMENT

- Work with communities to undertake monitoring of their natural resources.
- Regularly monitor size trends of finfish and catches of targeted fish species.
- Carry out further stock assessments of targeted macro-invertebrates, e.g. lobsters, sea cucumbers, crabs and *Trochus* and *Turbo* spp. to allow management programmes to be put in place to ensure the sustainability of harvesting.

- Establish yearly monitoring of coral reef health.
- Monitor roosting noddy numbers and collect catch data to ensure a sustainable harvest.
- Undertake regular monitoring of rare or endangered species every few years, including sea turtles, seabirds, whales and dolphins around Nauru to confirm presence and population status

INVASIVE SPECIES

- Develop a National Invasive Species Strategy and Action Plan including a prioritized list of species for targeted control within priority areas, and listing those that are threats for future incursions.
- Develop and implement a national border biosecurity programme to protect Nauru from the introduction of invasive plants and animals. Elsewhere, this has proven of significant benefit for biodiversity, food production, economy and health.
- Immediately take action to eradicate/and or manage the yellow crazy ant, a serious pest species recently detected at the port. Carry out a targeted survey for this species and identify management options.
- Investigate options for and initiate the control of the red-bead tree which severely restricts the return of native forest.
- Carry out further quantitative surveys for marine invasive species for the districts of Aiwo, Meneng and Anibare.

GOVERNANCE

- Develop legislation to protect the listed rare and endangered plant and animal species.
- Reduce fishing pressure and encourage best practices by establishing regulations to:
  - Restrict or regulate fishing gear
  - Set minimum size limits for some fish landings.
- Consider signing international conventions including the *Convention on International Trade in Endangered Species* (CITES) and the *Convention of Migratory Species* (CMS).
- Work with communities to develop legislation to manage and sustainably utilise the marine and terrestrial resources of Nauru.
  - Update and enact the draft Marine Conservation Bill.
  - Explore how resource ownership is defined in local culture and the legal framework, and how that could inform quotas, catch shares or harvest permits.
  - Ban spearfishing with SCUBA.
- Ensure compliance with new regulations and laws – checking and imposing consequences for non-compliance.

AWARENESS, EDUCATION AND TRADITIONAL KNOWLEDGE

It is important to work with local communities, especially those having ownership over land or marine resources, as well as developing constructive relationships with other land managers including the mining company and immigration centre.

- Provide training to help improve knowledge on conservation issues and effective strategies to aid protection of key resources that are crucial to biodiversity. This includes:
  - Border biosecurity at the port and airport and the risks and impacts of introducing invasive species.
  - Notifying landowners of the presence of native, rare or endangered plants and encourage them to protect and conserve these species.
  - Development of school curriculum materials on Nauru's important plants, animals and ecosystems.
- Rejuvenate and strengthen traditional environmental knowledge governing resource use that were once an integral part of Nauruan's connection to the land and sea.
- Develop a public awareness campaign on the importance of healthy ecosystems. Nauru has acute water and soil problems and solving these can bring a lot of benefits. Nauru has unique heritage in seabird roosting and reef associations and cherishing and enhancing these are a tremendous benefit strengthening national identity.
- Develop community awareness of noddy population dynamics and encourage a reduction in harvesting to ensure the populations survival for future generations.

Key sites for protecting Nauru's biodiversity

Priority sites for protection and management should be those showing the least disturbance, the highest species richness, the greatest numbers of rare or endangered species, and the most value as wildlife habitat.

Particular emphasis is placed on sites and species that are important as a food source including fish and other marine species, and noddy rookeries. Special consideration should also be given to those areas containing culturally important and useful plants such as coconut and pandanus groves, the remaining coastal strand and escarpment forest, and mangroves. It is also important that local communities (resource users and owners) are involved in the planning, implementation, monitoring, planting and maintenance of these areas.

While many areas on and around Nauru retain indigenous natural values, a total of eight areas and a scatter of near extinct coastal trees are being recommended as priorities for conservation action (see Figure 2). These include five terrestrial areas (Proposed Conservation Areas – PCAs) and three marine areas (Proposed Marine Management Areas – PMMAs). Local knowledge, historical reports and the findings from this BIORAP, underpin the recommendations for key conservation and management areas. The proposed areas are:

- possibly the minimum that is required to sustain very ancient but presently depleted and declining marine and terrestrial ecosystems;
- intended to compliment each other;
- intended to be inclusive of originally representative species patterns and habitats that define Nauru as distinct from other island ecosystems;
- designed to integrate habitat sequences and to be able to sustain coral, plant or animal populations within their boundaries.

They also:

- recognise that many birds, fishes and marine species travel vast distances and depend on these areas. This is a defining ecosystem feature for Nauru;
- recognise that the lack of early life stages for the majority of reef fishes observed during this survey suggests that Nauruan reefs may be distinctly isolated from source habitats, diminishing their resilience from any disturbance events;
- have multiple use areas and are sometimes where people may live or use them regularly. This will continue but with the insight that these areas have a special character and set of resources that are currently threatened and need to be sustained for future generations.

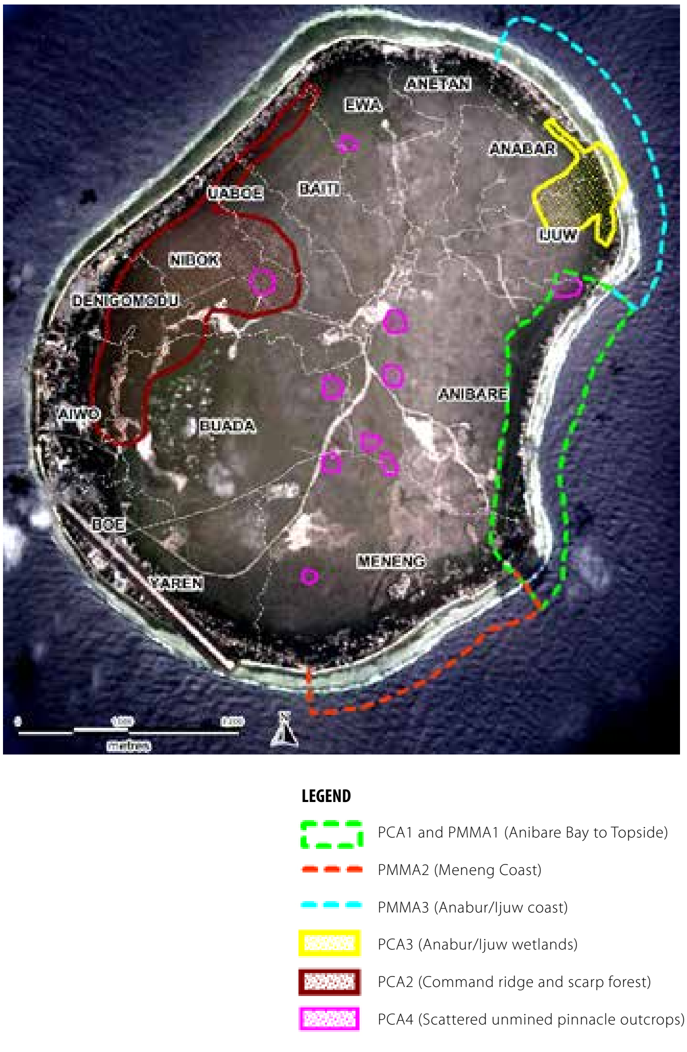

Figure 2. Priority terrestrial and marine sites for conservation.

PROPOSED CONSERVATION AREA 1 (PCA1) ANIBARE BAY

The landward part of a highly representative ocean to 'Topside' sequence. This includes coastal plain pinnacles and forests where rare trees and a newly discovered micro-moth are found. The Anibare escarpment bluffs are important for taller vegetation and bird roosts. On the 'Topside' margin are rare areas of un-mined shallow phosphate soils and original un-mined pinnacles that are critical for seabird breeding and undisturbed deeper soil ecosystems. A suite of lizard, Micronesian pigeon and Itsirir (Nauru reed warbler) habitats are also incorporated.

PROPOSED MARINE MANAGEMENT AREA 1 (PMMA1) ANIBARE BAY

The reef flat here is where the 're-discovered' giant clam is found and the emerging pinnacles are habitat for Nauru's endemic bug. Although there were signs of heavy fish harvesting, the fish community was better balanced at this site. All marine areas recommended should encompass the beach to the open ocean to a minimum of 100 metres beyond the reef edge.

(PMMA2) MENENG REEF FLATS AND OCEAN FRONT

This site combines with, and complements, the near shore environments of the adjacent Anibare Bay and northern Ijuw/Anabar marine areas. In addition to the reef flat, this area includes a comparatively high number of coral and fish species observed on the fringing reef in the Meneng District.

(PMMA3) IJUW AND ANABAR REEF FLATS AND OCEAN FRONT

This marine area complements PMMA1 and 2. This continuous area captures 40% of the coastline of Nauru and forms a vital marine management area. The area is away from negative effects from the airport runway and port development activities. The combined area is valued for marine invertebrates – snails, clams, sea cucumbers and crustaceans on the reef flat and coral slope. These are thought to be less heavily harvested at this site. PMMA3 has not yet been affected by any damage from sea protection works on the shore and it links inland to wetlands, forests and the pinnacles of PCA3.

(PCA2) COMMAND RIDGE – INCLUDING BUADA BASIN FOREST, TOPSIDE WESTERN SCARP FORESTS AND TOPSIDE RAILWAY ZONE

This area contains the most advanced natural forest regeneration within a mined site. The area provides habitat for most of the reptile species due to the mix of exposed habitat and vegetation cover, and may become a key landbird stronghold. The west coast escarpment forests and Buada basin forests are also proposed for conservation because they contain important indigenous trees. PCA2 includes the most noddy rookeries and some un-mined pinnacle outcrops in the northern part. Historic mining, railway and track networks are features that could be developed into a sustainable tourism site.

(PCA3) IJUW – ANABAR WETLANDS AND FORESTS

This site contains the most valuable brackish open water habitats for birdlife, significant areas of mangroves and supports the richest vegetation mosaic of the coastal plain. It also has high scenic values and holds endemic vascular plants. Aligned with PMMA3 it provides significant habitat for invertebrates, lizards and birds due to the absence of sea protection works, the uniqueness of the ponds and the inclusion of the coastal plain rubble forest and rocky scarp.

(PCA4) TOPSIDE UN-MINED PINNACLE OUTCROPS

These original elements of the landscape have no value for phosphate but retain pockets of vegetation and soils with lizard and invertebrate life. The vegetation will provide propagules to colonise the surrounding mined-out lands.

(PCA5) COASTAL LITTORAL TREES

This is not a single area but identifies that it is important to conserve and increase the numbers of these endangered tree species that are largely confined to the coastal zone (refer to Figure 3). This zone within 50 metres of the mean high tide mark should be protected immediately and, where possible, enriched with the planting of appropriate species, including collecting the seeds and regenerating the species. Conserving these trees will restore formerly powerful cultural associations and uses of both indigenous and introduced plants.

Figure 3. Proposed Conservation Area 5 (PCA5) is represented by the occurrence of five endangered trees species.

CHAPTER 1

BOTANICAL SURVEY OF NAURU

ART WHISTLER AND RANDY THAMAN

Summary

- A team of biologists visited Nauru from 18 to 26 June 2013 to do a vegetation and flora survey of the island. A total of 139 specimens were collected and distributed to various herbaria.
- The flora was determined to comprise about 56 native species and 125 naturalized species. The native species are all indigenous, with none of them endemic. Many of the native species were determined to be extirpated or on the verge of extirpation from the island, and many of the weeds found during previous surveys were not encountered during the present one.
- New records of weed species observed include *Boerhavia coccinea (Nyctaginaceae), Acalypha indica* (Euphorbiaceae), *Ruellia tuberosa* (Acanthaceae), *Digitaria fuscescens* (Poaceae), and an unidentified species of grass, possibly *Dichanthium* sp. (Poaceae).
- Eight permanent plots, mostly 10 x 50 m, were set up and all trees over 5 cm dbh in them were measured. The data was then collated into tables showing the presence and relative dominance of the component species, and the plots were geo-referenced.
- Seven plant communities were recognized: (1) littoral strand; (2) limestone forest; (3) mangrove forest; (4) freshwater marsh; (5) managed land vegetation; (6) secondary scrub; and (7) secondary forest. The majority of the island fits into the secondary scrub community. Very little native forest was found.

Introduction

The goals of the botanical survey portion of the study were as follows:

- Develop capacity building for counterpart staff of DCIE (Nauru Department of Commerce, Industry and Environment);
- Compile a checklist of the native and naturalized flora of the island. This was to be done in conjunction with the previous literature, which includes species that may no longer be found on the island (i.e., species that have been locally extirpated);
- Make voucher specimens of the native and naturalized flora. The specimens were to be collected, pressed, dried, and sorted into four voucher sets to be sent to various regional herbaria at the conclusion of the project;
- Survey the vegetation of the island and take notes on the types of vegetation that occur there;
- Set up permanent vegetation plots that can be monitored in the future to see what changes occur over time;
- Prepare a report including a description of the flora and vegetation; a checklist of the native and naturalized flora; vegetation plot data and geo-referenced location of the study plots; and recommendations for management of the flora and vegetation of the island, with particular attention to special conservation priorities such as rare and/or threatened species, while paying close attention to potential threats such as development (e.g. mining, roads tourism, facilities) and current threats (e.g. invasives).

1. THE PHYSICAL ENVIRONMENT

Nauru is an isolated, uplifted limestone island (a "makatea") located 41 km south of the equator at 166°56′ E longitude, some 2000 km east-northeast of Papua New Guinea, 4450 km south-southeast of the Philippines, and an equal distance to the southwest of Hawai'i. The nearest island is Banaba (Ocean Island) 300 km due east, which is part of the Republic of Kiribati. The Gilbert Islands, the main subdivision of Kiribati, lie a further 400 km to the east. The island, with an area of only 22 km^2, comprises a narrow coastal plain, ranging from 50 to 300 m wide, encircling a limestone escarpment rising some 30 m in elevation to the central plateau (Figure 1). The escarpment ranges from vertical cliffs to gradually-sloping areas of colluvial soil interspersed with limestone outcrops and pinnacles. The plateau, with a maximum elevation of 70 m, comprises a matrix of coralline stone pinnacles and limestone outcrops, between which lie extensive deposits of soil and high-grade phosphate rock. Buada Lagoon (actually a brackish lake) and its associated fertile depression are located in the low-lying southwest-central portion of the island. (Thaman 1992; Thaman et al. 1994)

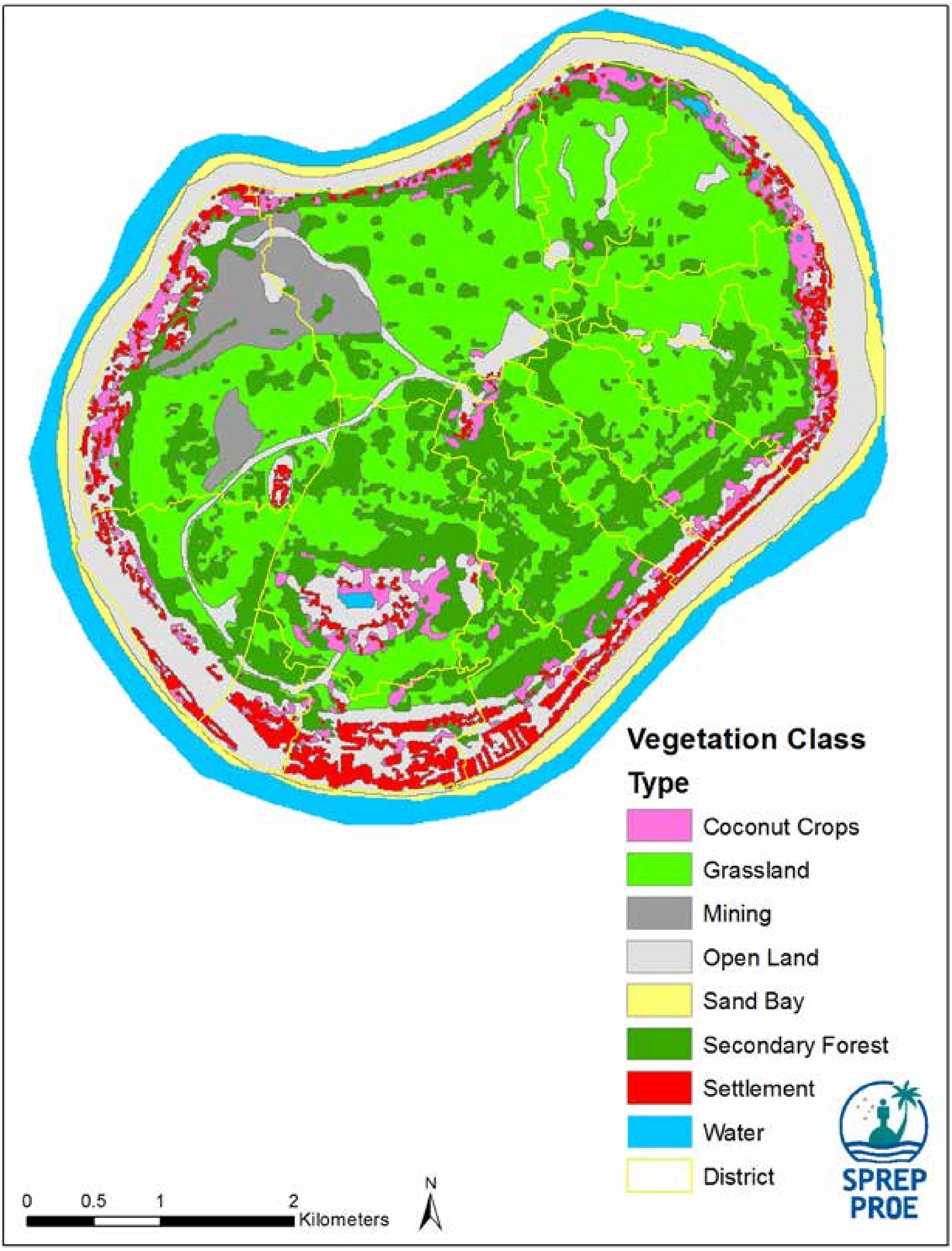

Figure 1. Distribution of the different vegetation types.

There are no surface freshwater resources on Nauru, although there are a few brackish ponds (anchialine ponds) on the northeast of the island, the brackish water Buada Lagoon (technically a lake rather than a lagoon), and an underground lake in Moqua Cave in the southeast (Viviani 1970). The only significant permanent freshwater resource is groundwater in the form of a lens of often slightly brackish freshwater hydrostatically "floating" on higher density saltwater beneath it. Replenishment or recharge of the lens is dependent on rainfall (Thaman et al. 2008a)

Climatically, Nauru is located in the dry belt of the equatorial oceanic zone, with mean daily temperatures ranging from 26 to 32° C. Annual rainfall is extremely variable, averaging 1500 mm per year with a range of 300 to 4572 mm. Severe prolonged droughts are common and place severe stress on even the most hardy coastal strand species, leading to the death of non-coastal exotics (such as breadfruit), and severely restricting the production of even coconut palms (Catala 1957).

The coastal soils of Nauru are among the poorest in the world. They comprise a shallow (only about 25 cm deep), alkaline, coarse-textured layer of organic matter, coral sand, and limestone fragments that overlay a limestone platform. They contain more coral gravel than sand in the lower horizons. Potassium levels are often extremely low, and pH values of up to 8.2 to 8.9 and high $CaCO_2$ levels make scarce trace elements, particularly iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn), unavailable to plants. Fertility is, therefore, highly dependent on organic matter for the concentration and recycling of plant nutrients, lowering soil pH, and for soil water retention in the excessively well-drained soils. Although levels of organic matter can be relatively high in undisturbed soils under natural vegetation, it can decrease dramatically as a result of clearance by fire or replacement by coconuts and other introduced plants (Morrison 1994).

The plateau soils of Nauru vary from shallow layers on the tops of limestone pinnacles, composed primarily of organic material and sand or dolomite with very little phosphate, to deep phosphatic soils and sandy phosphatic rock up to over 2 m deep between the pinnacles. Top soils range from 10 to 30 cm in depth, overlaying a deeper material that is frequently reddish yellow and between 25 and 75 cm in depth, changing to pinkish grey at greater depth. Undisturbed plateau soils (what little remains) have a high level of organic material and are generally fertile. Calcium dominates the exchange complex and exchangeable magnesium is also high. Exchangeable potassium is low, while extractable phosphate values are generally high and sulfate moderate. The trace elements manganese, copper, cobalt and molybdenum levels are very low, and these, plus iron and zinc, are rendered unavailable to plants under pH values >6.5. Poorly developed but relatively fertile, wet soils are found around Buada Lagoon and in some poorly drained swampy areas near the base of the escarpment on Nauru (Morrison 1994).

2. THE FLORA OF NAURU

The flora of an area comprises all the plants, or a list of all the plants, found there. Floras can include all plants, only vascular plants (including flowering plants, gymnosperms, and ferns) or even lower plants, such as algae. The flora discussed here comprises only the native and naturalized flowering plants of the island. Early collections and observations of the Nauruan flora have been made by Finch in 1881; Burges in 1933; Fosberg in 1980; Scully in 1980; Thaman, Hassall, and Manner in 1980 and 1981; Thaman and Manner in 1987; Swarbrick in 1988; and Raulerson in the early 1980s; little of this information was published. From these publications and reports, Fosberg et al. (1979, 1982, 1987) produced a checklist of the flora of Micronesia. However, the first report to deal specifically with the flora was published by Thaman (1992) and Thaman et al. (1994). This comprehensive report recorded 493 species or cultivars to have been present on Nauru, only 59 (12%) of which were possibly indigenous. No endemics were among these, and two or three of the native species (*Achyranthes canescens*, *Tarenna sambucina*, and *Aidia racemosa*) possibly being extirpated (locally extinct). (*Aidia* was, however, found in a subsequent survey.) For the present report, only the native species and naturalized species (alien species that have become establish on their own on the island, usually known as "weeds" or "adventive species". Thaman et al. (1994) noted that half of the native flora was "severely restricted in distribution, endangered or possibly extinct, due to removal and severe habitat modification or limitation."

A second comprehensive flora of the island was published by Thaman et al. (2008a). Based on the original collections and other collections since the time of the previous checklists, the authors recognized about 63 native species. Some of these were described as "ephemerals," i.e., species that occasionally reach a new locale, where they germinate, grow, and die out. They also noted that the total number of plant species and cultivars recorded had increased to 573, but only the native and naturalized species are dealt with in the present report. The same authors also published *Plants of Nauru: A guide to indigenous and introduced plants of particular cultural importance and weeds of potential threat to Nauru*, a guide to the flora of the island (Thaman et al. 2008b). In summary, about 63 indigenous species, and perhaps 125 weedy or adventive species (some of which have disappeared since they were first recorded) have been recorded from the island. Based upon this work, and the present survey, the flora of Nauru is relatively well known.

3. THE VEGETATION OF NAURU

The vegetation of an area is defined as how the species present are spatially arranged, often through the recognition of units called plant communities and/or associations. For example, the community recognized as "littoral forest" is typically dominated by one or several tree species characteristically found on seashores. Several visitors dating back to the late 1800s have made comments on, or done studies on, the vegetation of the island, including Burges (ca. 1935), Manner et al. (1984, 1985), Thaman (1992), and Thaman et al. (1994, 2008a). Several others, such as Davey (1966), the Commission of Inquiry (1988), and Hassall (1994), have discussed how to rehabilitate the surface of the island that has been severely disturbed by phosphate mining.

The first comprehensive delineation of the vegetation of Nauru was produced by Thaman et al. (1994). The authors divided the vegetation of the island as follows:

A. Primary Vegetation

1. Coastal strand
2. Mangroves and coastal marshes
3. Inland forest
4. Limestone escarpment or pinnacle vegetation.

B. Secondary and cultural vegetation

1. Coconut-palm-dominated lands
2. Houseyard gardens and urban vegetation;
3. Ruderal vegetation
4. Disclimax vegetation.

For the purposes of mapping, this scheme was somewhat modified to produce map units, as follows:

Disturbed areas	Ruderal Regeneration <15 years Regeneration <50 years Regeneration >50 years *Leucaena leucocephala* Horticulture/Agriculture Houseyard and institutional gardens Food gardens
Wetland vegetation	*Eichhornia crassipes-Ipomoea aquatica-Ipomoea pes-caprae* *Bruguiera gymnorrhiza-Rhizophora stylosa* *Thespesia populnea-Bruguiera gymnorrhiza*
Very tall closed forest	*Adenanthera pavonina-Mangifera indica-Calophyllum inophyllum*
Tall closed forest	*Calophyllum inophyllum-Phymatosorus grossus*
Complex (combination of the two previous categories)	*Ficus prolixa-Terminalia catappa-Hibiscus tiliaceus* *Adenanthera pavonina-Ficus prolixa-Hibiscus tiliaceus* *Adenanthera pavonina*
Tall open for./woodland	*Cocos nucifera*
Mid-high closed forest	*Hibiscus tiliaceus*
Closed shrubland	*Scaevola taccada-Ipomoea pes-caprae* *Clerodendrum inerme* *Colubrina asiatica*
Others	Lagoon/pond Sandy beach/rocky shore Runway Paved road

Although the units recognized somewhat follow the previous vegetation scheme, Thaman et al. (1994)'s scheme is not the same thing as a classification of the vegetation, because it was more meant for mapping purposes. In any case, most of the island is covered with a highly disturbed vegetation.

Methods

The provisional plan for the botanical study of Nauru envisioned a series of standard 1,000 m^2 or 500 m^2 permanent sample plots situated in different types of vegetation. Although this could have been done in ideal conditions, the situation on the extensively disturbed island with a relatively impassible "pit and pinnacle" topography necessitated some variations in both site selection and methodology used. First, there is almost no undisturbed native vegetation left on the island. Nearly the whole interior of the island comprises a rugged, pit and pinnacle-dominated landscape covered with forest or scrub of height and density related to the age of the disturbance. This landscape was so rugged that it many places it was virtually impossible to do standard plots due to the dangers and difficulty of traversing the area. Virtually all the flat land in the interior of the island has been turned into this landscape, with the remaining undisturbed vegetation lying on the escarpments, which themselves are too steep to allow standard plots. So modifications had to be made in the selection of plots and methods used.

The field work was carried out by the lead author (Whistler) on Nauru from 18 to 26 June 2013, assisted by a team supplied by the DCIE (Nauru Department of Commerce, Industry and Environment). The survey included two aspects: flora and vegetation. Prior to the study, the senior author reviewed the botanical literature and had the most recent work of Thaman et al. (2008a) at his disposal to get an idea of which species are known to occur on the island. A checklist was begun during the field work, and was added to day by day as new species were encountered. Although most of the species found were already known from the island, several new ones were encountered. These were either species that were entirely new to the island, or ones that had been previously misidentified. Special effort was taken to find all the previously recorded species, especially native species. This was not possible, however, because several of the previously recorded native species have apparently been extirpated from the island. This is either because their habitat was destroyed, or because they were "ephemeral" species that periodically arrive naturally on an island, germinate and grow (and are collected by a botanist), but do not reproduce and disappear when the individual dies. At the end of the field work, the final checklist of the flora was prepared (Appendix 1).

In addition to compiling the comprehensive checklist, voucher specimens were collected for most species recorded. Voucher specimens "vouch" for the presence of species in an area, because species on the checklist are sometimes called into question. In most cases four sets of each specimen were made. These will be distributed to the University of Hawai'i Botany Department Joseph Rock Herbarium, the University of the South Pacific Regional Herbarium, the Auckland War Memorial Museum Herbarium, and probably the National Tropical Botanical Garden in Hawai'i.

The specimens collected during the fieldwork were put into a section of newspaper, numbered, and placed in a plant press between cardboard separators. The press was closed, cinched up, and placed into a plant drier built from hollow concrete blocks and light bulbs set up for the purpose at the hotel where the survey crew was staying. The specimens were dried during the study. When a specimen was determined to be dry, it was removed and a new fresh specimen was inserted between the cardboards. The dried specimens were collated, i.e., the duplicates were put together in numerical order, and they were bundled up and wrapped in newspaper for transport out of Nauru. Most of the specimens were taken by the lead author upon his departure, but the specimens not yet dry at the time of departure were further dried to be sent later to him in Hawai'i. However, at the time of this report (September 2013), the specimens left behind on Nauru have yet to be sent out.

Most of the specimens were identified on the spot because the lead author recognized most of them from his years of work in the Pacific. Those not immediately identified were later identified by comparison with other specimens at the Bishop Museum in Honolulu. Most of the species present on the island can be found in photographs in Whistler (1992) for native species and Whistler (1994) for weedy alien species, as well as in Thaman et al. (2009b) *Plants of Nauru*. Four species found during the study appear to be new records for Nauru, and are discussed in the flora section below. The voucher specimen numbers are shown in the flora checklist in Appendix 2. After the identifications were complete, the labels were written up, printed, and added to the specimens. The four sets will eventually be sent to the institutions mentioned above.

The vegetation part of the survey comprised the accumulation of notes and setting out of permanent plots. Because of the rugged topography, limited areas of native vegetation, and limited time, only eight permanent plots were set up. Ideally, all of them would have been the same standard size, i.e., 1000 m^2. However, because of the difficulty of finding areas in which a plot could be set up in traversable homogenous vegetation, only eight plots were established (Appendix 3). Two of these were not traditional plots, because their topography was so rugged that it was not possible to put in boundaries because of the dangers of falling in pits between the rugged limestone pinnacles. In plot no. 2, individual trees were measured in areas of soil between the high limestone outcrops. In the other a line was laid out on a road, and all the trees reachable by excursions into the rugged pinnacle landscape, and which had a dbh (diameter at breast height) over 5 cm, were measured. These two plots do not have an area parameter, i.e., with no fixed boundaries or even a "plot," it is impossible to determine the density of trees in the "plot."

When establishing the plots, an area of representative vegetation (i.e., one without disturbance and in homogeneous forest) was selected and a 50 m tape was laid out through the forest. The plot comprised the area extending out 5 m from each side of the line, making the plot 50 x 10 m in extent. The survey crew then went down the line measuring all trees within 5 m of one side of the line. No boundaries were established ahead of time; any tree near the imaginary boundary had its distance from the line measured, and those trees just inside the boundary were often marked with plastic flagging tape to help visualize the boundary. Once the 50 x 5 m side was finished, the survey team reversed directions and measured all trees on the other side of the line. The trees were measured using a dbh tape placed around the trunk at breast height. If the trunk comprised multiple stems, the measurement was made lower down the trunk, or depending upon the shape of the tree, on all sufficiently large branches at breast height. The results of the measurements included 26 individual trees in the least dense forest and 61 in the densest.

After the plot was sampled, the data was collated and "relative dominance" for each species was calculated by dividing the total stem cross-sectional area of the species by the total stem cross-sectional area of all species. The stem area of an individual tree is determined by measuring the dbh, squaring this diameter, and multiplying the figure by 0.789 (the ratio of the area of a circle, i.e., a tree trunk cross-section, to the area of a square). In mathematical terms, this is πr2. The total basal areas of all of trees were summed up, and the species were then placed in a table in descending order of relative dominance (see Appendix 3). The first column to the right of the species name shows the number of individuals of that species in the plot. The second column shows the number of sampled individuals having a basal diameter of 15 cm or more, which is a simple indication of the relative size of the individuals (e.g., how many of the individuals were large trees). The third column shows the total basal area of each species. The last column shows the relative dominance of each species. The total number of trees, the total number over 15 cm dbh, and the total tree basal area of the plot are shown below each table in Appendix 3. Only trees were sampled quantitatively in the plots. Since dbh does not work with non-tree vegetation, just quantitative notes were taken on the ground cover species, epiphytes, and vines in the forest. Notes were taken on ground vegetation within forests and in areas of scrub, but these were only estimates of the component species relative dominance and are not presented here as data, but rather as part of the description of the vegetation types.

Results

1. THE FLORA

Based upon the present survey and the previous botanical studies, 181 native and naturalized plant species were recorded on the island (see Appendix 1). Most of these had already been recorded from the island, but several are either new records or new species identifications. The new records/species comprise *Acalypha indica* (Euphorbiaceae), *Ruellia tuberosa* (Acanthaceae), *Digitaria fuscescens* (possibly misidentified during earlier surveys), *Boerhavia coccinea* (also probably misidentified in earlier surveys), and an unidentified species of grass, possibly *Dichanthium* sp. (the specimen of this grass is still on Nauru and has not been further studied). It is not unusual to find new weedy species in an area, since they are arriving constantly, nor is it unusual to not find other previously recorded ones. This disappearance of formerly recorded species and detection of new species can occur for several reasons: (1) the species may be rare in the beginning and may subsequently die out ("ephemeral"); (2) the species may have been flowering and conspicuous during only one survey; (3) the plant may have been found in only one place that was not subsequently visited; or (4) the plant may have been misidentified on an earlier survey.

Previous botanical reports have reported the number of native species to be greater than 59. However, a re-analysis of the data indicates that the number of native species is about 56 (not including *Cerbera manghas*, a littoral forest tree known, at present, at least, only in cultivation). All of the native species are indigenous, i.e., they are species native to a region or place, but which are also found elsewhere. None are endemic, i.e., species restricted to a single region or area, i.e., restricted to Nauru. The vast majority of the 125 species encountered during the surveys are naturalized or weedy "alien" plants that were accidentally or intentionally introduced to Nauru, but which have now become established in the islands and can spread on their own.

Consequently, the flora of Nauru is relatively small and does not contain any unique species. A typical atoll in the region might have about 40 native plants, all of them littoral (restricted to areas near the seashore), but Nauru's larger number (56) is indicative of its larger land area and higher elevation than typical atolls. This size and elevation has allowed a few inland species to grow on the island. Perhaps the most unique plant on the island is *Ochrosia elliptica* (*eoerara*), an attractive tree with bright-red, keeled, almond-like fruits and a limited distribution in the Pacific islands. A list of the flora of Nauru is shown in Appendix 1, and the additional checklist in Appendix 2 shows the voucher collection numbers.

2. THE VEGETATION

Several plant communities can be distinguished on Nauru, but since the landscape has been so severely disturbed by mining (and earlier by human occupation), only remnants of this remain. The plant communities recognized here as occurring on the island are as follows: littoral strand; limestone forest and woodland; mangrove forest; freshwater marsh; managed land vegetation; secondary scrub; and secondary forest.

2.1. Littoral Strand

The term "littoral strand" refers to the natural vegetation occurring on the seashore and dominated by plant species whose presence and distribution are affected either directly or indirectly by the sea. This vegetation is sometimes called "coastal," but "littoral" (Latin: *litoris* = shore) is a more precise term. Littoral vegetation differs from most inland vegetation in both its extent (area) and distribution. It occupies a very narrow area on the immediate coast, and often exhibits zonation into several bands that run roughly parallel to the coastline. These zones have often been described as "communities," since they sometimes have distinct boundaries and may be characterized by distinctive life forms (e.g., herbs, shrubs, trees), and similar zones are widely recognized throughout the tropics. However, several factors support instead the recognition of a single community, which is referred to here as littoral strand: (1) the size of all of the littoral zones, even when combined, is very small compared to the extensive rainforest communities; (2) boundaries between zones are often difficult to determine; and (3) some littoral forests are entirely without herbaceous and shrubby zones on their seaward margin. The zones typically recognized in the literature are herbaceous strand (often further distinguished into those occurring on sandy shores and rocky shores), littoral shrubland, *Pandanus* scrub, and littoral forest.

The original littoral strand community of Nauru probably originally covered the shores all the way around the island, typically from just above the high-tide mark up to 5 or 10 m elevation. It probably graded imperceptibly into the limestone forest of the escarpment and interior. The environmental conditions present in areas of littoral vegetation are among the harshest of any the Pacific Islands. Although the annual rainfall exceeds 150 cm, the limestone rock or sandy substratum may retain little water for plant growth, at least at the surface. Soil drought is a major factor limiting the littoral habitat to species adapted to the arid conditions (i.e., "xerophytic" plants). The substratum itself is a limiting factor, either because of low organic content of the substrate (e.g., sandy beaches) or absence of soil (e.g., rocky limestone coastal outcrops). Temperature is another important environmental factor. The limestone rock or sand on which the plants grow is exposed to the sun, resulting in a high ground temperature during sunny days. The most critical environmental factor, however, is the effect of the sea. The sea winds are salty, the ground water is often saline or brackish, and occasional high waves, some with destructive force, can inundate the area. Littoral species, therefore, must have some degree of salt-tolerance to survive these harsh conditions.

Most littoral plants are also heliophytes ("sun plants") that require bright sunlight for establishment and growth, a need that generally excludes them from shady forest habitats. The physiological characteristics littoral plants share account for their typical restriction to a narrow zone of vegetation along the shore. Although the littoral species come in several different "life forms" (e.g., tree, shrub, herb, vine, etc.), they have important characteristics in common. Most have buoyant, saltwater-resistant seeds or fruits that can be carried for long distances by sea currents. Most of those lacking this characteristic instead have sticky fruits that adhere to seabird feathers (e.g., *Pisonia grandis*), or fruits that are eaten and transported internally by seabirds or migratory birds visiting the islands. These dispersal characteristics account for the wide distributions of most littoral species: few Pacific littoral species are endemic, and none in Nauru are. This vegetation was referred to by Thaman et al. (1994) as "coastal strand," virtually the same name.

Unfortunately the entire coastal zone of Nauru is highly disturbed (Figure 2), because it is where most of the population has lived since the island was first inhabited. As a result nearly all littoral vegetation has been cut down and replaced by housing and other structures, roads, plantations, and even the sedges, and, to a lesser extent, other herbs. On Nauru, the most common vine species found on sandy beach shores are *Ipomoea pes-caprae* (beach morning glory, *erekogo*) and lesser amounts of *Vigna marina* (beach pea, also *erekogo*). Common grass species include *Lepturus repens* and *Stenotaphrum micranthum* (both species are generally called *ibugibugi*, the generic term for grasses and weeds). Because of the extensive disturbance, the herbaceous zone on Nauru is often quite narrow (Figure 3) and sometimes non-existent. Strangely missing during the survey, but reported in 2007 at the beach seaside at the northern end of the airport, was the native *Chamaesyce chamissonis*, which is so characteristic of other tropical Pacific islands with a similar limestone and coastal areas. It is either very rare on the island today, or an example of an "ephemeral" species that disappears and reappears periodically.

Figure 2. Disturbed coastal area of Nauru originally covered with Littoral Forest.

Figure 3. Littoral Shrubland with a narrow zone of herbaceous strand.

A littoral shrubland zone usually comprises a fringe on the seaward margin of littoral forest in the Pacific islands. Sometimes this fringe is distinct, but often the shrubs are intermixed with low-growing littoral forest trees, which can make the recognition of two distinct zones almost impossible. On Nauru, it is commonly combined with the littoral forest, blurring the boundaries between the two zones. As noted above, the coastal zone on Nauru is highly disturbed, and only a few large areas of littoral shrubland are present nowadays on the island. The dominant species here is *Scaevola taccada* (*emet*), which often forms monodominant stands, and lesser amounts of *Clerodendrum inerme* (*eamwije*) and *Colubrina asiatica* (*ewongap*). One interesting species that is currently uncommon in this zone, but was more common in the past, is *Capparis cordifolia* (*ekabobwiya*). It is restricted mostly to coastal limestone outcrops, and was seen only a few times during the present survey. Strangely missing from Nauru is the wide-ranging shrub *Pemphis acidula*, which is the most characteristic and dominant littoral shrub on most other limestone coasts in the tropical Pacific. No areas of *Pandanus* littoral scrub were noted, and the species is less common on Nauru than most other similar Pacific Islands. The leafless parasitic vine *Cassytha filiformis* (beach dodder, *denuwenini*) and the liana *Ipomoea violacea* (*erekogo*) are also common to occasional in this zone.

A littoral forest zone is even less frequent on Nauru today than the other zones because of the extensive disturbance. Originally, it probably comprised a mixed or monodominant forest of *Calophyllum inophyllum* (Alexandrian laurel, *iyo*), *Terminalia catappa* (tropical almond, *etetö*), *Guettarda speciosa* (*iut*), *Barringtonia asiatica* (fish-poison tree, *kwenababai*), *Hibiscus tiliaceus* (beach hibiscus, *wone*), *Cordia subcordata* (Pacific rosewood, *eongo*), *Hernandia nymphaeifolia* (Chinese-lantern tree, *etiu*), *Tournefortia argentea* (tree heliotrope, *irin*), and *Pandanus tectorius* (screwpine, *epo*), and perhaps, if it is native, *Cocos nucifera* (coconut, *ini*).

Only a few areas of intact littoral forest were observed on the island. Perhaps the best one seen during the present survey was at the rocky area on the grounds of the Menen Hotel, where *Barringtonia asiatica* dominated along with *Ficus prolixa* (Pacific banyan, *eaeo*). The fish-poison tree is common, however, on some of the rugged coastal escarpments. *Tournefortia argentea* is locally common in a few rugged areas on the coast, such as just north of the Menen Hotel. *Calophyllum inophyllum*, *Terminalia catappa*, and *Guettarda speciosa* area all common in the limestone escarpment forest, and *Hibiscus tiliaceus* is common in disturbed coastal and inland areas, and is particularly common in some areas on the lower limestone escarpment. *Hernandia nymphaeifolia* and *Cordia subcordata* are currently uncommon on the island, especially the *Hernandia*, which was seen in only a couple of areas. It is not clear if these three species were always rare, or whether they are more susceptible to the extensive disturbance to the coastal zone.

The most intact area of littoral forest is probably found on the escarpment inland from Anibare Bay on the east of the island. This has relatively intact stands of *Barringtonia asiatica* and *Calophyllum inophyllum*. It also has, along the uppermost ridge and cliff face of the escarpment, the last largest remaining stands of *Pisonia grandis* (pisonia, **yangis)**, one of the Pacific most important bird rookery trees, an important roost for the black noddy (*Anous stolidus*, *darur*) a ceremonial food that is hunted in this area by Nauruans. This is also the area where the endangered tree, *Aidia racemosa* (*enga*?) was seen and photographed in 2007 by Thaman, and where *Neisosperma oppositifolium* was seen and photographed in 1996, but which is now presumed extirpated from Nauru.

Only one area of littoral forest was surveyed, but this was only a small patch at Uaboe (plot no. 1). The dominant species in that plot were *Calophyllum inophyllum*, with a 64% relative dominance, and *Terminalia catappa*, with 31%. Both of these species can be dominants in the adjacent limestone forest of the interior as well.

2.2. Limestone Forest and Woodland

Limestone forest and woodland is a type of lowland forest that occurs on limestone substrates, and is particularly common on Pacific makatea islands, such as Makatea in the Tuamotu Archipelago in French Polynesia, and Niue in western Polynesia. In cases where it is more open, without a closed canopy, it resembles more of a woodland. Since the limestone substrate tends to be rocky and somewhat sterile in regards to minerals needed for plant growth, it is often dominated by species that actually prefer this habitat. The case of Nauru is different than most limestone islands, in that the interior was once covered with extensive phosphate deposits, most of which have mined, the process of which required the removal of all vegetation and topsoil. However, its rocky nature and isolated location in the central Pacific has limited this forest's biodiversity on Nauru. It is likely that the original flora was not unlike that of the littoral forest zone of the littoral strand, making the distinction between the two communities somewhat tenuous. The separation between the two is clearer on larger islands, where the limestone forest flora may contain many species not found on the coasts, most of them dispersed by birds rather than by sea water as most littoral forest species are.

It is not clear what the composition of original limestone forest on Nauru was, because until recently very little was written about the island's vegetation. However, it is likely that areas with soil present were dominated by littoral forest canopy trees, such as *Calophyllum inophyllum* (Alexandrian Laurel), *Terminalia catappa* (tropical almond), and *Guettarda speciosa*, and the smaller trees *Morinda citrifolia* (Indian mulberry, *deneno*), *Premna serratifolia* (*idibiner*) and possibly *Ochrosia elliptica* (*eoerara*). In areas where limestone rocks prevailed, the dominant species was almost certainly *Ficus prolixa* (Pacific banyan, *eaeo*), as it is today. This community combines the two categories recognized by Thaman et al. (1994), "inland forest" and "limestone escarpment or pinnacle vegetation." The escarpment may best be described as a transition zone between littoral strand and limestone forest, since it is a combination of littoral species that are restricted to the coastal area, and littoral and limestone forest species that are able to reach and can survive in the inland habitat. Nearly all of this forest has been removed by mining operations over the last century. The little remaining limestone forest is now often disturbed, often seriously, by the invasion of alien trees such as *Adenathera pavonina* (red-bead tree) and *Leucaena leucocephala* (Caribbean tamarind).

Only a few areas of relatively undisturbed limestone forest were found, and most of these were very small and often mixed with alien species (especially *Adenanthera*). Two of the eight plots shown in Appendix 3, namely plots 2 and 3, can be classified as limestone forest (although one is on the escarpment). The dominant in these two combined forest plots were *Terminalia catappa*, with an average relative dominance of 39%, *Calophyllum inophyllum*, with 28%, and *Guettarda speciosa*, with 3%. The two other native species present were *Morinda citrifolia* and *Ficus prolixa* (and coconut, if that is native), but these combined had only an average of about 3% relative dominance. It is unclear how much of the latter species there would have been in the limestone forest, because it dominates limestone outcrops. In plot 2, only trees in the soil were measured, because the multi-trunk *Ficus* trees grew on the inaccessible tops and sides of emergent pinnacles and limestone outcrops that form a maze in this area. That these two plots were disturbed is attested to by the presence of *Adenanthera pavonina*, which had an average relative dominance of 27%. *Hibiscus tiliaceus* sometimes forms dense thickets in limestone forest, but this species may be of ancient introduction to Nauru, and its presence is often a sign of extensive disturbance in the past. In some places, the alien understory tree *Annona muricata* (sour sop) is common, especially near plantations and villages.

Undisturbed or relatively undisturbed limestone forest has an open floor (Figure 4), because few species occur here, and few still can survive the dense shade of the forest floor. The most common component of the forest floor comprises the seedlings of the dominant species. Herbs are virtually non-existent in this forest, with the most common species probably being the fern *Microsorum grossum* (*dageang ini Makin*?). Also possibly present in more open areas in the limestone forest is the interesting small shrub *Phyllanthus societatis* (*eoemangemang*). Vines are also uncommon, three of which are still rare to occasional in remaining escarpment forest are *Ipomoea violacea* (*erekogo*), the thorny sparsely leaved *Capparis quiniflora*, and *Canavalia cathartica* (also *erekogo*). Also still occasional in some sites on the lower escarpment are *Abutilon asiaticum* (*inen ekaura*), whereas *Sida fallax* (*idibin ekaura*), which used to be present in open area, seems to be extirpated. The terrestrial fern *Pteris tripartita* (*dageang*) is also occasional in some shaded sites in the escarpment forest.

Figure. 4. Nauru Limestone Forest with sparse ground cover comprised mostly of forest tree seedlings.

2.3. Mangrove Forest

The mangrove forest community in the Pacific is normally restricted to protected coastal areas, usually in estuaries or lagoons and intertidal reef flats, or on back-beaches or inner tidal basins or land-locked ponds. In the case of Nauru, which lacks both estuaries and protected lagoons, mangroves occur along the edges of inner basins or ponds, which are often referred to as anchialine ponds (Figure 5). The characteristic trees of mangrove vegetation typically belong to the mangrove family Rhizophoraceae, but elsewhere in the tropics mangrove species belong to several different families. Although they are most characteristic of the tropics, mangroves are occasionally found in subtropical areas. Their northernmost range is Bermuda (32° N), and their southernmost the Chatham Islands (44° S) east of New Zealand. Mangrove vegetation is remarkable for its homogeneity, both in physical characteristics and flora. Only two trees can be classified as mangroves on Nauru—*Rhizophora stylosa* (*eodongo*) and *Bruguiera gymnorrhiza* (*etõm*).

Figure 5. Nauru Mangrove Forest around an anchialine pond.

The essential difference in mangrove vegetation from other coastal types of vegetation on Nauru is the presence of brackish water that saturates the soil. The constantly waterlogged soil is dark, rich in organic material, and low in oxygen concentration. A constant smell of hydrogen sulfide produced by anaerobic respiration of swamp bacteria pervades the area. The waterlogged, anaerobic soil is the major factor precluding other species from inhabiting these wetlands. Mangroves are able to survive under these adverse conditions because of the presence of specialized breathing roots called "pneumatophores," an adaptation that allows the plants to absorb oxygen directly from the air. In *Rhizophora*, the pneumatophores are spreading prop roots), while in *Bruguiera* they appear as knobby roots protruding from the mucky soil.

The only areas of mangrove forest occurring on Nauru are around the anchialine ponds near the base of the escarpment in Menen, Anabar and Anetan Districts. It was reportedly present around Buada Lagoon in the past, but no longer is present although a few young trees were seen near a pool to the north of the main Buada Lagoon in 2007. The largest mangrove concentration is found around Araro Lake in Anetan. *Bruguiera gymnorrhiza* was found during the present survey, but *Rhizophora stylosa* was not. *Rhizophora* was first found on Nauru in 1996 and was seen again and photographed in 2007, and although it was not seen during the present survey, a single tree was reported by informants to still grow in Ijuw.

A few other woody species are commonly associated with *Bruguiera gymnorrhiza* in the mangrove forest, especially *Thespesia populnea* (Portia tree, *itira*) and the shrubby *Clerodendrum inerme* (*eamwije*). Less common are the vine *Derris trifolia*, the shrub *Vitex trifolia* (derris, *dagaidu*), and the sedge *Mariscus javanicus* (*reyenbangabangā*). The associated species are typical littoral strand and freshwater marsh species. Mangrove forest is only a very minor community type on Nauru, with a very low biodiversity. No plots were made there.

2.4 Freshwater Marsh

A marsh is an area of herbaceous, hydrophytic ("water plant") vegetation covering flat areas of soil saturated with fresh or brackish water. Nauru is a limestone island on which the porous rock is not favorable to the formation of wetlands. The only significant area of marsh is along the margins of Buada Lagoon (Figure 6), which is actually a small lake rather than a lagoon. This comprises only the margins, and is heavily disturbed since a road and house lots completely surround the lake. Earlier reports note mangroves along its margins, but these have apparently all been removed. The herbaceous vegetation is comprised mostly of the native sedge *Mariscus javanicus*, the escaped *Ipomoea aquatica* (swamp cabbage sometimes cultivated for its edible foliage), and in a few places, the two native littoral vines *Ipomoea pes-caprae* (beach morning glory) and *Vigna marina* (beach pea). The invasive weed *Sphagneticola trilobata* (wedelia) sometimes forms dense patches, long with *Ludwigia octovalvis* (willow primrose). The shrub *Clerodendrum inerme* is also common in places, as well as *Pandanus* sp. and coconuts. No plots were sampled in this disturbed herbaceous vegetation, which was referred to as "coastal marsh vegetation" in Thaman et al. (1994).

Figure 6. Nauru Freshwater Marsh around Buada Lagoon.

2.5 Managed Land Vegetation

Managed land vegetation comprises the vegetation on land actively managed by humans for their use. This includes houseyard gardens, roadside plantings and other landscaping, and vegetable gardens, such as the Taiwanese vegetable gardens at Buada and on the lower escarpment southeast of the airport, and plantations, such as copra plantations, of which there are now only remnants on Nauru. Active management prevents disturbed land from returning to its natural plant cover and promotes the dominance of cultivated plants (which are wanted) and weeds (which are not). The amount of management, in the form of weeding (mechanical means, hand-weeding, or herbicides), determines whether the cultivated or weedy plants will dominate; once active management ends, herbaceous weeds soon dominate. Managed land vegetation was included in three categories by Thaman et al. (1994)—coconut-palm-dominated lands, houseyard gardens and urban vegetation, and Ruderal vegetation. A weed may be defined as any plant growing where it is not wanted. This definition is based on both where the plant is growing and on its economic impact on man's activities, rather than on the intrinsic properties of the plant itself. Weeds are sometimes called "adventives," which is perhaps a better term that does not involve economic importance in its definition, but "weed" is the name in common usage. About 125 plants can be classified as weeds on Nauru (see flora section), most of which are non-native species ("aliens"). Weeds are typically heliophytes ("light-plants") plants that thrive only in sunny conditions; consequently, they are uncommon in undisturbed forests. Most weeds are alien rather than native species. When land is managed, such as when plantations are maintained and weeded, weeds (and intentionally grown species) will dominate until the management has ended or until secondary forest trees and shrubs shade out the alien plants after a period of plant succession.

Since managed land vegetation is regularly or irregularly managed, it cannot reach a state of climax, and it is comprised almost entirely of alien species. No plots of this kind of vegetation were made.

2.6. Secondary Scrub

This is the vegetation that covers most of the interior of the island where phosphate has been mined over the last century (Figure 7). Prior to mining, the vegetation is scraped off by bulldozers and the topsoil removed to expose the phosphate deposits that lie between coral-limestone pinnacles. The extraction of phosphate then causes dramatic changes in local relief, which varies between 4 and 8 m from the top of pinnacles to pit bottoms, with about three to four pinnacles occurring within each 100 m^2. Because mining is only about 20 per cent efficient, unconsolidated phosphate deposits remain in the pit bottoms and on the saddles and slopes between the pinnacles. These deposits (that are slated for future mining) and the pinnacle surfaces constitute the main sites for plant succession that can eventually lead back to a more stable type of vegetation (Manner et al.1984, 1985).

Figure 7. Nauru Secondary Scrub on formerly mined area.

Secondary scrub is referred to as being in a state of "disclimax," and this is the name used by Thaman et al. (1994) to refer to it. It is in a state of slow change of species composition and height that will eventually end up, without further disturbance, in limestone forest. However, the presence of aggressive alien species such as *Adenathera pavonina* (red-bead tree) may have a serious effect on the outcome, and prevent it from returning to its original state that existed before mining and forest clearing. The major factor determining which species dominate and how much they dominate in an area is largely a function of how long the area has been abandoned after mining, and what state the surface is in. Also important is the proximity of the area to seed sources. The latter factor is particularly the case with the two main limestone forest canopy tree species, *Calophyllum inophyllum* (Alexandrian laurel) and *Terminalia catappa* (tropical almond), which have large seeds that are not readily dispersed.

Although there is widespread evidence that exotics commonly replace indigenous species in highly disturbed habitats, the Nauru study by Manner, Thaman and Hassall (1984, 1985) supports the conclusion of Mueller-Dombois (1975) that indigenous (pioneer) species are often better adapted to edaphically harsh environments, given the cessation of human disturbance. Their study shows a very rapid colonization of mined areas by indigenous ferns and exotic herbs, followed by a fairly rapid replacement by native, primarily coastal strand, species.

The first stage of succession after mining has ended is similar to managed land vegetation dominated by alien weeds. Common species at this stage include *Conyza bonariensis*, *Cassytha filiformis*, *Tridax procumbens*, and *Microsorum grossum*. After a number of years, woody species, mostly shrubs and small trees, dominate the landscape. The dominant species at this stage include *Dodonaea viscosa*, *Morinda citrifolia* (Indian mulberry), *Scaevola taccada*, *Premna serratifolia*, and *Guettarda speciosa*. If there are nearby seed sources, *Terminalia catappa* and *Calophyllum inophyllum* may also become established. As noted above, the herbaceous species dominating the early stages are almost all alien weeds, while the shrubs that dominate the later stages of succession are virtually all native species. The later stages of secondary scrub are dominated by trees, which live longer and grow bigger.

Plots were established in this type of vegetation—plot nos. 4, 5, and 6. These areas were all on areas mined decades ago, so that canopy trees had time to develop, rather than being in the shrub-dominated stage. The dominant species in these three plots were *Calophyllum inophyllum*, which had an average relative dominance of 46%; *Guettarda speciosa*, with 26%; *Terminalia catappa*, with 7%; *Ficus prolixa*, with 7%; *Scaevola taccada*, with 5%; and *Premna serratifolia*, with 2%. Not counted in these totals was the disturbed forest alien tree *Adenanthera pavonina*, which in one plot had a 30% relative dominance.

In summary, plant succession begins when a piece of land has been abandoned from human activity, mostly mining in the case of Nauru. The stage of succession is characterized by a dominance of weedy, alien herbaceous species. At the site ages, shrubs, mostly of them native, dominate the scrubby vegetation. Small individuals of the large trees may also be common at this stage, it the site is near a seed source. At the last stage, the forest has the same composition as limestone forest, unless weedy species such as *Adenanthera pavonina*, *Casuarina equisetifolia* (ironwood), and *Muntingia calabura* (Panama cherry), invade. The main difference between this late secondary scrub phase and limestone forest may be related to the topography of the rugged land surface.

As argued by Manner et al. (1985), given no deliberate human intervention, the succession to a disclimax vegetation association capable of sustaining human life will probably take "many thousands of years." It is stressed that it is ironic that Nauru's central plateau, from which Nauruans formerly obtained some of the necessities of life, will be a "topographic jungle" stripped of its natural vegetation, before the next century, in order to provide the phosphate needed to revive phosphate-poor soils to fuel the development of Australia and New Zealand

2.7. Secondary Forest

Secondary forest is forest typically dominated by fast-growing trees with small, easily dispersed seeds that require relatively sunny conditions for germination and/or establishment. This term can easily be confused with the term "disturbed forest," which is usually applied to a climax forest damaged by cyclones or other natural phenomena, and which has a significant number of light-loving tree species present as a result of the disturbance. Secondary forest is a successional stage between secondary scrub (which has resulted from a more thorough disturbance, i.e., mining on Nauru) and limestone forest. Although superficially similar in structure to the climax forest types discussed above, its population structure and flora are quite different. Secondary forest trees typically dominate the canopy, but other species—particularly ones that can germinate and become established in shady conditions (and which usually have larger seeds)—dominate the smaller size classes. Without further disturbance, the sunny conditions required for germination and establishment of the secondary forest species will no longer be present, and the slower-growing canopy tree species that dominate the smaller size classes will eventually prevail when the larger secondary forest trees of the canopy age and die. After a long period, the climax forest that develops will be virtually indistinguishable from primary forests in the area.

However, secondary forest on Nauru is very atypical, mainly because only one tree, *Adenanthera pavonina* (red-bead tree), dominates (Figure 8). This is mainly because of the isolation of Nauru and perhaps the lack of a forestry industry that would have brought in many trees to see if they thrive on the island. *Adenanthera* is known to be invasive on many other islands, but the fact that it is the only significant invasive tree species on the island, and how it can totally dominate a forest, are unusual. Two plots (nos. 7 and 8) were sampled in type of forest. In plot no. 8, 58 of the 59 trees in the plot remarkably were *Adenanthera*. The only exception was one huge banyan that was growing on a rock. Nearly all of the seedlings in the plot were *Adenanthera*, indicating that the forest may have reached a "disclimax" forest that will not change much with time because there are not other species present in the plot to challenge it. The second plot (no. 7) was a somewhat different situation. *Adenanthera* comprised 20 of the 26 trees and 59% of the relative dominance in the plot, but three large *Terminalia catappa* trees comprised 41%. There were also two small individuals of native canopy trees present, *Calophyllum inophyllum* and *Guettarda speciosa*, so perhaps the plot will slowly revert back to limestone forest if given enough time.

Figure 8. Secondary Forest dominated by *Adenanthera pavonina* (red-bead tree) and *Ficus prolixa*.

Several of the other plots of disturbed limestone forest had large amounts of *Adenanthera*, some had none. It is possible that the tree does not spread very readily, but when it does become established in an area, it is likely that it will remain there for a very long time and may become dominant. Secondary forest is particularly common where the soil is deep or intact. Areas that are rocky instead are often dominated by limestone forest species, especially *Ficus prolixa* (Pacific banyan).

The only other trees species found as secondary vegetation in some locations are *Leucaena leucocephala* and *Casuarina equisetifolia*. Although more extensive in the past, *Leucaena leucocephala*, is found growing spontaneously in some unmined or reclaimed habitats on Topside and in some disturbed sites on the escarpment and on the coastal strip. *Casuarina equisetifolia*, although probably native to some larger Pacific Islands, is an introduction to Nauru. Although more common in the past, it is still present where it has spread on to some mined areas from the Topside workshops.

Discussion

As stressed by Thaman (1992), Nauru is one of, if not the, most degraded and disturbed island in the Pacific. The most significant changes in the vegetation and flora of Nauru are related to several factors: (1) the almost total clearance of the limestone forest; (2) the threatened status or loss of some important native and culturally important species; and (3) the expansion and increased dominance of some non-native invasive species, i.e., weeds. Long habitation, over a century of phosphate mining, rapid urbanization, and the abandonment of agriculture and subsistence activities have taken their toll on Nauru, resulting in over 90% of the vegetation of the island being severely disturbed. Most of the interior comprises a rugged, impassible topography of pinnacles and pits or crevasses that are almost impossible to traverse. Most of the topsoil of the interior was removed long ago, and as stressed by Manner et al. (1984), the limestone pinnacles are an unsuitable habitat for the re-establishment of native forest. In the early 1980s, over 70 years after mining, there has been very little regeneration of any native plants on the mined areas. Re-vegetating it presents many difficulties. Most of the little remaining areas of relatively undisturbed vegetation are located on the rugged escarpment, which because of its slope and rocky nature, has been unsuitable to both agriculture and phosphate mining. The coastal vegetation has also been severely impacted by centuries of habitation and human usage, so that almost no littoral forest has survived.

Even prior to the extensive human disturbance, Nauru had a limited flora because of its small size, isolated location in the vast Pacific, dry climate, lack of surface water, and limited habitat unfavorable to the development of a complex flora. The number of native species is considered to be 56, a small number for a elevated limestone island of this size, but high when compared to nearby, lower atolls. During the current inventory, only 42 of the native species were found. The missing ones are very rare, are extirpated from the island, or are "ephemerals" that occurred only for a short time and naturally disappeared. While no plant species is endemic to Nauru and most are probably elsewhere in the region, they are an integral part of the environment and it is important to maintain as much of the original flora as possible. No plants would qualify for "red-listing" as globally threatened or endangered, since all of them are found elsewhere in the Pacific. Eight of them are, however, listed in the recommendation section for some kind of protection and promotion status, as they are a natural part of the Nauru environment and/or have traditional uses or importance in Nauruan culture. A recommendation for listing of eight native species for some kind of protected status is shown in the recommendation section (6.1). All the native and naturalized plants found on Nauru are shown in Appendix 1.

Although the species of the limited native flora of Nauru have been severely out numbered and impacted by alien weedy species, many of the native species are still present, but unfortunately often in an endangered state. Approximately 125 weedy alien species have been recorded from the island, and most of them are still present. Native species often still dominate most habitats, including the later stages of the mined pinnacle topography of Nauru. While floristic degradation in Nauru appears to be among the most severe in the Pacific, the current flora still constitutes an important ecological and cultural resource that must be protected as part of the development process, and NOT as an afterthought.

The expansion and increased dominance of some non-native invasive species, especially *Adenanthera pavonina* (*bin*), have been quite dramatic in modern times. *Adenanthera* now forms almost monospecific stands in the area to the south of Buada Lagoon and in some remaining unmined areas just on the landward edge of the escarpment in the northern part of Anibare District. The spread of this tree species has undoubtedly inhibited the dispersal and regrowth of, and taken over habitats that could have been colonized by, native trees and other species that are important culturally, ecologically and as habitats for local birds and smaller plants. See recommendation 6.6.

Adenanthera pavonina is by the far the most invasive and damaging species. Several other species in the weedy flora are declared noxious weeds, but while they may be common on Nauru, none are seen as significant threats to the flora and vegetation of Nauru. Perhaps the species closest to being troublesome on the island is *Sphagneticola trilobata* (wedelia; formerly called *Wedelia trilobata*), which is spreading in some places to take over the ground cover, especially around Buada Lagoon. *Leucaena leucocephala* (bin) is also common and sometimes spreads and forms dense, monodominant thickets, but these probably do not affect the native species nearly as much as *Adenanthera pavonina*.

The damage to and loss of Nauru's native vegetation and flora is extensive, but this can be addressed to some degree in several ways, some of which are listed in the recommendations below. People have been living on the island for centuries and will continue to live on it for centuries, but it would be a much better life if the land was returned to a useable condition with plants that can provide both goods and ecological service to future Nauruans.

Conservation Recommendations

Based upon the field work carried out by the lead author during the survey, and upon the experience of the co-author in Nauru over the last 30 years, the following recommendations are made.

1. LISTING RARE PLANTS

A list of threatened, rare, or endangered plants on Nauru should be drawn up, and legislation passed to protect these species. The owners of land on which rare and endangered species are found should be notified of their presence and encouraged to take measures to protect and rehabilitate them. Thaman et al. (2008a) noted that about 30 of the native plants on the island are "extirpated (locally extinct on Nauru), rare, threatened or vulnerable." If nothing is done, many of these species will ultimately be lost or will be in such low numbers as to be of little future value to Nauruans. Many of these species have been used in traditional ways in the past and are still used when presently available. The list below comprises nine native species that should be considered for some kind of protective status. These are not candidates for "red-listing" because, while rare on Nauru, most of them are common elsewhere in the Pacific.

(1) *Aidia racemosa* (*enga*)—This limestone forest tree is an extremely rare species known from only two localities on Nauru, possibly now from only one, on the escarpment above Anibare Bay. A population size, now very small indicates this species is close to extinction, and requires urgent conservation measures.

(2) *Bruguiera gymnorrhiza* (*etõm*)—This mangrove tree is restricted to a few coastal ("anchialine") ponds and soaks in Meneng, Ijuw, Anetan, and Anabar. These areas were used to raise milkfish in the past and now contain large populations of *Tilapia*, a fish that could serve as an important protein source. The presence of the *etam* tree assists by its production of leaf litter and ability to act as a water purifying agent. The species therefore needs to be carefully conserved and further clearing restricted in the vicinity of the ponds.

(3) *Cordia subcordata* (*eongo*)—This littoral tree was recorded from seven localities in Aiwa, Buada and Nibok in the 1980s and 90s, but as of 2009 is now known in only three or four locations, in all cases as single trees, mostly in urban areas. It was seen only once during the present survey and is probably rare because of the loss of coastal habitat (littoral forest) everywhere on the island. The timber is possibly the most highly prized in the Pacific.

(4) *Erythrina variegata* (*eora*)—This littoral forest tree is less restricted now than it was in the 1990s, but is still threatened, and needs to be protected to survive in Nauru. It was seen only once during the present survey, and is probably rare because of the loss of habitat (littoral forest) all the way around the island.

(5) *Hernandia nymphaeifolia* (*etiu*)—This littoral forest tree has been recorded in only four localities on Nauru, where it grows naturally in the forests near the base of the escarpment. The timber was formerly prized for canoe hulls. It was found in only one location during the present survey.

(6) *Ochrosia elliptica* (*eoerara*)—This small, attractive tree with bright red fruit can also be planted as a shade tree in coastal situations. It is currently restricted to five to seven localities in five Districts. It is also found as an understory species in relict forest on topside and on the more gradually sloping parts of the escarpment.

(7) *Pisonia grandis* (*yangis*)—This littoral forest tree is severely restricted in the wild to four to five sites at present, three of which are on the upper, steepest parts of the escarpment, and two in relictual areas on topside. It occurs as an emergent in the forest dominated by *Calophyllum inophyllum* and *Ficus prolixa*, and is known throughout the Pacific to be a favorite nesting site for noddies. An examination of each locality indicates that the species is not regenerating naturally through seedlings. This situation is observed elsewhere where reproduction occurs through the rooting of fallen branches. In the Nauruan situation however, the presence of large numbers of *Adenanthera pavonina* seedlings in the understory suggests that this species may possibly interfere with the competitive ability of the *Pisonia* to regenerate, but this needs further clarification.

(8) *Rhizophora stylosa* (*dadongo*)—This mangrove species was a new record for Nauru in the 1990s, and was observed at two localities on the edge of the ponds at Ijuw and Anabar. As such, its distribution is extremely restricted by availability of the right habitat, which makes it all the more important to conserve these mangrove areas.

(9) *Thespesia populnea* (*itira*)—This littoral forest tree is now uncommon along the coastal margins of mangroves in Anetan, in a number of coastal sites in Meneng and Aiwo, and occasionally in houseyard gardens. It is considered the best wood for traditional house construction, woodcarving, furniture and canoe outriggers, and is one of the best trees for replanting and coastal reforestation.

2. AWARENESS OF OTHER RARE NATIVE SPECIES

Several other native species may have been extirpated from the island, including *Sida fallax* (*ibidin kaura*), *Achyranthes canescens*, *Neisosperma oppositifolium*, *Chamaesyce chamissonis*, and *Ipomoea littoralis*. DCIE staff and visiting botanists should be on the lookout for these rarest of rare Nauruan species. Also of interest are what appear to be "ephemeral" species that arrive on the island, grow in one place where they are record, but naturally die out, in fact, as suggested above, *Chamaesyce chamissonis* could fall into this category. Ephemeral species are a natural occurrence and do not have the same importance as native species established on the island. In the case of *Sida fallax*, which along with *Abutilon asiaticum*, are both considered of cultural importance for use in garlands, although probably extirpated, it could be re-introduced from Kiribati, where it is still common on some atolls, such as Abemama and Kiritimati Atolls.

3. PROTECTING THREATENED HABITATS

Reiterating the recommendations by Thaman *et al*. (2008a), the protection of existing stands of coastal, escarpment and inland forest and threatened individual plant populations is seen as the highest priority, because so little remains that there is a danger of losing all of the original limestone forest of the interior as re-mining and rehabilitation takes its toll. The focus of protection should include not only "natural" vegetation and indigenous plants, but also the cultural vegetation and plants found in and around settlements, which often include some of the most important food and multi-purpose plants. Priority sites for forest protection and management should be those showing the lowest level of disturbance, the highest species richness, the greatest numbers of rare or endangered species, and the most value as wildlife habitat. Particular emphasis should be placed on those sites and species (e.g., *Pisonia grandis*, *yangis*) that are important as noddy bird rookeries, because of the special cultural importance of noddies and noddy hunting in Nauru. It is important that local communities (resource users and owners) and their representatives are involved in the planning, implementation, monitoring and modification of the protection, planting and maintenance of these areas. If they are not involved in the beginning, such initiatives, many of which can be done at the community or household level, will probably not work. Based on these criteria , and supporting the recommendations of Thaman et al. (2008a), the priority sites for protection status as conservation or sustainable-use areas, and which should be considered for formal designation as conservation areas, include the following:

(1) The entire Anibare Bay area from the Meneng-Anibare District boundary to the Anibare-Ijuw District boundary, and including the Meneng Hotel and extending up the escarpment to the edge of current mining).

(2) The east and west coast escarpment forests (this would include the Anibare escarpment, which, as stressed above, has special significance) are proposed because they are important aesthetically as green buffers to topside, as important bird habitats, as refuges for rare and endangered species of plants, and for potential recreational purposes.

(3) The Ijuw-Anabar-Anetan mangrove and wetland area because of its unique ecological importance, stands of mangroves and scenic beauty.

(4) Buada Lagoon (a unique landlocked freshwater or slightly brackish central lagoon) and suitable portions of the remaining forest in the Buada basin. As stressed by Hassall (1994) the Buada lagoon forest and soils surrounding the lagoon have the greatest potential for agroforestry and food production.

(5) Selected un-mined rocky outcrops as wildlife habitats and examples of pre-mining ecosystems. This would include the remaining forest areas behind Buada Lagoon). There remain very few such areas, but consideration should be given to their protection

(6) Command Ridge and the railway zone of Topside as a possible focus for historical and environmental-based ecotourism, once mining has ceased. This area contains the deepest mining, about 20 meters deep, and the "Grand Canyon" of Nauru, and the most advanced natural regeneration in mined sites. Because it was hand-mined at a very early stage of mining, there is probably less residual phosphate and less reason for re-mining (Thaman et al. 2008a).

(7) Selected noddy nesting sites (rookeries) and tree groves along the crest of the escarpment.

(8) The coastal littoral zone in which all mature coastal trees and forest remnants within 50 m of the mean high tide line should be protected (this would include the implementation of an active program of coastal reforestation and enrichment planting with endangered or culturally-useful salt-tolerant trees, which is discussed below). These areas and their trees should be protected immediately and, where possible, enriched with the planting of appropriate indigenous and introduced species.

4. COASTAL REPLANTING

Because of the critical role that coastal trees play in coastal protection, replanting of selected trees should be carried out as part of a comprehensive agroforestry program. A public awareness campaign should be carried out to stress the importance of the protection and replanting of coastal forests and trees as protection against coastal erosion, loss of property and other negative effects of sea-level rise. The campaign should also stress the cultural and economic importance of indigenous cultural species and why they should be protected and replanted as part of the cultural heritage of Nauru. Thaman et al. (2009a) gives a detailed plan of how the coastal replanting should be done.

5. REHABILITATION OF MINED LAND

The program needed the most on Nauru is the rehabilitation of the highly degraded interior of the island. In contrast to the focus on protection, enrichment and restoration activities, this will require grading and site preparation, followed by all new planting. This should only be done on areas that have already been re-mined so that there will be no further disturbance to the site. There is already a rehabilitation plan in effect, but it has at least two major problems. First, the species being used are not all native species, and there seems to be no logical replanting plan. Second, one replanted area seen during the survey had recently been bulldozed and cleared to make way for some new development. There is no sense in replanting an area if it is going to be used for another purpose, as the reestablishment of native forest seems currently to have a low priority. Thaman et al. (2009a) gives a detailed plan of how the rehabilitation should be done. There needs to be more coordination between government agencies. Importantly, naturally regenerating vegetation older than approximately 10 years should not be touched.

6. CONTROL OF THE RED-BEAD TREE

Adenanthera pavonina (red-bead tree) is by far the most invasive and harmful plant species on Nauru. In one plot sampled during the present survey (plot 8), all but one of the trees in the sample was this invasive species, and virtually all of the seedlings as well. The lead author has never seen such dominance by one species in any Pacific forest before. A study should be made to see if there are appropriate control measures. Without some kind of control, this tree will continue to severely restrict any return of the damaged vegetation to native forest.

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CHAPTER 2

TERRESTRIAL INVERTEBRATES OF NAURU AND THEIR CONSERVATION

ERIC EDWARDS

Summary

- The terrestrial invertebrate fauna of Nauru is broadly sampled for the first time. New records of moths, land snails and ants are reported including at least one identified new endemic moth species.
- Moth richness was low and only 51 species (46 new records for Nauru) were detected but a reasonable richness of 19 moth families was recorded. Eleven out of 13 land snails are reported (including six new records).
- Forty percent of both the moth and land snail fauna is native and 100% (all six) dragonflies are native, but for the ants; 100% or seventeen newly recorded species are exotic.
- Thirteen species of land snails are now known from Nauru, including three endemic species, two widespread Pacific species that are probably indigenous to this island, and eight introduced species. One endemic species recorded by Boettger (1904) was not found at all during the present survey, and another species was represented by a single old empty shell. Both these land snails are possibly extinct.
- Faunal habitats are highly disturbed and invaded by exotic snails, insects and plants
- A new incursion of the yellow crazy ant, a highly destructive and invasive pest species, was detected in the port. It may be possible to eradicate this small population and urgent assessment of the option is recommended.
- Despite the strong representation of exotic moths, ants and snails, many of the most damaging pests present elsewhere in Micronesia have not yet arrived on Nauru, providing the opportunity to protect Nauruan species from the scale of biodiversity losses seen on northern Mariana Islands and other islands where for example yellow crazy ant, red imported fire ant, giant African snail and cannibal snail have established.
- The indigenous character of Nauru biota includes; a generally low number of terrestrial invertebrate species, a high proportion of Pacific wide and world-wide insects, and, a small proportion of island endemic insects and snails. It reflects a geologically young, isolated and small land mass representative of Oceanic nations but distinct from Pacific Rim.
- The Nauru Rehabilitation Corporation programme mining residual phosphate and also rock resource and then levelling (restoring) the land is to sustain livelihoods and provide for infrastructure or food production. The assessment shows this work is destructive for biodiversity.
- The old mined pinnacles areas are not a wasteland. We recommend many specific areas of pinnacles are to be celebrated as Nauruan in landform, visual impact, culture and biodiversity.
- With this integration of values in mind, we propose five land and shoreline areas for conservation protection. These should be evaluated by local communities (See Figure 19).

Introduction

Nauru (21 km^2) is a small elevated limestone (makatea) island on top of an isolated seamount in the open Pacific. It is not closely associated with any archipelago but is usually associated with either the large Micronesia region east of the Philippines and north of the Solomon Islands/New Guinea Region, or, with Kiribati archipelago. Its interior and coastal reef landforms are not like the typical atoll landforms of its nearest neighbours apart from the much smaller Banaba (Ocean) Island (6 km^2) about 320 kilometres east of Nauru. Nauru is quite isolated in its oceanic position and has a mild but drought prone equatorial climate. This has made it a natural haven for massive seabird colonies and for development or at least retention of deep phosphate rich soils. Note that a marine or guano origin for the phosphate is not currently resolved (Morrison and Manner 2005). Being an isolated raised seamount, insects, snails and other fauna have assembled from long distance dispersal and island hoping. Typical of many Pacific oceanic islands, drift, seabird dispersal and long aerial journeys will have all played a part. Evolution of Nauru endemic species will be limited also due to the geologically young age of volcanic seamount derived land.

While northern Micronesia has some of its fauna derived from Asia and Japan, Nauru is at the southern extreme of Micronesia whose native fauna is derived from sources in the central Pacific, from New Guinea/Solomons and from Philippines (Gressitt 1954, Munroe 1996, Clouse 2007). In many such islands, the number of exotic insects and other invertebrates is continually increasing through human introductions.

Although not well sampled, the fauna of Gilbert and Marshall Islands nearby has a low species richness when compared to similar sized islands near to larger land masses (Gressitt 1954, Gates Clark 1976, Munroe 1996, Clouse 2007).This can be expected for Nauru for similar reasons of geological or evolutionary young age, remoteness from large land masses, small size, lack of streams and simplicity of ecosystems.

Habitat management is in the context of a rich Nauruan culture that retains strong village association with the land, despite mining rights or urban and infrastructure development over most of the island.

Much of the rock phosphate resource available for mining has been extracted. However, an inter-decadal Master Land Use Plan run by the NRC – Nauru Rehabilitation Corporation is mining a secondary phosphate resource among the mined phosphate lands. And this includes proposals of using local resources (soil and rock) to rehabilitate some of the mined phosphate lands (Nauru National Assessment Report; Anon May 2013). Both this analysis and the recent United Nations Food and Agriculture Organisation assessment for Nauru's future (Fa'anunu 2012) identify scarcity and competing demand for existing soils. But sustaining Nauruan identity through protection and rehabilitation of natural areas is proposed along with many other proposals (Fa'anunu 2012, Anon 2013).

In June 2013 a biological survey – BIORAP completed extensive sampling. The GEF Implementing the Island Biodiversity Programme of Work by integrating the conservation management of Island Biodiversity Project (IBP) supported a partnership between the Secretariat for the Pacific Regional Environment Programme (SPREP), the Ministry for Commerce, Industry & Environment (CIE) and local communities on Nauru, to investigate and describe the land and marine biota, and recommend appropriate conservation actions.

Prior to this survey, Nauru's fauna is almost entirely undocumented with no major Micronesian insect study including Nauru in their surveys. Nauru as a species locality does not appear in the 'Insects of Micronesia' series running from 1954 to the present. Thirty-two land invertebrate species including five moths/butterflies, five beetles, two grasshoppers, six dragonflies/damselfly, four mosquitoes, a tidal reef bug, five spiders and five land snails are the only records noted (Rainbow 1903, Boettger 1904, Belkin 1962, Herring and Chapman 1967, Buden 2008, Buden and Tennant 2008). Froggatt (1910) notes Nauru insects and names beetles, cockroaches and earwigs but the names are tentative and not relied on here.

These groups were all recorded during the rapid inventory process. But this report focuses on moths, butterflies, and land snails to gain insight on ecological associations with vegetation and invertebrate biogeography. To further interpret invertebrate invasion, ants were also targeted. This report focuses on terrestrial invertebrate values, landscape ecology and threats, and suggests management implications that can be shared with local community leadership.

Methods

Following an initial drive around the island and across the interior 'topside', three representative sites were chosen for intensive sampling by a team assembled from local and international expertise. These included an area of shallow permanent ponds close to the northern shore at the toe of a scarp slope including exposed limestone pinnacles and mixed disturbed shrub and forest vegetation. Soils were dominated by coral rubble and leaf litter. The second site was among a plot of trees in the sheltered interior village of Buada Lagoon with soils dominated by stones but including an organic component and woody debris. The third site was set in the margin of Adenanthera/Terminalia dominated forest on original phosphate soil which contrasted with open sparsely vegetated limestone pinnacles where phosphate had been mined.

Five methods were used for insect, snail and spider sampling. These included, insect malaise trapping, pitfall trapping, litter sampling and insect light trapping (Figures 1 -7). Light trapping also occurred in a few other sites and hand collecting often with a sweep net occurred in all three sites and in general survey.

Figure 1. Hand collecting with nets. Darner dragonfly Buada Lagoon.

Figure 2. Insect malaise trap Anabare topside between bush and pinnacles.

Figure 3. Pitfall sample of insects

Figure 4. Litter sampling site – Denigomodu topside old pinnacles

Figure 5. Litter sorting

Figure 6. Light trapping

Figure 7. Curating the insects

Insect malaise traps (Figure 2) are suitable for sampling a great range of very mobile insects and spiders during the day or night in relatively sheltered but open areas associated with forest margins. The trap is made from a fine mesh in a tent shape and is similar in size to an actual two person tent. It traps insects that fly into the mesh and then walk up through a mesh funnel where they fall and accumulate in a preservative solution. Malaise traps can be set in place for several days with sampling jars replaced every few days.

Pitfalls were created using eight plastic cups (~13 cm in diameter) dug into the soil adjacent to a malaise trap at each site. Each was filled four cm deep with water and five ml detergent to aid retention of invertebrates. Every few days, the sample was retained on a sieve and then preserved in 80% ethanol to be sorted later. Ground dwelling invertebrates sampled in this way can include land snails, ants, spiders, centipedes, beetles and many other invertebrates (Figure 3).

Litter samples were also collected at each of the three sites and some additional sites by scraping litter plus loose topsoil in a net where all large wood, stones and leaves are removed and the remaining material bagged for later sorting (Figure 4). Our team used shallow trays and forceps to pick out small land snails, ants and other insects (Figure 5).

Insect light trapping begins at dusk and continues for about three hours. A powerful 240 volt 120 watt mercury vapour ballasted ultraviolet light powered by a portable generator was used to attract moths, queen and drone ants, beetles, flies, bugs and other winged insects. A large white sheet is placed on the ground and the light placed in the middle (Figure 6). Expedition team members captured specimens of as many species as possible individually in small plastic jars to be later preserved and identified.

Simple hand collecting techniques were based on observing insects in a range of habitats and capturing samples in small plastic jars for later curation. A sweep net was also used aerially or through vegetation to capture moths, ants, beetles, bugs and flies. Observations were made during the night as well as in daylight.

COLLECTIONS

While snails, ants and moths were the key target, a general collection of invertebrates was made including beetles, flies, wasps, bugs, spiders, and smaller invertebrate orders (see Figure 7) for later analysis and reporting elsewhere. Collections will eventually be housed in the New Zealand Arthropod Collection (NZAC) in Auckland with most material presently held by the author for analysis and determination of new species. NZAC is an institutional insect collection with a strong representation of collections from many Pacific Islands – particularly Lepidoptera (i.e. moths and butterflies). Some of the material can potentially be studied in association with other institutions with Pacific collections such as the Bishop Museum in Honolulu.

Process of identifying taxonomic richness for snails, ants and moths

Identification of taxa curated from the expedition was carried out by comparison with other collections and by use of published works for Micronesia, Marquesas, French Polynesia, Hawaii, Samoa and Fiji. See the list of references but some of the key sources include:

- Te Papa Tongarewa Museum of New Zealand collection and Boettger (1904) for snails;
- New Zealand Arthropod Collection – NZAC and Clouse (2007) for ants and
- NZAC, Zimmermann (1958,1978), Robinson 1975, Gates Clarke (1986), Oboyski (2013), and keys to Lepidoptera families (Dugdale 1988, Nielsen & Common 1991).

Many species might be only determined by detailed genitalia dissections and comparison with original Type specimens and in some cases would be new to science. Such 'species' have been listed as un-named or 'tag named' taxa and are given a numerical code in the attached Appendix 1. For moths, some caterpillar host plant associations were drawn from literature (including those listed above, as well as online databases, Herbison-Evans & Crossley (2012), Robinson et al. (2012). Family nomenclature for moths follows Van Nieukerken et al. (2011).

Results

We found a simplified invertebrate fauna of relatively low species richness. Many components were dominated by introduced and often globally distributed species. Some indigenous species were recorded and species extinctions appeared likely. A high proportion of the native fauna is also native to the other islands of Micronesia and occurring more widely on far flung island archipelago such as Marquesas Islands or French Polynesia (see examples Figures 8 a-l and Appendices 1 & 3).

Figure 8a. Nauru endemic tidal rock bug *Corallocoris nauruensis* rediscovered at Anibare Bay (Photo D. Roscoe).

Figure 8b. Probable new endemic discovery for Nauru; micro-moth Stigmella new species. Caterpillars mine leaves. It's likely plant host is *Laportea ruderalis* (Urticaceae) (Photo D. Roscoe).

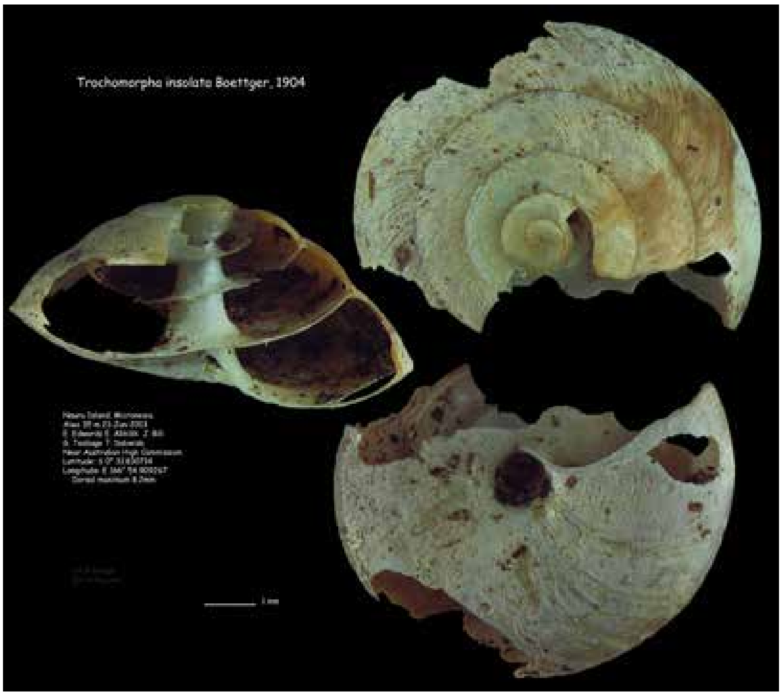

Figure 8c. Land snail *Trochomorpha insolata* shell. No live individuals of this Nauru endemic were found and this may possibly be an extinct species (Photo D. Roscoe).

Figure 8d. Land snail *Sturanya subsuturalis* A Nauru endemic found in many localities but still at risk from further invasions of pest ants and predatory snails (Photo D. Roscoe)

Figure 8e. Pacific almond blue butterfly *Petrelaea tombugensis*. Larvae feed on Terminalia catappa a widespread native tree on Nauru.

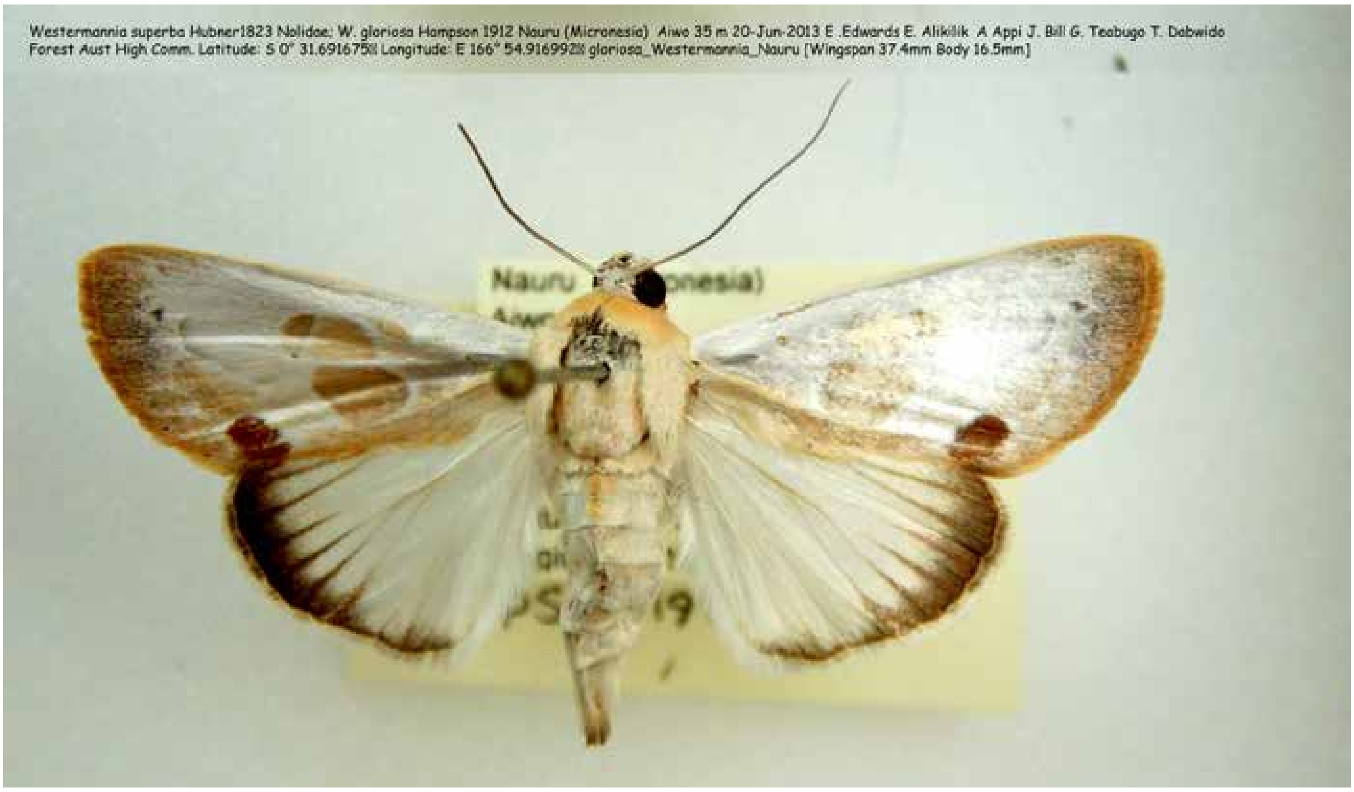

Figure 8f. A large tuft moth *Westermannia superba*. First Pacific islands record of this moth otherwise known from Australia, New Guinea and Southeast Asia. Caterpillars also feed on *Terminalia catappa*.

Figure 8g. White browed hawkmoth caterpillar *Gnathothlibus erotus* feeding on native *Morinda citrifolia* tree.

Figure 8h. Monarch butterfly caterpillar *Danaus plexippus* feeding on the garden milkweed *Calatropis gigantea*.

Figure 8i. Damselfly *Ischnura aurora* common in rushes and grass near ponded water.

Figure 8j. Huntsman spider with sac of juveniles. Commonly seen at night on pinnacles clothed in forest. May be the widely distributed banana spider *Heteropoda venatoria*.

Figure 8k. A common millipede on Nauru.

Figure 8l. A scorpion species found on Nauru

MOTHS LEPIDOPTERA

As a key target group, moths and butterflies were not well sampled and given a tropical island environment, a low species richness of 51 taxa was recorded (Appendix 4.). Four butterflies were previously known and three of these were reconfirmed with the fourth species, almond skipper butterfly almost certain to be present as unobserved larvae rather than easily observed adults. Nineteen families of moths with three butterfly families were recorded and 30 taxa identified to species level. The most species rich families of moths were Tineidae with eight taxa, Crambidae with seven and Noctuidae with seven. The other families had three or less taxa and fifteen families had only one species representative (Appendix 4). Table 1. shows eighteen exotic introduced moths and thirteen putative native moths with twenty species of unknown geographic origin. Forty-six moth taxa including twenty-six identified species are new records for Nauru.

LAND SNAILS

Eleven species of land snails were found during the survey, of which two were endemic, two were probably indigenous, and seven were exotic (Figures 8 b & C; Appendix 4). Two of the species recorded from Nauru by Boettger (1904) were not found during the present study, namely the endemic *Trochomorpha contigua* var. *nauruana*, and exotic species *Opeas heptagyrum*,. Another endemic species recorded by Boettger (1904), *Trochomorpha insolata*, was represented by a single old broken shell in the 2013 survey collection. A third endemic species, *Sturanya subsuturalis*, was relatively widespread and locally common.

Table 1. Comparing the number of indigenous (native) species versus exotic introduced species for some invertebrate groups and vascular plants of Nauru.

Invertebrate group	Total number of taxa recorded	Putative number indigenous to Nauru	Exotic introduced species	Taxa of unknown origin (excluded from % calculations)
Moths and butterflies -Lepidoptera	51	13 (42%)*	18 (58%)	20
Ants -Formicidae:Hymenoptera	17	0	15 (100%)	2
Land snails -terrestrial Gastropoda	13	5 (38%)	8 (62%)	0
Dragonflies and damselfly -Odonata	6	6 (100%)	0	0
Plants**				
Vascular flora of Nauru	493	57 (12%)	434 (88%)	
Flora excluding garden ornamentals	236	57 (24%)	177 (76%)	

* note percentages exclude "taxa of unknown origin"

** Plant data from Thaman, Fosberg, Manner and Hassall (1994)

ANTS

Seventeen ant species (Hymenoptera: Formicidae) are recorded for the first time and all are exotic with many significant as ecosystem pests and pests of crops and households (Appendix 4). Yellow crazy ant, *Anoplolepis gracilipes* was only recorded among containers and a shed at the Aiwo port facilities and appears to be a recent invader confined to the port. Yellow crazy ants are renowned for their impact on native island ecosystems and species in the Pacific.

ODONATA

Five out of six known Odonata (dragonflies & damselfly) were recorded and all are native but also Pacific wide species.

OTHER INVERTEBRATES

Appendix 4 shows numerous species of several other insect families and orders that were curated for further analysis including ten families of wasps (Hymenoptera) and species among another twelve insect orders.

In addition to insects; thirteen families of spiders are noted for further analysis and another eight invertebrate classes are also available (Appendix 4.)

ENDEMIC INVERTEBRATES

In reviewing the literature, only 32 land invertebrate species were noted as being reported from Nauru. Sixteen of these were identified during the survey with unidentified spiders, mosquitoes, beetles and grasshoppers probably bringing the total to 23. The 32 species included; moths/butterflies, beetles, grasshoppers, dragonflies/damselfly, mosquitoes, a tidal reef bug and land snails. The only known Nauru endemic invertebrates (not known anywhere else) include three land snails and one tidal reef inhabiting bug. Of the three land snails, *Sturanya subsuturalis* (Figure 8d) is widespread and common on the island but still vulnerable to decline and extinction. The other two *Trochomorpha* species snails discussed above are rare or extinct. The tiny 2 mm long tidal reef bug *Corallocoris nauruensis* is only known from northern Anibare Bay on limestone rocks emergent from the tide (Figure 8a). Emergent rocks in the marine intertidal zone are a small minor habitat for Nauru suggesting a vulnerability to decline or extinction for this island endemic bug.

GEOGRAPHIC ASSOCIATIONS OF THE NATIVE FAUNA

Putative native species are recorded (Appendix 4) for 10 moths, three butterflies, four snails, five dragonflies and a few other species. The geography of associations with other Pacific Islands and land regions elsewhere shows two extremes. A handful of native or indigenous species are entirely endemic to Nauru. But by far most indigenous species (eg. insects and snails that arrived without the assistance of man) are also pan Pacific and often known from Australia, New Guinea, Indonesia, and Asia as well. The limited data does not indicate a faunal element particularly confined to a group of Micronesian Islands (Appendix 4.)

Discussion

Surprisingly for Nauru, this is the first general terrestrial invertebrate survey. Historically, only 27 species of insects and five species of snail have been previously reported. However resurveying for the Nauru endemics among these has provided valuable insights. Of three endemic snails last noted in Nauru over a hundred years ago (Boettger 1904), one (*S. subsuturalis*) remains common and widespread on the island but the other two *Trochomorpha* species are rare or extinct. A tentative assessment of extinction threat for these three snails (IUCN Red List threat of extinction, Appendix 5.) finds the two *Trochomorpha* species to be critically endangered.. And, the land snail *S. subsuturalis* tentatively vulnerable (IUCN 2012, ver 3.1 2nd ed. categories and criteria). Key to these findings is the small total land area of Nauru, coupled with extensive soil fragmentation and the threat of new invertebrate predators such as further ant species or predatory exotic snails that might arrive – having already colonised some other Micronesian islands of the region.

Figure 9 a & b. Anabare Bay dolomatised limestone pinnacles in the tide. Spectacular landform and habitat for Nauru endemic bug *Corallocoris naruensis*.

The forth previously reported endemic is a tiny bug (*Corallocoris nauruensis*; Figure 8a confined to a specialised marine intertidal habitat among limestone rocks presently only known at Anabare Bay (Figure 9 a & b). *Corallocoris nauruensis* is one of only four species in the family Omaniidae (Polhemus 1976) and while not yet assessed, potentially the most threatened and vulnerable. Its phylogenetic distinctiveness adds weight to its priority for protection along with its habitat which is distinct from typical atoll lagoon and reef. Rather than raised coral, the fringing rock platform of Nauru and the resistant stone pillars of Anabare Bay are composed of hard dolomitised limestone (Morrison and Manner 2005). While there is some limestone reef only 320 kilometres away at Banaba Island, such geology and landform must be considered rare in the Pacific. On Nauru this is one of the most natural habitat classes that remain.

NATIVE VERSUS EXOTIC SPECIES

Table 1 compiled from the annotated species data in the appendix suggests that across diverse groups such as moths ants, dragonflies and land snails, pan Pacific species or pan tropical species make up more than half the fauna. It is interesting to note that for dragonflies which are all at least pan Pacific, they are also classed as native. But in the case of ants, they are all classed as tramp species with likely human assisted recent arrival (Wilson and Taylor 1967, Clouse 2007). Evidence from analysing the species richness of island archipelagos and island remoteness in the Pacific and for the Micronesia – Kiribati region (Wilson and Taylor 1967, Clouse 2007) suggests there were few if any native ants on Nauru prior to human intervention. Nauru's land snail fauna contrasts with the dragonflies and ants since natives include both tramps and island endemics (Appendix 4). and the picture of invasion and extinction is more similar to that documented for plants (Thaman et al. 1994). Two native land snails are possibly extinct and if so then the percentage of exotic land snails reflects the percentage of exotic vascular plants (Table 1). Cowie (2000) favours rare chance dispersal by wind and by seabirds for land snails suggesting that in either case smaller species would be favoured for islands such as Nauru that are both geologically young and remote. It is likely that Nauru experienced many hundred thousand years of dense seabird abundance though better evidence is needed to interpret this and to consider the influence on invertebrate dispersal that this may have had.

LEPIDOPTERA DISPERSAL

The moth fauna has been incompletely sampled in the brief survey time and it is a challenge to discern the native widespread moths from those that are introduced. The four butterflies are far better known in terms of species status, ecology and distribution. They are all Pacific wide species although the almond blue butterfly, *Petrelaea tombugensis* is probably not much further east than the Samoas. The monarch butterfly represents the common example for many insects where its host plant (*Calatropis* or *Asclepias* – Apocynaceae) has been spread throughout the Pacific in the 1800's providing the opportunity for monarch butterflies to colonise in the 1850's and 1860s. Many other insects of weedy plants and horticultural crops may have dispersed in this way along with the more usual introduction as a passenger of human cargo. Two native butterflies (almond blue butterfly *P. tombugensis* on flowers and almond skipper butterfly *Badamia exclamationis*) have larvae feeding on native almond *Terminalia catappa* which also grows from Australia to Asia and on most forested Pacific Islands. We also recorded the macro-moth *Westermannia superba* (Figure 8f) whose larvae feed on *T. catappa* and it has a similar distribution to the tree except it is not known from Pacific islands (Micronesia or Polynesia) and forms an enigma for Nauru. With decades of industrial shipping traffic frequently from Australia, *W. superba* is perhaps more likely an introduction than native. Molecular genetic analysis would solve this question.

LEPIDOPTERA ENDEMISM

While no moths confined to the island are presently known, there are most probably a few small micro-moth species endemic to Nauru. Possibilities for further study in the records include the discovery of minute leaf mining moth *Stigmella* species (Figure 8b), and another 18 moths among eight micro-moth families plus three Crambid taxa and one in Tortricidae (Appendix 4.). The tiny Nepticulid moth *Stigmella* species is of note for Nauru since Nepticulidae are rarely recorded for the Pacific with only four species ever recorded (van Nieukerken and van den Berg 2003). These are all in the genus *Stigmella* and all mine leaves of Urticaceae. The researchers, van Nieukerken and van den Berg (2003) note localities for the three un-named moths being Tahiti uplands, Rarotonga (Cook Is.) and from Moce Island (Fiji Is.). The only other record is *Stigmella ebbenielseni* from Mariana Islands including Guam, Tinian and Alamagan (van Nieukerken and van den Berg 2003). *Laportea ruderalis* (Urticaceae) is listed as indigenous to Nauru by Thaman et al. (1994) and its leaves are most likely the host for the new species discovered on Nauru. The alternative would be the moth is an exotic introduction which appears unlikely since no other Nepticulidae introductions for the tropical Pacific are recorded.

INSECT ENDEMISM

The survey results together with evidence from the series of Micronesian insect publications (Micronesiaca 1954 – present) suggests that a small number of endemic insects are likely to be detected in the future among moths, beetles and bugs curated from the survey. Across all of the Micronesian Archipelago and Islands, Gressitt (1954) cites Townes (1946) in estimating that from a fauna of approximately 7000 species of insects in the Micronesian region, 15% were [at that time] introduced, 45% were widely distributed Polynesian and East Indian species and 40% were endemic [to Micronesia]. However, for any one island and particularly in the case of Nauru, endemism will be much less than 40% and the proportion of exotic introduced species is much greater than 15% for Nauru (see Table 1). The geologically and evolutionarily young age of Nauru land above sea-level (perhaps only Pleistocene, Morrison and Manner 2005), means that endemic insect genera are very unlikely.

LEPIDOPTERA SPECIES RICHNESS

While the moth fauna is undoubtedly much larger than the 47 taxa sampled, the overall moth species richness is almost certainly much lower than for an island of equivalent size nearer to a large land mass (Gressitt 1954, Munroe 1996). The butterfly fauna was much more confidently sampled and is restricted to only four butterfly species with a very small chance it could be five or six. The butterfly species tally would be much greater for an island of similar size close to Papua New Guinea (Gressitt 1958 and see Parson 1999) simply reflecting the remoteness and size of Nauru.

Though the moth fauna has been supplemented by exotic species, the butterfly fauna has only the monarch species in addition to native but widespread species. Butterflies that could easily have been present but are not found include a number of widespread species where caterpillar host plants are ancient natives on Nauru. For example white butterflies Peridae with caterpillars that eat *Capparis* Capparidaceae; skippers Hesperidae with caterpillars on grasses; crow butterflies Euploea with caterpillars on *Ficus* (Moraceae); blue butterflies Lycaenidae with caterpillars on Fabaceae/Leguminosae and many others. That such butterflies are not present is a defining special feature of Nauru biodiversity.

FAUNAL HABITAT ASSOCIATIONS

The list of moths and butterflies in Appendix 4 includes notes on what each species' caterpillars eat (where known) and microhabitats include flower feeder, nut-borer, leaf miner and detritus feeder as well as leaf or shoot feeding. Many moths recorded are generalist feeders on a range of plants, but many specialise as well. Moths on grasses, Amaranthaceae, Cucurbitaceae, Fabaceae, *Calatropis, Callophylum, Cordia, Ficus, Laportia*(tentative), *Morinda, Pandanus* and *Terminalia* are included in Appendix 4. None of these clearly defines a particular habitat association for Nauru. The small tree *Cordia* and related *Tornefortia* (Figure 10) hint at coastal sites. For Nauru, these trees have moth *Ethmia nigroapicella* and probably other moth associations as well as attracting Daininae butterflies (only the monarch on Nauru). Some of the moth-plant associations are secondary cultural vegetation or garden of the coastal plain and the remaining are a component of almost any of three forest types described by Thaman et. al. (1994).

Figure 10. Coastal strand tree *Tournefortia argentea*. One of the hosts for Kou leafworm moth *Ethmia nigroapicella* and attractive for other butterflies including the male Monarch which is found on Nauru.

Morrisson and Manner (2005) have interpreted the pre-mining pattern of soils and therefore broad vegetation pattern and faunal associations in soils and vegetation. This pattern has been modified and in many areas grossly simplified by both dense settlement on the coastal plain and coastline of Nauru as well as widespread mining of the interior 'topside' of the island. Invasion by habitat generalists among plants (Thaman et. al. (1994) and invertebrates (e.g. ants, snails and moths Appendix 1) also provides elements common across many habitat areas and likely increases the rarity of distinctive invertebrates such as some native snails.

FRAMEWORK FOR RECOMMENDING REPRESENTATIVE AND DISTINCTIVE BIODIVERSITY CONSERVATION AREAS

In proposing and recommending biodiversity conservation areas as a key outcome from the BioRap analysis, an attempt is made to encompass representative, viable and best remaining examples of the ten land-system/soil classes mapped by Morrison and Manners (2005) together with good examples of post mining biological succession and historical mining infrastructure (see both Figure 11 and Figure 19.

There are however, two exceptions to this. The first is that Buada Lagoon has not been proposed to be protected for biodiversity values. Buada Lagoon is culturally highly important and a national strategy (Smith et. al. 2009) proposes management to gradually improve opportunity for crop irrigation. The second exception is the additional inclusion of the northern Anabare Bay rocky intertidal environment which includes insects and spiders on the marine interface (eg. *C. nauruensis*, Gerridae – bugs, Ephydridae flies and Desidae spiders). Clearly the Anibare Bay limestone platform can also retain a high value for seafood gathering and its dominant marine faunal component.

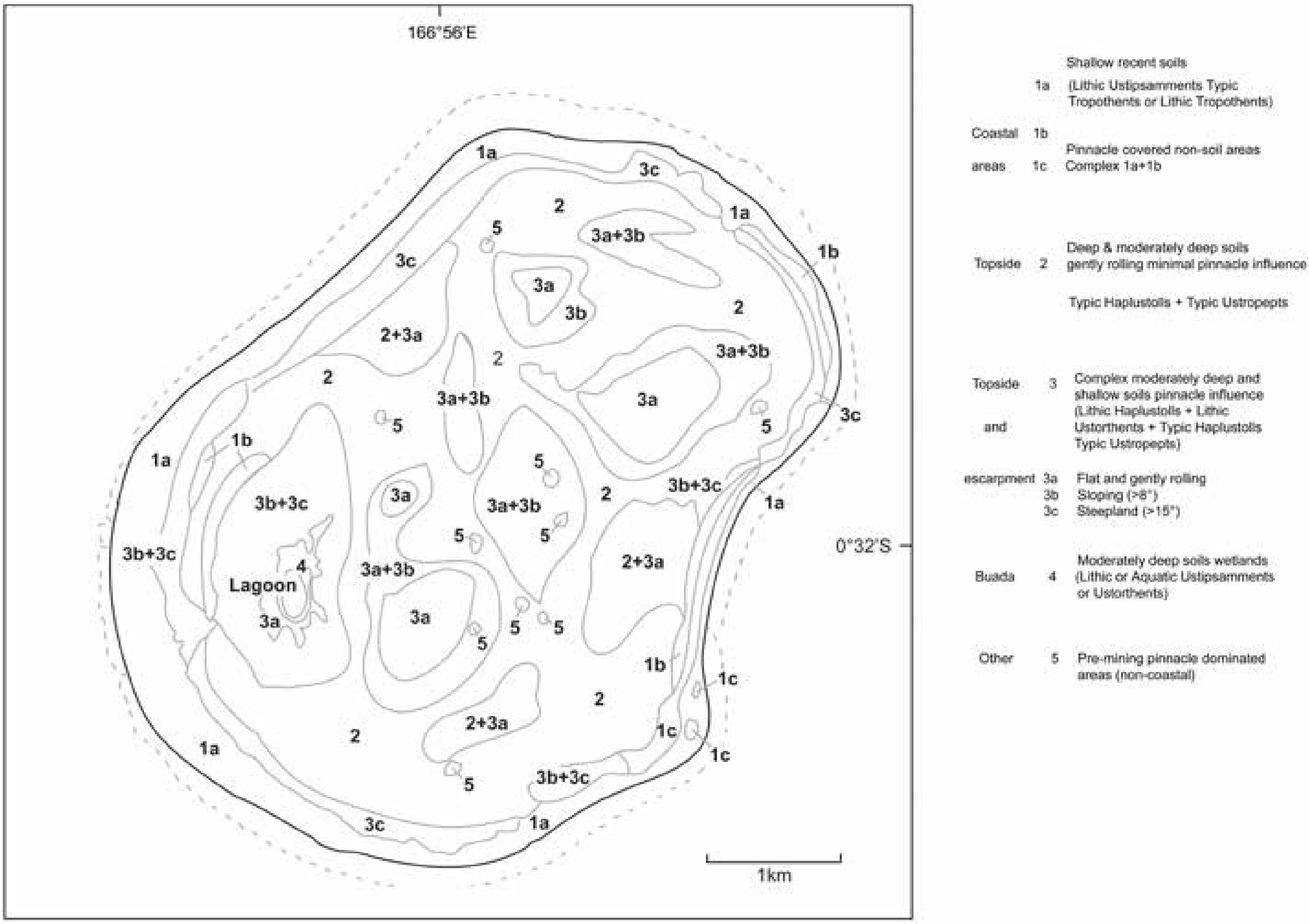

Figure 11 Redrawn from Morrison and Manner (2005). The map interprets pre-mining pattern of soils and therefore former- major faunal habitat divisions for Nauru.

The range of ecosystems worthy of protection

SEABIRD COLONY HABITATS PROMOTE INVERTEBRATE COMMUNITIES

It is well known that seabird colonies on oceanic islands deliver guano nutrients that drive the productivity of whole island ecosystems including vegetation and invertebrate production (Stapp et. al. 1999). 'Topside' and scarp tree roosts remain important on Nauru promoting this globally declining seabird-island ecosystem. It has survived perhaps many centuries of bird gathering but is now vulnerable and threatened due to potential for further forest depletion and perhaps high rate of cultural take. This ancient seabird-forest-island biodiversity remnant has ancient intrinsic ecological value for Nauru. It is to be celebrated and opportunities to protect and promote it are encouraged.

TOPSIDE HABITATS OF HIGH BIODIVERSITY VALUE AMONG THE MINED LANDS

Areas of earliest phosphate mining disturbance will have had the best chance of being colonised post disturbance by native and pre-European fauna (with few recent weeds present) and the longest period of recovery to the present. Mining was apparently sometimes inefficient and at times leaving some soil residues in narrow depressions among the hard rock pinnacles (E. Edwards pers. obs. and, Nauru Rehabilitation Corporation "Secondary mining" currently operating). Some of the more mature and floristically rich and extensive pinnacle habitats appear to be in the region of Command Ridge and the old railway line extending behind Denigomodu and Aiwo (Figure 12 a – g) The richest moth records are from Command Ridge track behind the Australian High Commission (Aiwo 35 m above sea level Appendix 4). The single record of indigenous snail *T. insolata* was made on the edge of the mined lands here. Moths, butterflies and other insects and snails were hand collected on tracks behind Denigomodu.

Figure 12 a – g. Command Ridge and railway region on the 'topside' of Nauru. With the mining long past there is a heritage history set among more advanced vegetation regeneration found on Nauru pinnacles mining lands.

COMMAND RIDGE: A SUITE OF SIGNIFICANT VALUES

The Command Ridge/ railway region probably has additional significance in bird gathering, cultural history, Japanese occupation history and the railway alignment (see Figure 12 b, d & e) as well as landform and landform interpretive values. A sparse tree cover of *Calophyllum, Ficus, Premna Terminalia* and other species are among kaast dolomite-limestone formations and pinnacles (Figure 12 a, f & g) easily accessed on well-formed paths.

For this region and other topside areas of either tall pinnacles or reasonable post mining vegetation development, the proposed mechanical levelling and layering of soils would be destructive causing further loss of biodiversity values. Proposed secondary resource extraction or proposed rehabilitation works (anon 2013) applied indiscriminately would most likely cause significant further loss of faunal values.

PINNACLES BEFORE THE MINING STARTED

Morrison and Manner (2005) (Figure 11 and approximated as blue areas (4) on Figure 19) identify a number of small scale pre-mining pinnacle dominated areas. These together with 'topside' mature vegetation remnants should remain undisturbed as valuable faunal and floral reserves and also sources of native species colonising surrounding areas.

SITES WHERE SCIENCE INVESTIGATION CAN PROVIDE A WINDOW ON THE PAST

As yet undocumented sites; kaast sinks or caves with intact fossil deposits of scientific importance. It is valuable to know extinct fauna and interpret past biodiversity and therefore future restoration opportunities (eg. Steadman et. al. 2007). A fossil study telling the story of historical habitats and environments should form an early part of any terrestrial restoration programme on Nauru. Sites good for such study would likely be worthy of protection.

THE DISTINCTIVE COLUMNS IN THE TIDE AT ANIBARE BAY

Significant and distinctive for the tropical Pacific; dolomite columns on the tidal rock platform of Anabare Bay (Figure 9 a & b) are worthy of protection. In part because they are the stronghold of *C. nauruensis* endemic tidal reef bug.

UN-MINED PHOSPHATE SOILS

Small areas of un-mined phosphate soils now remain (see Figure 2) and are made valuable for nature by their rarity. Where these have vegetation cover including trees then soil faunal values including land snails are most probably of importance for species vulnerable to extinction. Seabird roosting and nesting in such sites would also add value.

ESCARPMENT BLUFFS AND SLOPES

Representatives of these soils, habitats and landforms are also worthy of protection for invertebrate values

COASTAL PLAIN: MIXED FOREST AND PINNACLES

Beneath the escarpment and often with dwellings among the dolomite walls and lumps; representatives of these habitats and landforms are also worthy of protection for invertebrate values.

MANGROVE AND MARSH AT TIBINOR PONDS – ANIBAR

These distinctive soils, habitats and landforms (Figure 13) are worthy of protection, including for invertebrate values.

COASTAL *SCAVIOLA, TORNEFORTIA* AND *IPOMOEA* DOMINATED SITES

Highly representative of many Pacific islands. Still some examples of these soils, habitats and landforms (Figure 10 & 15) are also worthy of protection including their invertebrate values

Figure 13. Down on the coastal plain, dolomite limestone pinnacles among disturbed forest – Anibar.

Figure 14. Anibar Ponds.

Figure 15 a & b. Coastal *Ipomoea* and *Scaviola* typical around the Pacific.

Biodiversity threats

Mitigating biodiversity loss through mining and rehabilitation?

Proposals outlined in May 2014 – Nauru national assessment report for the Third International Conference on Small Island Developing States (SIDS, anon 2013) include 'Topside' rehabilitation. This must not be confused with biodiversity restoration. It is clear that developing and sustaining livelihoods is intended. The rehabilitation is likely targeted at making land available for crops, housing and infrastructure. It is noted that positive biodiversity outcomes from proposed rehabilitation are likely to mislead and should not be claimed.

Positive biodiversity outcomes are possible however. This will instead be achieved by setting up a process where it should be possible for practical three way agreement to set aside semi-natural and natural areas described in this report, maintain a mining/rehabilitation regime and satisfy land owners

Mining industry night light pollution

Mining activity continues at night and is carried out under powerful lights. Studies have noted the effect of undirected industrial lighting on birds and insects (Le Corre et. al. 2002, Longcore and Rich 2004). Given the modest scale of Topside habitats, lack of competition from other light sources and dispersal ability of many insects and seabirds, it is likely undirected industrial lighting is having significant ongoing effect on moths, beetles and other insects as well as some seabirds. This can be mitigated by lighting that is shielded and downward pointing so that only work sites are lit at night. Expert advice is available world-wide on biodiversity sensitive industrial lighting.

Figure 16. Yellow Crazy Ant collected from Nauru June 2013.

ANT FAUNA

Ants were widely recorded on Nauru at 22 sites (Figure 18). All of the specimens were interpreted apart from a few fertile males and females. Unfortunately, we found 17 species of which 100% were exotic invasive or perhaps tramp species. Elsewhere such evidence would suggest a loss of native species largely replaced by pan Pacific ants. However, in reviewing the Micronesian ant fauna, Clouse (2007) found around 25% of species endemic to the vast Micronesian region. The others are either strongly linked to Polynesia & Melanesia, or pan Pacific or almost pan tropical. Among the Marshall Islands and Kiribati archipelago all are tramp species records apart from a single endemic on Kiribati (Close 2007). This makes the Nauru result less surprising. Of the Nauru ants with the exception of one taxon (*Nylanderia* sp. small brown) and a tentative *Tetramorium* species, all have been recorded elsewhere in Micronesia.

TROPICAL FIRE ANT

The most serious invader presently in Nauru ecosystems is the tropical fire ant *Solenopsis geminata*. This ant is known for ecosystem level effects mediated by dominance over many other ants, seed gathering and tending of scale insects for honey dew (GISD – Global Invasive Species Database Oct 2013). Tropical fire ant is internationally listed as one of the six most widespread, abundant, and damaging invasive ants by Holway et. al. (2002). The survey shows tropical fire ant is widespread on the island being recorded at six localities.

YELLOW CRAZY ANT

The survey team also recorded yellow crazy ant *Anoplolepis gracilipes* at a single locality among containers and concrete buildings at the Aiwo port facility (Figure 17 a -d; locality map Figure 18). This appears to be a new incursion given that the ant was not recorded at twenty other localities where ants were collected and not observed elsewhere on the island. For example, at a weedy roadside area nearby to the port facilities (100 metres away, opposite the power generation plant) none were observed. We have high confidence since at this roadside we light trap surveyed and swept vegetation. We recorded several ant workers and winged forms of other ants at this roadside, but no yellow crazy ant.

While there are a number of other pest ants present on the island, it is uncertain what potential influence yellow crazy ants might have on Nauru. They are dominant in many other situations elsewhere and are also listed by Holway (2002) as globally one of the six most widespread, abundant, and damaging invasive ants. Certainly in the tropical Pacific there are records of high densities with significant impacts on species and ecosystems on islands. In addition to biodiversity impact, they are significant urban and crop pests (GISD – Oct 2013).

Figure 17 a-d Yellow crazy ant (*Anoplolepis gracilipes*) site; Aiwo port, Nauru. June 2013.

Figure 18. Map of Nauru showing 22 ant sampling localities including the single record of yellow crazy ant from Aiwo port facilities.

There is the potential that the spread of yellow crazy ants on Nauru could be contained. The Global Invasive Species Database notes that colony budding is an important form of dispersal for *A. gracilipes* increasing the chances of containing the incursion. It may also be possible to consider eradication while the invasion appears limited to a small area.

Since Nauru remains free of the most serious ant pests such as big headed ants (*Pheidole megacephala),* red imported fire ants (*Solenopsis invicta),* little fire ants *(Wasmannia auropunctata),* Argentine ants (*Linepithema humile*), and other such invasive pest invertebrates, there is more reason to address this incursion. Also as part of the response, it is important to improve local awareness and future bio-security.

These circumstances show a high priority for urgent delimitation of *A. gracilipes* with a view to containment and potential eradication. It is recommended a expert in ant incursion response begin these actions immediately.

INVASIVE SNAILS AND SLUGS

In the survey we recorded six alien land snails and one slug. Four of the snails are predators of other snails and some of these were numerous in some sites. Their impact is not considered as bad as other invasive snails that threaten Nauru. However, impacts on the native fauna can be expected since for example, the densities of *Allopeas gracile* are high at some sites and *Subulina octona* (also a snail predator) is very widespread. The slug *Laevicaulis alte* is assessed as a high risk crop pest for the US (Cowie 2009) and quite possibly favoured over other species in Nauru by its tolerance to drought episodes.

It is Nauru's good fortune that the giant African snail, *Achatina fulica* and the very damaging cannibal snail, *Euglandina rosea* have not invaded. These are found in other parts of Micronesia and the Pacific. Réigner et. al. (2009) discuss more than 120 native snail extinctions in the Pacific region attributed to the cannibal snail. Preventing the cannibal snail from establishing and stopping other damaging land snails, remains important for Nauru's endemic snail fauna to persist (eg. Cowie 2000).

The rarity or possible extinction of two endemic land snails, *Trochomorpha insolata* and *T. contigua* var. *nauruana* cannot be determined. It could be caused by many factors such as exotic predatory snails, exotic ants or other insects or habitat destruction or pigs (presently no feral pigs are present) or a species of rodent. It is probable that a combination of such factors and variable climate has caused extinctions, and now threatens snails and other fauna.

Conservation recommendations and justification

- To address yellow crazy ant incursion:
  - It is strongly recommended an urgent delimitation survey of yellow crazy ant *Anoplolepis gracilipes* on Nauru Island is carried out by experts to assess the option for control and eradication of this serious pest.
  - Both the Nauru and the Australian authorities managing secure infrastructure areas will also need to be involved in this work.
- Also to protect biodiversity and food production, a sustainable national biosecurity programme needs to be developed for shipping and the port as well as for air travel.
- Pinnacles have value: Many areas of older mined 'pinnacles' and taller or remnant pinnacles should be celebrated and valued for their biodiversity association, landscape values and as a national identity distinct from Pacific wide atoll lands.
- Many areas of post mining ecological succession have developed so much biodiversity and landscape significance that 'rehabilitation' actions would be very damaging and the location of any rehabilitation activities must consider this.
- Secondary mining could also cause significant biodiversity losses in areas of advancing ecological succession. Therefore, practical decision making involving a kaast or vegetation ecologist together with mining engineers over sites for further mining is recommended.
- Seek positive biodiversity outcomes in ongoing mining programme: Establish a process for a three way agreement among landowners, mining engineers and biodiversity experts to set aside semi-natural and natural areas from mining or rehabilitation.
- Sites identified as pre-mining pinnacle dominated areas should not be disturbed or mined, including rock removal for high grade rock or stone tile export. Justification for this includes protection of undisturbed soils and sediments of faunal value for anciently associated insects and land snails lost from many areas. Such sites are also of scientific importance for determining the history of change in plant and animal communities.
- Recommend engaging an archaeologist to study fossil plants, birds and other animals to better interpret the history of biodiversity change and establish goals for restoration. Sediments in undisturbed karst sites (potentially caves) and also in the few wetlands of the island are valuable storehouses of historical information.
- Expert advice on industrial light pollution is needed to address the bird and insect impact of powerful night lights for mining. Best practice mitigation includes lighting that is shielded and downward pointing so that only work sites are lit at night.
- This report suggests protection of representative shoreline areas. Engineering storm protection works on these shores would damage the coastal landform-strand plant-invertebrate-bird ecosystems present. Managing this threat would form part of each sites protection.
- Proposed conservation areas are presented in Figure 19 which can be used for community consultation. The intended goal is to protect viable and representative examples of endemic insects and snails identified in this report and many other vulnerable and threatened species and ecosystem values together with cultural, scenic and historic values.

Figure 19. Recommended areas for conservation protection*

Proposed conservation areas include:

1. **Topside Command Ridge – core area of spectacular and highly representative scenic, historic and biodiversity values.** These appear to have the best history and longest recovery time since mining.
2. **Northern Anabare Bay.** Possibly the most celebrated and distinctive scene in Nauru. Tide-washed hard dolomite columns where the ocean pours across the rock platform to the beach. Importantly, -harbours indigenous and rare Nauru marine pinnacle bug *Corallocoris nauruensis* as well as other intertidal, and shore line biodiversity of reasonable natural character.
3. **Tibinor Ponds – Topside to the sea.** Combines multiple biodiversity values in one conservation area. The shore has not been damaged by sea protection works, The ponds are almost unique and include coastal plains rubble forest and rocky scarp to pinnacle transition.
4. **Non-coastal pre-mining pinnacle areas** (blue sites). High value as remnant biodiversity areas and important landform scenes where these are near the road. Thousands of years of biological history can be interpreted among some of these scientifically valuable sites. (locations approximated from map of Morrison and Manner (2005) – see Figure 11).
5. **Anabare topside phosphate soil remnant.** One of few representative examples remaining. Forest cover is exotic but the 'seabird – tree – enriched soil ecosystem' is highly representative for Nauru, threatened around the Pacific and deserving of conservation.
6. **An integrated conservation concept:** That combines the component values of topside ecosystems (4), & (5), Scarp and bluff systems, Coastal plain urban living space, Dolomite reef food resource area (including (2) above) and potentially a near-shore marine resource area. All of these sites have high scenic as well as cultural and biodiversity value.

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CHAPTER 3 REPTILES OF NAURU

ADAM R. BACKLIN, JONATHAN Q. RICHMOND AND ROBERT N. FISHER

Summary

- Nauru was surveyed for terrestrial reptiles and amphibians from June 18–26, 2013.
- The reptile team conducted six transects around Nauru sampling all known vegetation types. We conducted transect surveys within the districts of Anabar, Denigomodu, Nibok, Anibare, Ewa, and Buada and visual encounter surveys across all districts.
- We detected a total of seven species of reptiles, including two species of ground skinks, four species of gecko (one of these invasive), and one introduced snake species.
- We found no amphibians.
- Molecular data indicate that the Micronesian Black Skink *Emoia arnoensis nauru* is an undescribed species of *Emoia* that is distinct from *E. a. arnoensis* from Micronesia.

Introduction

In a recent study of the conservation status of the world's reptiles, Böhm et al. (2013) identify Oceania as the region with the highest proportion of threatened species globally and a high priority for reptile conservation. Baseline knowledge on the herpetological diversity of Oceania is lacking due to vastness of the region and the fact that much of the diversity resides on small isolated islands. Addressing this gap is critical to understanding the processes that gave rise to this diversity, and more importantly, to document it as accurately as possible in places where the native flora and fauna are at high risk of extinction.

The small island of Nauru (21 km^2) is centrally located in the western Pacific Ocean and represents a potentially important historical biogeographic link to other neighboring islands in the region. Although knowledge about the island's biodiversity has grown in recent years, much remains to be explored and understood. Buden (2008) provided a summary of the current state of knowledge of the island. He included the first reports of lizards by Waite (1903) and additional information on geckos over the last 25 years. Additionally there are 41 museum records of terrestrial reptiles representing seven species from Nauru housed at four museums (HerpNet.org, accessed 21 Aug 2013); the American Museum of Natural History, New York (AMNH), Smithsonian National Museum of Natural History (USNM), Museum of Comparative Zoology, Harvard University (MCZ), and the California Academy of Sciences, San Francisco, CA (CAS).

In this study, we describe the current species composition of the herpetofauna on Nauru (2013), building on the data collected in Buden (2008). This included confirmation of previously known terrestrial reptiles, identifying undocumented species that may naturally occur on the island, and identifying newly established invasive species. A second objective was to implement a survey protocol that can be repeated in future monitoring studies, and a fourth objective was to outline conservation recommendations to help preserve Nauru's native herpetofauna long into the future.

Methods

Our field efforts consisted mainly of transect surveys on foot, allowing us to explore as much of the landscape as possible (Figure 1). Surveys totalled 3.5 km and were divided into six transects distributed across the island. Transects covered a variety of habitats, from coastal beaches to disturbed secondary forests and grasslands, to jagged limestone pinnacles up to 15 m high with different stages of vegetation regrowth (Figures 2–6). The pinnacles represent artefacts of extensive phosphorus mining that took place on the island during the 1970's and '80's, which has destroyed approximately 80 % of Nauru's natural land area.

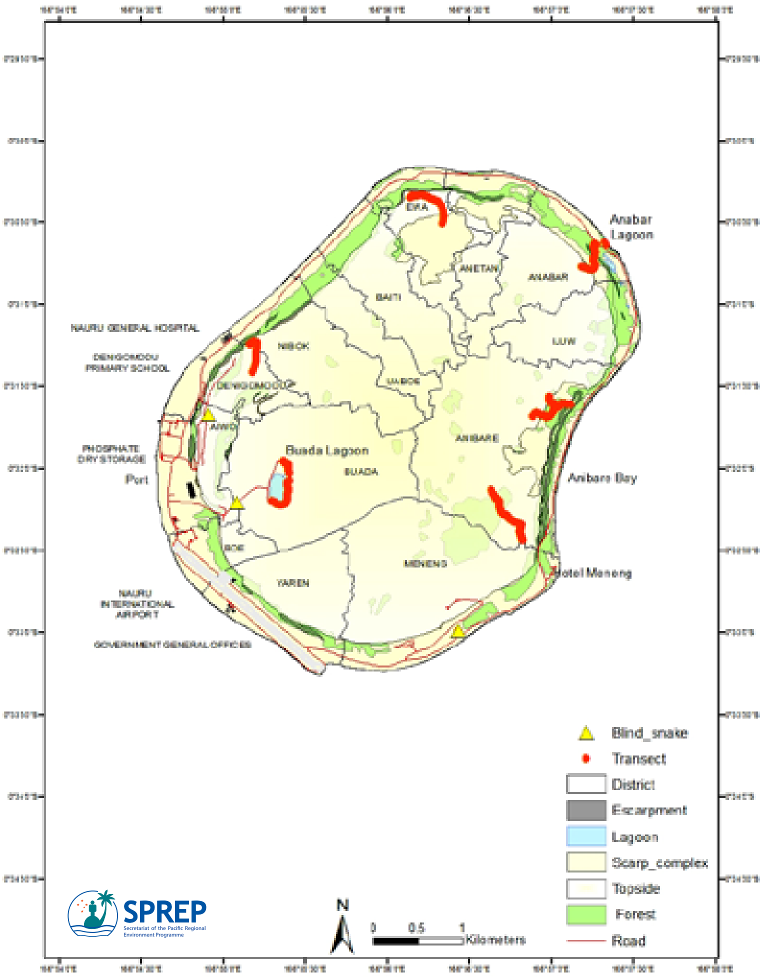

Figure 1. Location of reptile survey transects and stations on Nauru with collecting locations for the Brahminy blindsnake (*Ramphotyphlops braminus*).

Survey efforts across Nauru consisted of three main techniques (Fisher 2011): (1) hand capture of animals during daytime visual-encounter surveys of the different habitat types; (2) trap transect stations placed in different habitat types (Figures 1–3, 5–7), where each station consisted of one standard sticky mouse trap placed on the ground one placed on a log off of the ground, and a third one stapled to a tree approximately 1.5 m off the ground; and (3) hand capture of animals during nighttime walking transects to provide additional data on nocturnal geckos. We also recorded the presence of invasive mammal and ant species.

For each sticky trap transect, we deployed traps in the afternoon and placed a sampling station every 30 m. We collected and removed all traps the following morning to ensure that we sampled both diurnal and nocturnal species. We selected transect locations to represent the variety of habitats and vegetation types across Nauru. Captured lizards were removed from the traps using vegetable oil and rubbing it along their body to peel them off the trap. Once removed, we recorded the location of the sticky trap and identified any captured animals to species. We weighed (g), measured snout-to-vent (SVL in mm), and excised either a tissue sample or collected the whole lizard as a voucher specimen. We recorded any evidence of rats (specimen, fur, and chew marks) and counted and collected all ants from the traps.

After completing the field study, we performed scale counts and additional measurements from skink specimens. We sequenced four individuals that we tentatively identified as Emoia arnoensis nauru and a possible second, undescribed species of Emoia to verify taxonomic identity and to identify the closest evolutionary relatives on other Pacific Islands. We extracted DNA from alcohol-preserved liver samples using a Qiagen DNA extraction kit and collected sequence data for the mitochondrial ND2 gene. This gene has been used to good effect in our ongoing studies on Emoia phylogeography and speciation throughout the western Pacific and Indo-Pacific regions. The primer sequences were as follows: heavy t-MET 5′- AAG CTY TYG GGC CCA TAC CCC GA-3′; light t-ALA 5′- CVT TAA TKA AAG TGT KTG AGT TGC ATT CAG-3′. PCR cycling were as follows: 95°C for three minutes; 95°C for 30 seconds/58°C for 45 seconds/72°C for 1 minute for 30 cycles;

Figure 2. Pinnacle habitat at the Corridor in Nibok District (Photo by A. Backlin).

Figure 3. Reptile team in Anabar processing lizards captured on sticky traps (Photo by E. Edwards).

Figure 4. Fialelei Enoka searching for blind snakes (Photo by A. Backlin).

Figure 5. Beach habitat sampled in Anabar (Photo by E. Edwards).

Figure 6. Reptile team setting traps in varied habitats (Photos by A. Backlin).

72°C extension step for 10 minutes. DNA sequencing was performed using Sanger methods and Big Dye v3.1 chemistry on an ABI3730XL DNA analyzer at Genewiz (La Jolla, CA USA).

We used the software MrBayes v3.2 (Ronquist and Huelsenbeck 2003) to estimate a phylogenetic tree based on the DNA sequence data. The analysis incorporated sequences for a number of Emoia species that have been considered to be close relatives to the Emoia on Nauru based on morphology and geography, including the putative conspecific E. arnoensis arnoensis from Arno Atoll in the Marshall Islands. MrBayes uses a model-based, Bayesian statistical approach to infer a phylogenetic tree from the DNA sequence data, and provides probability estimates for the evolutionary relationships inferred from the tree topology.

Results

We detected seven species of terrestrial reptiles on Nauru. This included two species of ground skinks, four gecko species and one snake species (Table 1). We did not detect any amphibians or yellow crazy ants (Anoplolepis gracilipes) along our transects. The trap locations and identity of the reptiles captured on the traps are provided in Appendix 7.

Table 1. Terrestrial reptiles captured on Nauru, June 18–26, 2013.

Scientific Name	Common Name	Total Captures
Emoia cyanura	White-bellied Copper-striped Skink	193
Emoia sp.[1]	Undescribed Skink	13
Gehyra insulensis	Stumped -toed Gecko	11
Gehyra oceanica	Oceania Gecko	15
Hemidactylus frenatus	Common House Gecko	30
Lepidodactylus lugubris	Mourning Gecko	23
Ramphotyphlops braminus	Brahminy Blindsnake	5
Total Reptile Captures:		**290**

[1] Formerly *Emoia arnoensis nauru,* Micronesian Black Skink

SKINKS

White-bellied copper-striped skink *Emoia cyanura* (Figures 7, 8)

This was the most abundant species (193 captures) and was the only skink species captured in all six transects. It was most commonly found in secondary forest, although we observed them in all habitats (including urbanized areas). Individuals typically occurred on the ground or substrate (logs/rocks) near to the ground.

Figure 7. White-bellied Copper-striped Skinks (*Emoia cyanura*) captured on a sticky trap (Photo A. Backlin).

Figure 8. White-bellied Copper-striped Skink (*Emoia cyanura*) (Photo by R. Stirnemann).

Undescribed Skink *Emoia spp*. (Figures 9, 10)

We captured 13 individuals of an undescribed skink (genus Emoia) during this study. They were captured at half of the transects, including Transects 1, 3, and 4. The 13 specimens ranged from 35–82 mm SVL and weighed 2.0–18.0 grams. We captured these skinks mainly in vegetation that transitioned from secondary forest to pinnacle habitat, and pinnacle habitat that had significant secondary vegetative regrowth (Figure 11). All 13 skinks were captured on the ground or on a log.

Of the 13 unidentified skink specimens, we captured four large, black individuals that we initially identified as *Emoia arnoensis nauru* (Brown 1991, Zug 2013) and nine smaller, mottled brown skinks that we believed to be a second undescribed Emoia. We detected the adults on transects and on walking transects and only detected the juveniles on the sticky traps. Preliminary measurements and scale counts confirmed that these specimens do not match any described species, and thus it appeared to be endemic to Nauru. Further DNA sequencing and phylogenetic analysis revealed that the individuals we believed to be a second undescribed Emoia species are the same as those that we initially identified as *E. a. nauru*, indicating that the former are juveniles of the latter (and thus constitute one species). The phylogenetic tree (Figure 12) also shows that *E. a. nauru* is more closely related to *E. boettgeri* (known from the Caroline and Marshal Islands of Micronesia) than to the purported conspecific *E. a. arnoensis*. The sister-lineage relationship between *E. boettgeri* and *E. a. nau*ru is statistically well-supported, indicating that *E. a. nauru* is an undescribed, cryptic species that only superficially resembles *E. a. arnoensis* in size and coloration.

Figure 9. Undescribed skink (adult) formerly known as the Micronesian Black Skink (*Emoia arnoensis nauru*) (Photo by R. Stirnemann).

Figure 10. Undescribed skink (juvenile) (Photo by R. Stirnemann).

Figure 11. Habitat of the undescribed skink (Photo by A. Backlin).

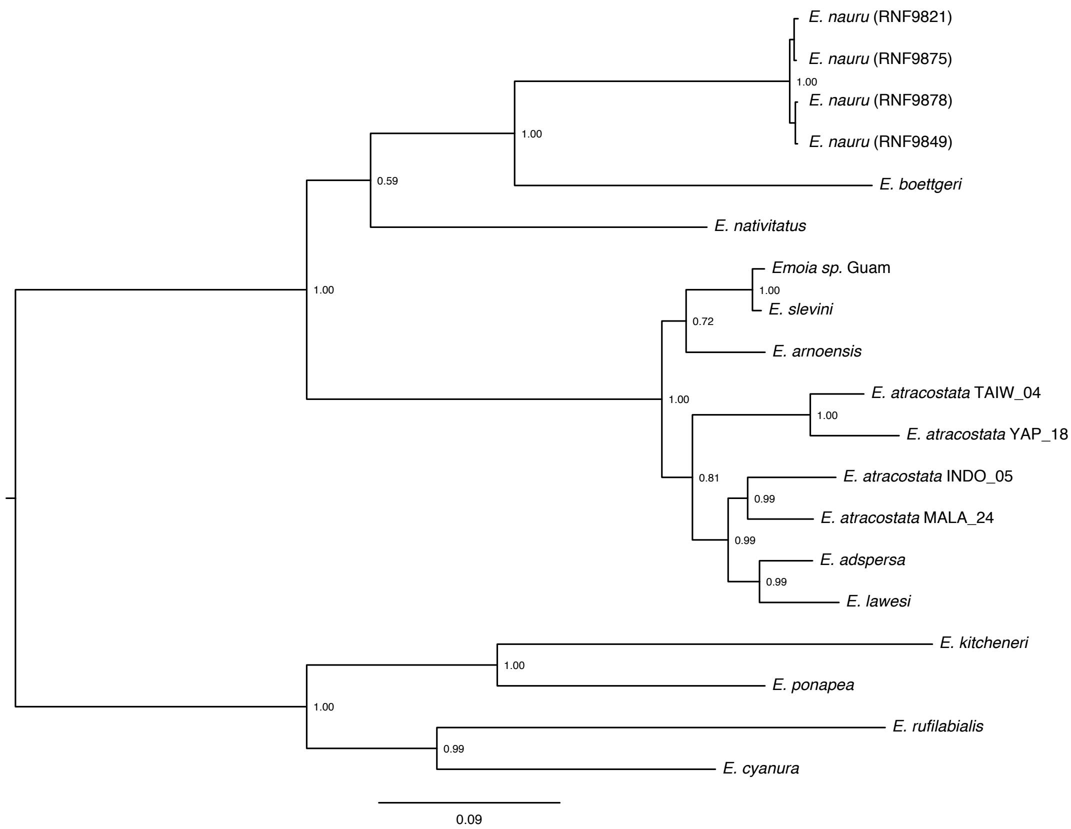

Figure 12. Fifty-percent majority consensus tree based on mitochondrial ND_2 sequences for a number of *Emoia* species that have been considered to be close relatives to the *Emoia* on Nauru based on morphology and geography. Note the four individuals from Nauru at the top of the tree are more closely related to *E. boettgeri* than to *E. arnoensis*.

GECKOS

Pacific stump-toed gecko *Gehyra insulensis*

The Pacific Stump-toed Gecko Gehyra insulensis, formerly *G. multilata*, is a widespread Asian and Pacific species that we captured with the lowest frequency compared to all other gecko species on Nauru (11 captures). We captured eight on sticky traps, five of which were on trees (Transects 1–4), and we observed many other individuals while conducting night surveys. This gecko likely colonized Nauru within the last 300 years via human dispersal (Fisher 1997). It was the least common gecko species collected by Buden (2008), with only two records from his trip; thus, the use of sticky traps in our study appeared to increase the detectability of this species. Like the Buden study, we failed to detect this species in edificarian habitats.

Oceania gecko *Gehyra oceanica* (Figure 13)

This is the largest gecko on Nauru. We captured 15 specimens, eight of which were on traps and seven of those on trees. We observed many others during night surveys. We detected or captured this species at Transects 1–3 and 5. We also detected this species on buildings, but not as frequently as the house gecko.

Common house gecko *Hemidactylus frenatus* (Figure 14)

This is an invasive species on Nauru (Bauer and Henle 1994, Case et al. 1994, Kraus 2009) and is the only gecko that vocalizes and can be heard at night around structures and in rural areas. It was the most abundant and widespread gecko species on the island (30 captures) and was present at all six transects. It was captured on the ground, on logs, and on tree traps.

Mourning gecko *Lepidodactylus lugubris* (Figure 13)

This is a widespread species across the Pacific region and on Nauru. We captured 23 across five of the six transects. Like Hemidactylus frenatus, we captured it on the ground, on logs, and on tree traps.

Figure 13. Oceanica Gecko (*Gehyra oceanica* – left) and the Mourning Gecko (*Lepidodactylus lugubris* – right). (Photos by R. Stirnemann ©)

Figure 14. Common House Gecko (*Hemidactylus frenatus*) captured on a sticky trap (Photo by A. Backlin).

SNAKE

Brahminy blindsnake *Ramphotyphlops braminus*

This is an invasive small worm-like snake that often goes undetected due to its underground habits. It is common in the Pacific and is established worldwide in the tropics through transport in the root balls of nursery plants (Zug 2013). We captured five specimens on Nauru, and all were found at night under rocks, logs, or debris. Buden (2008) collected the only previous record of a road-killed specimen (Figure 1).

Discussion

This study contributes three important findings that add to growing baseline knowledge about the herpetofauna and the status of invasive species on Nauru. These include: (1) the terrestrial reptile community remains intact despite major habitat alteration across the island; 2) the invasive and widespread yellow crazy ant Anoplolepis gracilipes has not become established, nor have other new invasive reptiles or amphibians; and 3) an undescribed skink species has been persisting on Nauru under the guise of a morphologically similar species that occurs in Micronesia.

AN INTACT REPTILE COMMUNITY DESPITE WIDESPREAD HABITAT DESTRUCTION

With over a century of phosphate mining throughout this small island and a history of physical devastation from World War II, the reptile community appears unchanged in recent times and is apparently thriving. We detected all species at multiple locations across Nauru with relatively high capture rates, indicating that many if not all are still common. To better understand the habitat preferences of the reptiles of Nauru, we overlaid our transects and blindsnake captures on a vegetation map prepared by S. Takeda in Thaman et al. (2009) (Figure 15). Transect 1 had the highest numbers of lizard captures with 120 (7.1 captures per sampling station) and traversed the highest diversity of vegetation types, including the Ijuw-Anabar-Anetan mangrove and wetland area. This transect consisted mainly of 15–50 years of regenerated vegetation following mining activities. Transect 6 had the lowest number of lizard captures at seven (0.3 captures per sampling station). This transect largely fell within a mined area that has less than 15 years of regenerated vegetation. It is likely that the reptiles on Nauru thrive with older and more complex vegetation communities, and areas where these communities have remained intact despite the extensive mining practices have allowed these species to persist up to the present day.

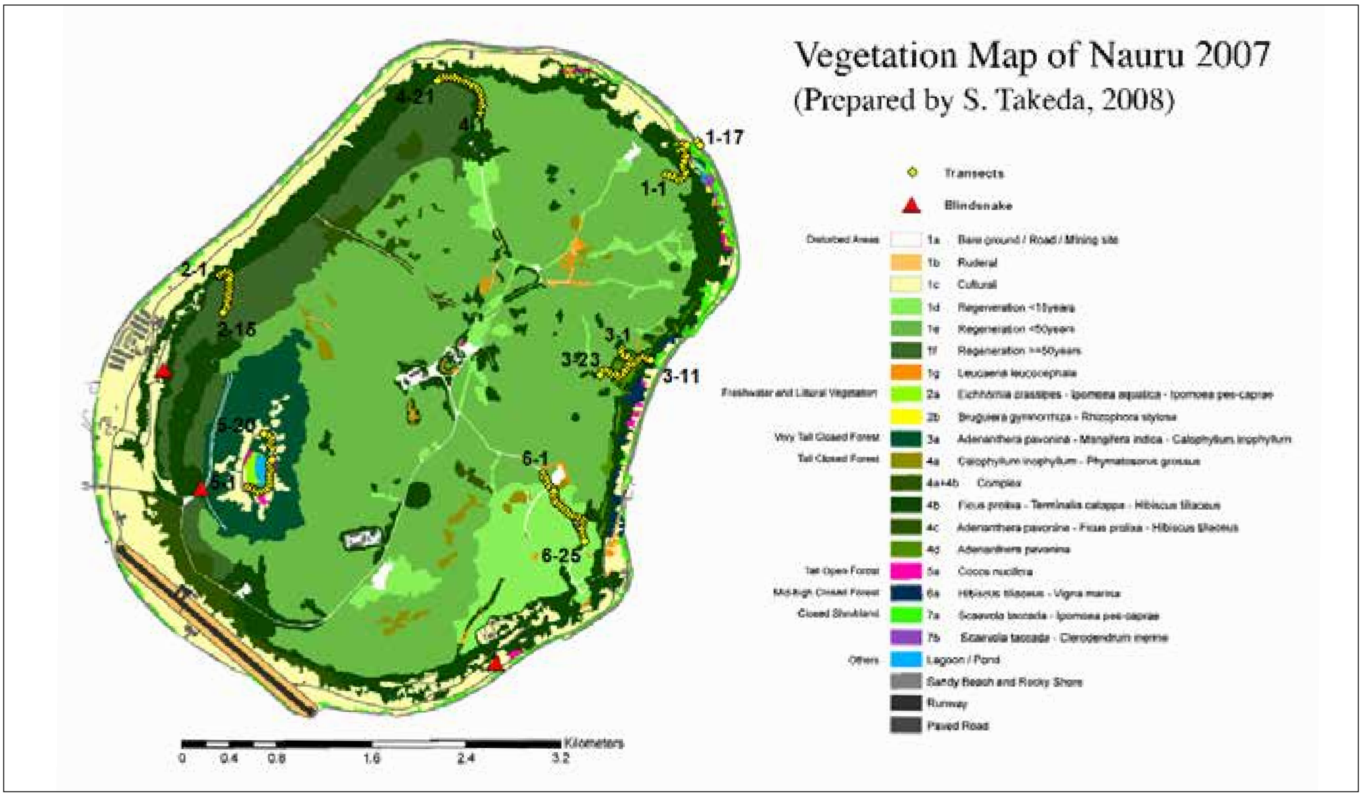

Figure 15. Vegetation map of Nauru overlaid with reptile transects and blindsnake (*Ramphotyphlops braminus*) captures.

THE STATUS OF INVASIVE SPECIES

Rats, mice, and cats were seen along the transects on the night surveys, and some rats were captured on the sticky traps. These invasive species appeared to be at higher density near the Buada Lagoon, probably due to the large human presence in that area and the greater abundance of food source. Despite their widespread introduction in the western Pacific and Indo-Pacific regions and their detection around shipping containers, concreted areas, and sheds in the Aiwo Port facility, we found no evidence of the invasive A. gracilipes, consistent with previous survey efforts on Nauru (Wetterer 2005). Establishment of these ants on Nauru would have severe, negative impacts on Nauru's herpetofauna, as they have elsewhere on other small islands where they are not native (e.g. Christmas Island; Fisher et al. 2012, Smith et al. 2012).

The two most recent invasive reptiles (*H. frenatus* and *R. braminus)* show no obvious signs of expansion on the island, and we found no evidence of any additional invasive reptile species. We also did not detect any amphibians, suggesting that Nauru's remote location and low shipping and air traffic may be protecting it from some of the more common amphibian invaders on other Pacific islands (e.g. the cane toad *Rhinella marina* and the coqui frog *Eleutherodactylus coqui*).

CRYPTIC SPECIES DIVERSITY

The smaller, mottled brown skinks that we assumed were an undescribed species of Emoia on Nauru are apparently juveniles of the larger, uniform black-colored (i.e. melanic) skink that we initially identified as *E. arnoensis nauru* based on earlier species descriptions by Brown and Marshall (1953). However, *E. a. nauru* itself appears to be an undescribed, cryptic species that is not closely related to *E. a. arnoensis* from Micronesia. This indicates that a large-bodied, melanic skink has evolved at least three times independently within Emoia across the western Pacific, with the other two examples being *E. arnoensis* (northern hemisphere) and *E. nigra* (southern hemisphere). Convergent melanism within Emoia suggests that uniform dark coloration may confer some selective advantage for these different insular species, although it is unclear what that advantage might be. It is also interesting that replicate evolution of melanism appears to be correlated with the evolution of large body size, at least relatively speaking for Emoia.

The endemic skink requires a mix of exposed habitat for basking and vegetative cover for refugia. On Nauru, previously mined areas with regenerated vegetation (more than 15 years) appear to constitute preferred habitat. If additional habitat, especially on Topside, were included as priority sites within the protected areas 1, 2, 3, 5, and 6 (from Thaman et al. (2009), sufficient lands would exist to protect this and other reptile species on Nauru.

Conservation Recommendations

Based on our findings, we suggest the following recommendations:

- Biosecurity training to educate and support community understanding on the risks of non-native species introductions.
- Develop protected areas for the endemic Nauru skink species to establish long-term preservation of the species.
- Identify methods for extermination of *A. gracilipes* from the Aiwo Port facility and enact biosecurity measures to prevent its establishment.
- Provide training for locals to help improve knowledge on conservation issues and to developing strategies for protecting key resources that are critical to maintaining biodiversity.
- Develop a strong relationship between local communities, private landowners, and other relevant stakeholders to ensure successful implementation of all conservation actions in the future.
- Propose follow-up surveys to include areas that are under-studied to continue building on baseline knowledge of the island's biodiversity.
- Obtain knowledge from local Nauruans on the island's environment prior to the major mining activities to better assess the extent of the damage to the island over the last millennium.

Protecting Threatened Habitats

Protecting the reptile community of Nauru should be a high priority due to its unique composition. One of the seven species of terrestrial reptiles on Nauru is endemic to the island, and is an undescribed species of skink formerly identified as the Micronesian Black Skink (*Emoia arnoensis nauru*). Thaman et al. (2009) identifies eight priority sites for protection that if implemented, would provide refugia for most of the reptiles on Nauru.

1. The entire Anibare Bay area from the Meneng-Anibare District boundary to the Anibare-Ijuw District boundary, including the Meneng Hotel, and extending up the escarpment to the edge of current mining activity. This would not preclude normal activities of current residents, but would protect escarpment and coastal vegetation.
2. The East and West Coast Escarpment Forests, including the Anibare escarpment, are important bird habitats and are refuges for rare and endangered species of plants. These areas may also be useful for recreational purposes, and are important for aesthetic reasons.
3. The Ijuw-Anabar-Anetan mangrove and wetland area because of its unique ecological importance (i.e. stands of mangroves) and scenic beauty.
4. Buada Lagoon (a unique landlocked freshwater or slightly brackish central lagoon) and suitable portions of the remaining forest in the Buada basin.
5. Un-mined rocky outcrops as wildlife habitats, which likely represent the condition of natural ecosystems that formerly existed on the island. This would include the remaining forest areas behind Buada Lagoon. Few such areas remain, but their protection should be considered a high priority.
6. Command Ridge and the railway zone of Topside as a possible focus for historical and environmental-based ecotourism, once mining has ceased. This area contains the deepest mining (~20 m deep) and the "Grand Canyon" of Nauru. It also contains the most advanced natural regeneration of all the mined sites. Because this area was hand-mined during the very early stages of mining on the island, there is probably less residual phosphate and less reason for re-mining.
7. Selected noddy bird nesting sites (rookeries) and tree groves along the crest of the escarpment.
8. The coastal littoral zone in which all mature coastal trees and forest remnants within 50 m of the mean high tide line should be protected. This would include the implementation of an active program of coastal reforestation and enrichment planting with endangered or culturally-useful salt-tolerant trees. The locations of most of the remaining threatened trees that should be protected are shown in the Nauru Vegetation Map 2007 GIS. These areas and their trees should be protected immediately and, where possible, enriched with the planting of appropriate indigenous and introduced species.

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CHAPTER 4 **BIRD FAUNA OF NAURU**

REBECCA STIRNEMANN

Summary

- A total of 36 species of birds were recorded on the island of Nauru. Two, the masked booby (*Sula dactylatra*) and Audubon's shearwater (*Puffinus iherminieri)* are new seabird records for Nauru.
- The survey indicates the Nauru reed warbler commonly occurs across most of the island, with the exception of recently mined areas where vegetation regeneration was low. We therefore do not recommend a recovery program for this species though monitoring should occur at 5 year intervals.
- The Micronesian pigeon still exists on Nauru in very small numbers. It occurs almost exclusively in the topside of the pinnacles, an area that currently offers a partial refuge from hunters. Pinnacle removal during rehabilitation may impact on the Micronesian pigeon and thereby also impact regeneration by this important seed disperser.
- Initial surveys of black and brown noddy breeding and take levels by hunters, indicated local nest sites and breeding activity were low in comparison to the current hunting pressure. It is critical that current nesting areas are preserved and native trees are planted to enable local noddy numbers to increase. Further surveys of noddy hunting are also recommended along with hunter education about potential over exploitation.
- Further conservation recommendations also include control of wild dogs to aid in the recovery of wader species. Restoration of key sites will aid in recovery of species and in maintaining future food security.

Introduction

In total 34 species of birds had previously been recorded on the Pacific Island of Nauru (Buden 2008). Six of these are rare vagrants; three other species have been introduced to the island. Eighteen of the 25 indigenous species are non-breeding visitors and are mainly migrating seabirds and shorebirds. The seven confirmed resident breeding bird species include only two land birds, the Micronesian pigeon (*Ducula oceanica*) and the endemic Nauru reed warbler (*Acrocephalus rehsei*).

The Nauru reed warbler is the only endemic bird on Nauru (Buden 2008) and is currently listed as vulnerable by the IUCN red data list (Birdlife 2013). It qualifies for the IUCN ranking of vulnerable because of its very small range, which leaves it susceptible to chance events such as cyclones and the introduction of alien predators (Birdlife 2013). Buden (2008) estimated the Nauru warbler population at 5,000 individuals. This estimate is equivalent to 3,000 mature individuals. There is little information on additional threats to the species. However, the impact of invasive species on island birds have been well documented (Drake and Hunt 2009) and predation by introduced *Rattus* spp. have caused severe declines in other small-island *Acrocephalus* species. Invasive species may be also be impacting the Nauru warbler. The Micronesian pigeon, although still reasonably abundant on some islands in its range, is becoming increasingly scarce due to hunting and habitat loss; it is therefore classified as Near Threatened by the IUCN red list (Birdlife 2013). Recent surveys in the Pacific suggest the species may be declining more rapidly on some islands but further surveys are required to confirm this. Should analysis reveal the species is declining at a more rapid rate, the species may need to be upgraded to a more critical IUCN listing (Birdlife 2013). Little is known about the status of this species in Nauru.

The current condition of seabird sites varies across the Pacific region. At some sites, seabird populations are stable or increasing while at other sites they are declining rapidly. Many sites lack sufficient up-to-date information to reliably assess their condition. Nauru is no exception and although a number of seabird and wader species have been recorded (Buden 2008), their local status is unknown. Two of these species, the black (*Anous minutus*) and brown noddy (*Anous stolidus,*) are important food sources to the Nauruan people. Although recorded as least concern by the IUCN red data list, it is important to ensure current take levels are sustainable to both maintain local bird populations and to maintain food security for local people. Frigate birds (*Fregata sp*.) are not used for food but are captured as a sport in Nauru. They are currently listed as least concern by the IUCN red data list and it is important that the local practices are sustainable into the future. Bristle-thighed curlew (*Numenius tahitiensis*) are currently listed by the IUCN red data list as vulnerable (Birdlife 2013) but the population of this migratory species is now small and believed to be declining.

This is probably a result of predation and hunting on its wintering grounds, when perhaps more than 50% of adults are flightless and vulnerable during autumn moult (Birdlife 2013). It is during this period that the species is likely to be present in Nauru.

Knowledge of the status, distribution and threats to Nauru's bird species is therefore required to inform management decisions. This study collected baseline information on all birds by extending the Nauru species list. We also collected information on the spatial use and abundance of the Nauru warbler and Micronesian pigeon. Rodents were collected in an ad hoc manner in a number of areas to determine which species are present. Finally, we surveyed local hunters to determine take levels of native avifauna, and collected information so that a more comprehensive survey can be designed for the future.

Study Area

Nauru is an uplifted limestone island with a total area of 22 sq. km (2,200ha). The land consists of a narrow coastal plain ranging from 100 to 300 meters wide, which encircles a limestone escarpment that rises 30 meters to a central plateau. The escarpment ranges in gradient from steep vertical limestone cliffs to gradual sloping areas of colluvial soil. The coastal plain is predominantly flat with two small areas of brackish water which form lagoons. People live predominately around the coastal plain but on the raised plateau there are some refugee settlements and one other around a lagoon.

The raised plateau consists of a matrix of limestone pinnacles and limestone outcrops, which lie in extensive areas of soil and high grade tricalcic phosphate rock. Over the last 112 years this area has been the focus of extensive mining activity. This has reshaped the land into a mosaic of areas that have been mined both by hand, approximately 80-100 years ago, and more recently (from current to 40 years ago) with heavy machinery.

Methods

NAURUAN REED WARBLER ABUNDANCE

Index counts for warbler abundance were made using the five-minute count technique whereby both calls and sightings of the species were recorded over a five minute period within a 50 meter area (Dawson and Bull 1975). Point count sites were selected to cover a variety of habitat types across Nauru. Each point count station was counted at least twice, once in each direction to minimize bias that might result from counting certain stations at particular times of the day. The counts were undertaken during good weather (not during high wind or heavy rain), to minimize the effects of weather on bird activity. Additional notes were also made on the breeding activity of the warblers in an ad hoc manner since little has been recorded previously in regards to the breeding biology for this species. Three warblers were captured incidentally on sticky traps during a concurrent reptile survey. All captured birds were measured and weighed. Measurements of tarsus length, head-bill length, bill length, bill depth, and bill width were made with vernier callipers (k 0.1 mm); wing and tail lengths were measured with a ruler (+1 mm). Birds were weighed using "Pesola" scales (+5 g).

MICRONESIAN PIGEON MONITORING

Surveys were conducted across the island using the same sites used for the Nauru warbler. Although the positions of sites were limited by the lack of accessibility to some of the topside area, the selected point count sites covered most of the island and a large variety of habitats and potentialty suitable areas for the species. Each point count was repeated two times. A playback of a Micronesian pigeon call was recorded at the beginning of the survey. This call was used on a Foxpro playback recorder at each survey site for 2 minutes prior to a 3 minute period of listening, to increase the detectability of pigeons at the site. Detectability of a pigeon by both calls and sight were recorded. The location of preferred sites and species abundance were also noted.

NAURU CHECKLIST

Whenever travelling by boat, motorcycle or car along main roads by day, a record was kept of species seen and the section of the island or sea travelled (categorized as lower escarpment: reef flat, lagoon, forested escarpment, upper escarpment: old mining site (where vegetation is now taking hold), new mining site (little vegetation present, no large trees), pinnacle cliffs, and ocean: deep sea, shoreline).

Hunting rates and breeding of the brown and black noddies

BREEDING

Two techniques were required to assess the number of black noddy breeding on Nauru. This was necessary because accessibility to potential breeding areas was limited because of past phosphate mining activity. All accessible land was surveyed on foot and by vehicle. The number and position of trees used by black noddy for breeding were recorded. Counts were made of all nests in each assessable tree. To assess the number of breeding trees which were in the pinnacles and therefore not accessible at dusk we climbed to the highest view points on the island and looked for sites where a large number of birds were returning (indicative of a nesting tree/group of trees). Because counts of breeding pairs could not be made in these pinnacle areas we extrapolated the average number of breeding birds from our other sites to provide an estimate of the current breeding population. Brown noddy breeding could not be assessed since they breed in the topside pinnacles in inaccessible sites.

Figure 1. a) Adult black noddy in the hand, **b)** noddy captured using traditional methods, and **c)** the nets used in combination with playback techniques to catch noddy (Photos by R. Stirnemann ©)

HUNTING

We accompanied three hunters to observe their hunting methods, and to record their success rates. Captured noddies were measured and weighed as described in the methods, when possible.

Surveys of ten hunters were also undertaken to:

1) Determine whether hunters target either of the two species in particular (i.e. if one species is preferred or if a particular species' calls are being used to call birds in for capture) and thus hunting rates of the species are not equal); 2) Determine if there is any variation in hunting rates (i.e. ceremonies, holiday periods during which they are more popular); 3) Clarify other factors which affect daily harvest take (ie. weather, season) and 4) determine whether there are any current restrictions to the level of harvest taken. 5) People were also questioned to determine to what extend harvest rates had altered over the last thirty years (i.e. have they observed a decrease in take level).

RAT TRAPPING

To determine which rat species were present in the upper and lower escarpment, rat traps were set and baited with roasted coconut. Six traps were set over three nights in the upper escarpment and six in the lower escarpment. Rat species captured in an ad hoc way with reptile sticky traps were also recorded.

Results

Nauru reed warbler, itsirir (*Acrocephalus rehsei*) was common and occurred across both the lowland and the upland (topside) of Nauru (Table 1 and Appendix 8). In the upland the reed warbler numbers increased near forest areas where the abundance of regenerating scrub (under 2 meters) was high. It was also present in the old mined pinnacle sites in the upland, where vegetation had grown back post-mining. Yet it was not found throughout the uplands and was absent from the newly mined sites that contained little regenerated vegetation. In the lowland it occurred in both the shoreline vegetation and the forest, mangrove and shrub habitat surrounding the houses and the lagoons.

Table 1. Nauru reed warbler distribution

	Percentage of surveys with species		
	Site 1: old mined pinnacle area	Site 2: newly mined pinnacle area	Site 3: Forested sites
No. of sites surveyed	16	15	27
Average number	0.87	0.13	3
Standard Deviation	0.84	0.29	1.98
Percentage of point counts with birds present	68.75%	20%	92.59%

Nauru reed warblers were observed breeding on two occasions during the survey. One nest was in the nest-building stage whilst the other contained 2 eggs (Fig. 2b). Both were positioned low to the ground (1m and 2m) in bushes and eggs were not concealed. Three Nauru reed warblers were captured and standard measurements were taken (Fig, 2a, Table 2).

Figure 2. a) Adult Nauru warbler in the hand and **b)** Nauru warbler nest containing 2 eggs (Photos by R. Stirnemann ©)

Table 2. The morphology of three captured Nauru reed warblers

Bird No.	Beak (mm)	Head and beak (mm)	Tail (mm)	Tarsus (mm)	Wing length (mm)	Weight (g)
1	15.72	37.60	60.53	26.56	70.03	22
2	16.58	40.54	66.32	28.55	75.08	18
3	17.16	40.93	66.48	27.87	71.28	18

Micronesian pigeon, tope (*Ducula oceanica*). Point counts performed during this survey only recorded Micronesian pigeons in the topside sites (Table 3). Due to mining activity, which limits access to interior pinnacle sites, and the current position of the refugee camp, pigeon hunting activity can only occur along certain roads on topside. We found the abundance of Micronesian pigeons was higher in areas with fruiting aeo (*Ficus prolixa*). Observations from our survey transects suggest a population of approximately 50–150 Micronesian pigeons on Nauru (Appendix 8).

Table 3. Micronesian pigeon distribution on Nauru

	Percentage of surveys with species		
	Site 1: old mined pinnacle area	Site 2: newly mined pinnacle area	Site 3: Forested sites
No. of sites surveyed	16	15	27
Average number	0.75	0	0
STD	0.81	0	0
Percentage of point counts with birds present	43.75%	0%	0%

INVASIVE BIRDS

Feral pigeon (*Columba livia*) were introduced to Nauru as pets and for racing but are now completely wild. They are currently only found near human housing and we did not detect any on topside.

Feral fowl (**domestic fowl**), domo (*Gallus gallus*)are common throughout the coastal zone and roam freely in and around the settlements. No feral fowl were observed in the central plateau suggesting a limited distribution. The introduction of new fowl breeds is not unusual and a number have recently been brought to the island from Asia for cock fighting. It is possible that new avian diseases could enter the country this way.

SEABIRDS

The white tern, dagigia (*Gygis alba*) is a common breeding resident. It is encountered throughout the island but was most numerous in the remnant forest, particularly at the edge of the central plateau (topside) near Buanda lagoon, and in the un-mined forest patch near Anibare escarpment where it breeds in a small forest of tall non-native trees. The species is not targeted for food and is one of the most abundant on the island. During this survey white tern were observed breeding.

White tailed tropic birds, dedage (*Phaethon lepturus*), nest in the limestone cliffs of Anibare Bay Escarpment. During the survey only 2-3 individuals were sighted in the Anibare escarpment.

Bristle-thighed curlew (*Numenius tahitiensis*) were not observed during the surveys in this study. However, local people reported seeing small numbers (3-10 individuals) on the airstrip and along the shoreline this year. This is a substantial decrease in the numbers previously seen. In the 1980s large flocks of +100 birds were previously seen along the shoreline (pers com Dick Watling). Local people have observed curlew being killed by wild dogs along the shoreline (pers com Dick). The number of wild dogs has increased substantially on the island in the last 30 years since the introduction of three non-neutered individuals. Prior to this period all dogs on the island were de-sexed and therefore population numbers were controlled.

Great frigatebird, itsi (*Fregata minor*), and **lesser frigatebird**, itsi (*F. ariel*), used to breed on Nauru on the Anibare Bay Escarpment, according to local people. However, no birds have been observed breeding since young were collected from the nests over 10 years ago (pers com M. Dick). Traditional frigate bird capture games continue to occur in Nauru as previously reported by Buden (2008). There are two main sites where this occurs and only two unmarked birds were observed during our survey. At the largest site approximately 310 frigate birds are captured per year and tamed. Approximately 10-15 birds die per month during the taming process (as evidenced by the fresh wings attached to the catching station and through interviews with the local itsi catchers). Although juveniles are marked with the tribal wing marks (Fig. 3) and released following the taming process, any adult bird which either returns post taming, or any bird which is captured for the first time, is kept caged. These individuals are therefore effectively removed as breeders from the population. All caged birds appeared to be *F. ariel*, and none could be positively identified as *F. minor*.

Figure 3 a) Frigate bird with the traditional wing markings post capture and taming, **b)** adult frigate birds held in the cage (Photos by R. Stirnemann ©).

Hunting

Brown noddy, doquae (*Anous stolidus*), and **black noddy**, demererik (*Anous minutus*), are caught for food throughout the year. Although the smaller black noddy is reported as being better tasting, and thus preferred by some people, the bigger brown noddy has more meat and neither species is targeted specifically. During capture, playbacks are used to call in birds with recordings of both species played simultaneously (Figure 1). These MP3 recordings have replaced the practice of using human noises produced by manipulation of the voice and nose to call in the noddy species, and the practice of keeping tame live birds, which were previously used as bait to lure in other individuals. The capture of both noddy species continues to occur using traditional methods whereby a long bamboo pole has a large net affixed at the end. In the early evening, when birds fly in from the sea to roost, they are lured in with the played calls and the netter captures them when they are close (Figure 1) using a technique similar to catching a butterfly. Capture rates for all nights we observed (n=3) were almost 100% when a bird was successfully lured towards the call. However, despite hunters saying there was no preference towards a particular noddy species, over the three nights we observed five hunters captured three brown and 15 black noddies. This is because black noddy are more abundant rather than a preference for a particular species. The capture rates of these nights were not necessarily representative of other nights since weather (wind and lack of clouds) and the period of the lunar cycle (high light levels) negatively influenced capture rates over this period. Hunters can capture up to 100 birds a night and 15 to 25 is a common number to capture even on a poor night (range per person = 3-300 noddy per night). In addition, prior to hunting taking place there is often a cash prize offered for the most noddy captured. Therefore effort and harvest rates can be extremely variable. There are approximately 25 groups out catching noddy every night. Although estimates are rough, calculations suggest over 6125 noddy are captured every week and 319, 375 taken per year (25 groups of people* 35 birds on average a night 875 *7= 6125 birds captured per week) based on our interviews with local hunters. This is likely to be well below the actual number of birds which are taken per annum.

CHANGES IN EFFORT VERSES HUNTING RATES

Interviews with hunters suggested noddy capture rates have decreased relative to the amount of effort (i.e. time spent at capture sites). Forty years ago a catching period of one and a half hours would have resulted in 60-90 birds being easily captured (pers com Dick Watling). Now, over two or three hours under similar conditions only nine birds are captured (pers com local hunters on Nauru).

Noddy breeding populations

Black noddies were breeding in the following locations (Figure 4). Each of the trees where it was possible to count birds had a mean of 21 breeding birds with a range of nests 8-32 per tree (n=9). Three of the sites could not be counted. Based on the assumption that a similar number of noddy were breeding in trees in the sites where we could not gain access, we estimate that 252 black noddy were breeding on Nauru at this time. Nest site trees, such as the tomano tree (*Calophyllum inophyllum*), a species that does not die under the physiological strain of the high nitrogen levels from the seabirds' fecal matter, are becoming rare on Nauru. Therefore, the seabirds are increasingly killing the nesting trees that they require for breeding. Further nest sites have recently been lost due to mining near Bunda lagoon. Nesting trees are therefore likely to be a limited resource.

Figure 4. Breeding locations of black noddy in Nauru during the survey (indicated as diamonds).

Brown noddy, doquae (*Anous stolidus*), were found breeding both near the lagoon in coconut trees and in small shrubs in the pinnacles. More than 50 were counted nesting outside the pinnacles. It was not possible to determine the exact number of breeding birds due to lack of accessibility to topside sites.

OTHER NAURU BIRD SPECIES

Audubon's shearwater, ederakui (*Puffinus lherminieri*), was commonly sighted flying within sight of the shoreline. Approximately 10-30 birds were sighted when circling the island with a boat. However, no birds were seen inland or recorded breeding on Nauru.

Grey-tailed tattler (*Tringa brevipes*) and **wandering tattler** (*T. incana*) were encountered regularly on the beaches and reef flats at low tide. At high tide they were found at the Anabar Lagoon. Most of the tattlers were identified as *T. incana*, based on their calls. However, since not all individuals were heard calling, *T. brevipes* may have been present.

Long-tailed koel or long-tailed cuckoo, (*Eudynamys taitensis*), were not found during this survey. It is possible that the required forest habitat no longer occurs on Nauru.

Ruddy turnstone, dugudubwa, *(Arenaria interpres),* despite extensive surveys on the shoreline no *E. taitensis* were found during this survey. Reports from locals suggest wild dogs may be impacting the population.

Whimbrel, kiwoiy (*Numenius phaeopus*), Whimbrel were not observed during the survey and there was no evidence of nesting occurring on the island.

Pacific golden plover, iwyiyi (*Pluvialis fulva*), No *P. fulva* were observed during the survey. This might be because it was outside the season or indicative of a decline in the population.

Lesser sandplover (*Charadrius mongolus*) and greater sandplover (*C. leschenaultii*). Sandplover were not observed during the survey and there was no evidence of nesting occurring on the island.

Pacific reef heron, gogora (*Egretta sacra*), No *E. sacra* were observed during the survey and there was no evidence of nesting occurring on the island.

Brown booby, gogora (*Sula leucogaster*), was not observed during the survey and we found no evidence of nesting occurring on the island.

Masked booby, (*Sula dactylatra*). A single masked booby was seen flying off shore from Anabar Lagoon during the survey. This is the first time to our knowledge this species has been recorded near to Nauru. There was no evidence of nesting on the island. A second masked booby was observed at the fish attraction device at S 00 26'58.3" and E 166 56'34.0.

Rats, *Rattus sp (either R. rattus or tramazine)* and *Rattus exulans* were captured during the survey. Only *Rattus exulans* was captured in the pinnacle areas in the uplands while the larger *Rattus sp.* dominated the areas closer to humans and appeared to be particularly numerous near the old lagoon.

Discussion

Nauru contains a diverse suite of bird species, which are not only important for their biodiversity value but also for cultural and food values to the Nauruan people. Some of these bird species require conservation action if they are to be maintained locally into the future. Based on both of our surveys and previous surveys/studies, the current population status of Nauru avifauna and management recommendations to maintaining species are made below. Our discussion firstly covers seabirds, with a particular emphasis on local hunting, followed by both of the land birds and it then makes recommendations on conservation and general monitoring.

SEABIRDS

The data collected during this survey suggests that population sizes for many seabird species on Nauru have declined. Frigate birds, black and brown noddies and bristle-thighed curlew populations are particularly impacted. The decline of these seabird populations is potentially occurring for a suite of reasons. The major threats on land are invasive species (dogs, cats and rats), loss of nesting sites or nesting site disturbance, and unsustainable use of seabirds for food.

Seabirds have long formed a component of people's diets in Nauru. Although it is possible to hunt seabird populations sustainably, when adults are removed at a faster rate than can be naturally replaced (through recruitment of chicks into the population), population declines occur. In Nauru, noddy populations are likely to be affected by both the loss of nesting trees (as a result of phosphate mining on topside), which affects recruitment, and by high local take levels by the Nauruan people for food. In Nauru, the current noddy successful hunting rate by local people can only occur because non-local noddy birds are supplementing local populations. The current take rate by Nauruan people is not only affecting the local Nauruan noddy populations, but also the non-local noddy populations. Where the non-local birds come from and how much the current take rate is affecting their population levels is poorly understood and could not be addressed in this study. However, it is important to note that Nauru could be causing significant seabird population declines in the surrounding area.

It is important to note that the assessments made during this survey are only an indication of take level and maybe a severe under estimate. A year or two of count data and productivity would improve assessments of take sustainability. A survey of take levels would optimally be similar to the one used in fisheries, whereby people are placed at particular points where noddy catches can be recorded. Hunters level the noddy capture sites after hunting has occurred. This survey would need to occur in both good (low light levels, no moon or clouds and wind in the right direction) and bad noddy catching nights, and therefore must be carefully coordinated. Written surveys are not recommended as people are secretive about where the best noddy hunting sites are located. It is critical that further studies are undertaken to enable populations of noddy to persist in the long term, and to ensure that the associated food security for the Nauru people is maintained into the future.

LAND BIRDS

Micronesian pigeon

The continued survival of the Micronesian pigeon is most likely due to the difficulty in accessing interior pinnacle sites. Opening these sites by removing the pinnacles is likely to result in the decline of this species, unless laws reducing hunting are put in place and enforced. Although there is much talk on Nauru of rehabilitation of topside, it is also important to note that the oldest mined areas have become vegetated once again. These areas are important habitat not only for the Micronesian pigeon, but also for the Nauru warbler, brown noddy (which is nesting there now), and black noddy.

Nauru reed warbler

This survey suggests that the Nauru reed warbler is abundant and no recovery measures are currently required to ensure the survival of the species. The relative abundance of this species is surprising since invasive rats are present and this is a species which nests low to the ground (nesting 1–2 meters above ground appears common). Based on this survey, a recovery plan for the species is not currently recommended. It is possible, however, that this status might change if topside mining continues at its current rate. Old topside mining sites may serve as important source population sites where rat predation rates are lower than they are closer to human habilitation. The introduction of additional invasive species may also have a large and sudden impact on the Nauru reed warbler population. We recommend that while this species is still common, a small study of its basic biology is undertaken so that appropriate management to maintain the population can be implemented when required. We also recommend the species is monitored every five years so that declines will be noticed if they are occurring, and that its status is updated following these surveys.

Conservation recommendations

Based on our findings, the following three conservation actions and two monitoring programs are recommended to occur:

- Site restoration or maintenance at 1) Anabar lagoon, 2) Anibare cliffs and 3) where tall trees still occur. For example the top of Anibare, which is one of the few non-mined sites located topside, is critical for breeding seabirds. Nesting trees, especially Tomano, should also be replanted for nesting seabirds to maintain future food security for the Nauru people as well as maintaining breeding sites for the noddy.
- Control wild dog numbers to reduce the mortality of shoreline seabirds, which cannot fly during moult and thus escape predation. This action may have a large positive impact on the numbers of bristle-thighed curlew that migrate through the area.
- Monitor the harvesting of noddy and potentially control to maintain food security.
- Combine the above activities with appropriate conservation education so that everyone understands why these actions are occurring.

Also recommend that annual monitoring should be undertaken on 1) the harvest rates of noddy and the number of breeding trees and breeding birds, and 2) numbers of bristle-thighed curlew that come to Nauru.

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CHAPTER 5 REEF CORALS OF NAURU

DOUGLAS FENNER

Summary

- The reefs of Nauru have a low diversity of hard corals, with a mean of 17.2 species per dive site and a total of 51 species of hard corals observed during 20 dives in this brief survey. Details of dive sites are listed in Appendix 9.
- Nauru has a coral diversity similar to Hawaii or the Caribbean, but much lower diversity than in the archipelagos that surround Nauru.
- The sites with the greatest numbers of coral species were site 19 (27 species), site 20 (26 species), site 12 (22 species), and site 4 (21 species).
- All sites except one were heavily dominated by a single species of coral, *Porites rus*.
- Not only did *Acropora* have few species in Nauru (only 5 species), but colonies were rare. *Acropora* was reported to be more common in the past.
- One coral species, *Pocillopora fungiformis*, was found, which was previously only known from one site in Madagascar. It is listed as "Endangered" by the IUCN (International Union for Conservation of Nature) Red List, and as one of the top 50 "EDGE" (Evolutionarily Distinct & Globally Endangered) coral species in the world.
- One coral species, *Montipora caliculata*, was found, which has been proposed for "Threatened" status under the U.S. Endangered Species Act; it was also listed as "vulnerable" by the IUCN Red list. *Heliopora coerulea* (blue coral) was also listed as "vulnerable" by IUCN, as was *Pavona venosa*.
- Seven species were recorded that represented extensions of their known biogeographic range.
- Applying the IUCN Red List criteria to the data revealed four coral species may be locally Critically Endangered, another seven may be locally Endangered, and all others are locally Vulnerable.
- High coral cover, good coral health, good coralline algae cover, and low macroalgal cover all support the view that the reefs are healthy. The low diversity is due to the small size of the island and relatively large distance to areas of high diversity (as predicted by the Theory of Island Biodiversity and metapopulation theory). In this case it is not a sign of an unhealthy reef.
- Conservation recommendations include making the taking of coral illegal, the establishment of MPAs, protecting the largest reef fish species throughout the country, banning scuba spear fishing, protecting sea turtles, signing CITES, and monitoring the reefs by repeating our benthic and fish transects annually.

Introduction

Hard corals are a critical component of coral reefs worldwide. Coral reefs have the highest diversity known in marine ecosystems. Corals contribute to the build-up of the calcium structure of coral reefs (along with certain algae) and are critical to holding reefs together. Further, corals are a primary contributor of habitat diversity used by many species associated with coral reefs, notably fish but also cryptic, sessile and commensal organisms. Corals are highly vulnerable to a range of disturbances, many of which are caused by humans, and are undergoing rapid declines in many parts of the world. Coral reefs produce many ecosystem services for people, including fisheries, shoreline protection, and tourism, worth billions of dollars annually around the world.

Many corals can now be identified *in-situ* on coral reefs, due to field identification guidebooks such as Veron (1986, 2000) and taxonomic revisions such as those by Hoeksema (1989) and Wallace (1999). Field identification allows one to see the entire colony, and often times many colonies, while identification from collected specimens often must be based on small samples that don't show the colony shape or range of morphological variation. Although the number of coral species is less than that for fish, identification is more difficult due to greater morphological variation within species (Veron 1995, 2000; Todd 2008). However, field identification is much easier than with groups such as sponges or ascidians, which require extensive collecting and laboratory analysis because they cannot be identified in the field.

The combination of the critical role of corals for coral reefs, the high diversity of coral reefs, and the ability to identify most coral species rapidly in underwater visual census makes them a critical component in any rapid assessment of coral reefs.

Nauru is one of the world's smallest independent countries, consisting of one small island about 4 km by 6 km in size. It is located just south of the equator in the western Pacific, west of Kiribati and distant from other archipelagos. Nauru is a raised limestone island, which had abundant phosphate deposits on top of the limestone, which have been mined for many years and continue to be mined and exported. The island is reported to be surrounded by a narrow reef flat which has little or no coral on it (UNEP/IUCN, 1988), and submarine slopes which have coral on them (King, 1992; Jacob, 2000; Lovell et al. 2004; Chin et al. 2011; PROCFish/C and CoFish Team, 2007;). The reefs of Nauru, particularly the corals, have been little studied (Jacob, 2000). In 1990-91, there was a lack of large colonies (King, 1992). Lovell et al. (2004) report that "Reef development is generally poor and coral communities are either sparse or contain mostly dead corals, especially near the populated and developed areas of Nauru. Small encrusting colonies grow on the reef slope and live coral cover is 0-20% in areas from Uaboe District to Gahab Channel and Boe District." A survey of the reef in 2004 was reported to have found that live coral cover ranged from 44% to 78% (Chin et al. 2011). There are several anecdotal reports that the reefs have low diversity (King, 1992; Jacob, 2000). Jacob (2000) reported that the low diversity was said to be due to the small size of the island and the great distance from the center of marine diversity. However, a leading coral biogeographer, J.E.N. Veron commented that "The reefs of Nauru and Banaba islands had a lower diversity of coral genera than one would expect, based on biogeographical predictions" (King, 1992). Banaba is a similar small island to the east of Narau, the closest island to Nauru, and part of Kiribati. In 1990-91, *Pocillopora* was the most common genus, followed by *Porites*. Only two large table corals (*Acropora*) were found, and both were dead (King, 1992). Lovell et al. (2004) reported that "Recent surveys showed high mortality of *Acropora* colonies on Nauru, whereas massive and encrusting (non-*Acropora*) coral species have now become dominant." An SPC (Secretariat of the Pacific Community) PROCFish survey in 2005 did not record coral cover or species, but photographs of the reef are posted on the SPC website (http://www.spc.int/CoastalFisheries/SurveyData/Site?id=19D41B9F-817C-4CC8-98FF-F65C10BFC4F5). The photos show high cover of *Porites rus* in some areas, other areas that had *Pocillopora* and massive *Porites*, and areas without coral cover. In 1990-91, there were many white corals that were bleached or dead. Suspicion that phosphate may have damaged the reefs led a Cousteau group in 1990-1991 to collect samples of corals and fish and have them tested for cadmium, a toxic contaminant of phosphate, but unhealthy levels were not found. Thus, it appears that in 1991 and 2000 the reefs had low diversity, but that some time before 2004 (and probably before 1991) there was high mortality of *Acropora* leaving low live coral cover, which had increased by 2005 and perhaps more so by 2011. *Porites rus* had begun to increase by 2005. The Cousteau report from the 1990-91 study (King, 1992) concluded from the low diversity, the dead *Acropora*, the presence of phosphate mining, and the bleaching, that the reefs were unhealthy.

Nauru is remote from all other islands and reefs. It is 300 km from Banaba, Kiribati, 711 km from Tarawa, Kiribati (and the other islands in the Gilbert Islands), 974 km from Majuro, Marshall Islands (and about 750 km to the nearest atoll in the Marshalls), 1250 km from Honiara, Solomon Islands, 1274 km from Pohnpei, Federated States of Micronesia (FSM; and about 800 km from Kosrae, FSM), 1186 km from Port Vila, Vanuatu, 2632 km from Port Moresby, Papua New Guinea and about 1350 km from the nearest part of Papua New Guinea. There is quite a bit of ocean current variability in the area around Nauru. In March currents around Narau come from the east on the average, and in August currents come from the west (based on maps from the NOAA OSCAR model, www.oscar.noaa.gov derived from satellite data, courtesy of Dr. Philip Wiles). A simulation of where water comes from when it is coming from the west shows that larvae would take more than 30 days to come to Nauru from the eastern end of Papua New Guinea or the Solomon Islands (based on a map from the Australian BLUElink model based on tracer data, courtesy of Dr. Philip Wiles). During La Nina years, currents are more likely to come from the east (Philip Wiles, personal comm.). The Gilbert Islands to the east of Nauru are much closer (700 km) than New Guinea or the Solomon Is. to the west (1250-1350 km), so the Gilbert Islands may supply most of the larvae that actually reach Nauru.

Van Hooidonk et al. (2013) concluded that reefs close to the equator will reach temperatures at which they accumulate 8 degree heating weeks of coral bleaching stress every summer before reefs elsewhere. Nauru is one of those places, and the authors predict Nauru will reach these temperatures around 2023. On the other hand, they also predict that equatorial reefs like Nauru will be the last to reach high levels of acidification.

The following is a report of the reef coral fauna of the 20 sites surveyed around Nauru by the author during the Secretariat of the Pacific Regional Environmental Program (SPREP) and Conservation International (CI) Biological Rapid Assessment Program (BIORAP) June 17-27, 2013. The principle goals of the coral survey were to provide an inventory of the coral species growing on reefs and associated habitats, to compare the coral fauna at different sites, to compare the diversity of corals with other areas, and to look for species that would be outside their known range or which have heightened risk of extinction. The primary group of hard corals on coral reefs is the zooxanthellate scleractinian corals, that is, those that contain single-cell algae and which contribute to building the reef. Also included are a small number of zooxanthellate nonscleractinian corals which also produce large skeletons which contribute to the reef (e.g., *Millepora*: fire coral and *Heliopora*: blue coral), one azooxanthellate scleractinian coral (*Tubastraea*), and two azooxanthellate non-scleractinian corals (*Distichopora* and *Stylaster*). All produce calcium carbonate skeletons that contribute to reef building to some degree.

Most of the world's reef coral species have now been evaluated for the level of risk of global extinction (Carpenter et al. 2008) based on criteria developed by the IUCN Red List (IUCN, 2012a). The status of individual species is now available from the IUCN Red List (www.iucnredlist.org), and any species with heighten risk of extinction found in Nauru will be reported here. Species can also be evaluated for the risk of local extinction based on a separate set of protocols provided by IUCN (Gärdenfors et al. 2001; IUCN, 2012b). The first such local evaluations for corals have now been reported (Richards and Beger, 2013). In most cases, the evaluation of species depends on information on how isolated the area under consideration is. For very isolated areas, the rules for local extinction are the same as for global extinction, since the local population is not connected with other populations and thus behaves like a species endemic to that area. Evidence of isolation and connectivity will be examined, and the threat of local extinction evaluated based on the IUCN Red List criteria.

Methods

Coral diversity and abundance were surveyed at each one of the 20 sites (Appendix 9 and visually presented in Figure 1 of Chapter 7) while SCUBA diving for 60 minutes, using a "roving diver" search method. The roving diver search method detects more of the species present than belt transects and distinguishes differences in diversity at different sites as well as belt transects (Holt et al. 2013). The roving diver method likely detects more species because the area searched is larger. A direct descent was made in most cases to 30-35 m, which was the lower limit of abundant coral. The bulk of the dive consisted of a slow ascent along the reef in a zigzag path to the shallowest depth that was safe. Heavy wave surge above about 3-4 m depth made work in shallow water too dangerous to attempt. Corals were usually identified *in-situ,* however where an identification could not be made rapidly, a photograph or small sample was taken. Coral species and their abundance data were recorded on an underwater slate or printed form. Species abundance was recorded on the "DAFOR" scale, where "D" stands for dominant, "A" for abundant, "F" for frequent, "O" for occasional, and "R" for rare (DAFOR being an acronym for the categories; Mumby et al. 1996). Rare was defined as only one or two colonies seen, and dominant was defined as over half of all corals or coral cover. Other studies of corals which have used this sort of scale include DeVantier et al. (1998; 2006), Richards et al. (2008) and Richards and Beger (2013). Abundance categories were then given a numerical value, by assigning R = 1, O = 2, F = 3, A = 4, and D = 5. Coral species were also noted during walks on five reef flat areas, one just south of the boat harbor, one at the northern end of the island, one on the northeast side of the island, one under the old cantilevers on the west side of the island, and one just south of the old cantilevers. Reef flat walk durations were not recorded, but did not exceed one hour each. Many corals can be identified to species with certainty in the water and a few must be identified alive since they cannot be identified without living tissues. In addition, there are some that are easier to identify alive than from skeletons. Several comprehensive guides assisted identification (Hoeksema 1989; Wallace 1999; Veron 2000). However, there are some species that normally require collection for verification. Samples of species that could not be identified with certainty, or could represent new species were collected at some sites. Samples were later bleached in a household bleach solution then rinsed in freshwater and dried, but could not be taken into the U.S. for study because of CITES (Convention on the International Trade of Endangered Species) restrictions. Nauru is not a signatory to CITES so the U.S. will not allow imports from Nauru. The species collected are listed in Table 1.

Table 1. List of species collected with number of samples.

	Species	No. samples		Species	No. samples
1.	*Acropora* sp. 1	2	7.	*Millepora* sp. 1	1
2.	*Acropora* sp. 2	1	8.	*Montipora* sp. 1	2
3.	*Acropora* sp. 3	2	9.	*Pocillopora* sp. 1	1
4.	*Acropora* sp. 4	1	10.	*Porites* sp. 1	2
5.	*Heliopora coerulea*	1	11.	*Porites* sp. 2	2
6.	*Leptoseris* sp. 1	1			

Additional references used in identifying corals are listed in references (Randall and Cheng 1984; Veron 1986, 2000, 2001; Wallace 1999; Glynn et al. 2001, Ditlev, 2003; Razak and Hoeksema 2003, Wolstenholme et al. 2003; Richards and Wallace, 2004; Fenner 2005, Benzoni 2006; Benzoni et al. 2007; Wallace et al. 2007; Foresman and Birkeland 2009; Wallace et al. 2011). The nomenclature of Veron (2000) has been followed for fungiids, though the illustrations and descriptions in Hoeksema (1989) were the primary source for actual identification. The nomenclatures of these two authors differ primarily at the level of genera and sub-genera, not species. Further references used in identifying corals can be found in Hoeksema (1989), Wallace (1999), and Veron (2000).

DeVantier et al. (1998) used an index for evaluating reef sites for conservation, called the "coral replenishment index" or CI. The presence of high diversity, abundance and cover of coral can provide an ability to replenish or restock local area reefs in the case of a major disturbance. Their index, CI, is based on the abundance of each species and the total cover at a site, to get a measure of the local population of the species at the site. The index is

$$CI = \sum AiHi/100$$

Where Ai is the abundance score of each species at the site on the 0-5 scale used in this study, and Hi is the rank coral cover at the site. They assign ranks to coral cover such that 0% cover = 0, 1-10% cover = 1, 11-30% cover = 2, 31-50% cover = 3, 51-75% cover = 4, and 76-100% = 5. The mean site coral cover from the chapter by Sheila McKenna was used for this purpose.

DeVantier et al. (1998) also used an index for evaluating reef sites for conservation, called the "rarity index" (RI). This is an index of how many relatively rare species are found on a site and how abundant they are. It is

$$RI = \sum Ai / 3Pi$$

Where Ai is the abundance rank and Pi is the proportion of sites in which the species was present.

The probability of local extinction of species was evaluated following the rules set by the IUCN Red List (IUCN, 2012a,b). Nauru is isolated from other islands and reefs, with the nearest island being Banaba which is 300 km away, and the nearest archipelago being Kiribati, 700 km away. Connectivity with other archipelagoes was evaluated by comparing coral diversity at Nauru with surrounding archipelagoes. The probability of local extinction was evaluated by calculating total estimated populations of coral species which were rarely sighted, based on numbers sighted, the reef area searched, and the total area of Nauru reefs. The island of Nauru is about 4 km by 6 km, and approximated as a circle it would have a circumference of 15.7 km, but the island is somewhat bean-shaped so the circumference is larger, and was estimated at 20 km. PROCFish gave the island circumference as 19 km (PROCFish/C and CoFish Team, 2007). The reef slope is at about a 45 degree angle, and a depth of 30 m, the lower limit of corals on the slope, would be about 30 m from the reef crest, and the slope would be about 42 meters from a few meters deep to 30 m deep. The reef slope area would thus be about 1 million m^2 (= 1 km^2). PROCFISH gave the area of the slope down to 25 m depth as 2.5 km^2 (PROCFish/C and CoFish Team, 2007), based on satellite photography, where the principle uncertainty would be the depth which would be estimated from water color. The area searched in one roving dive has been estimated at about 2500 m^2 (Richards et al. 2008), so the total area surveyed in 20 dives would be about 50,000 m^2. Thus, the total reef area would be about 20-50 times the area searched in this study, and a species for which one individual was found would be estimated to have a population on Nauru of about 20-50 individuals. The minimum population for a species was calculated as the minimum number of individuals observed times the minimum estimated reef area (20 times the survey area) and the maximum population as the maximum number of individuals times the maximum estimated reef area (50 times the survey area). Species that were recorded at only one site and received an "R" on the DAFOR scale, had only 1-2 individuals sighted in this study. For some of those, just one individual was sighted. For those which received an "R" score at several sites, the estimated range of Nauru populations was based on 1-2 individuals at each of the recorded sites. Total estimated local populations were then compared to the criteria set in the IUCN Red List (IUCN, 2012a).

Results

CORAL SPECIES DIVERSITY

A total of 51 species in 18 genera of stony corals (including 46 species in 13 genera of zooxanthellate Scleractinina) were found in Nauru. Almost all of these species are illustrated in Veron (2000), most *Acropora* are illustrated in Wallace (1999) and fungiids are illustrated in Hoeksema (1989). The total of 51 species including 46 zooxanthellate Scleractinia is a little less than that known from Hawaii (65 species including 57 zooxanthellate Scleractinia, Fenner 2005) and the Caribbean (about 89 species including 61 zooxanthellate Scleractinia, Fenner 1999; Humann and Deloach 2002). It is much less than the number of species found on six other Pacific Rapid Assessments using the same methodology with the same identifier, ranging from 253 species in Fiji (Fenner 2006), to 333 species in New Caledonia (Fenner 2011). Each study included a different number of sites, but all had more sites than this study. The number of species found increases with increasing numbers of sites, so these numbers of species are not strictly comparable measures of diversity.

Nauru is surrounded by archipelagoes with much higher coral diversity than Nauru. The Solomon Islands are to the southwest of Nauru and eastern Papua New Guinea to the west of the Solomons. Pohnpei is to the northwest of Nauru, the Marshall Islands are to the north, the Gilbert Islands of Kirbati are to the east, and Vanuatu to the south. All have much higher coral diversity than Nauru (Figure 1). Nauru has coral diversity more similar to Hawaii (the most isolated archipelago on earth) and other isolated small islands such as Johnston Is., Cocos (Keeling) Atoll, Okinotorishima Is. and Wake Is. Different numbers of sites were surveyed in these studies, but the differences with Nauru are so large that there can be no doubt that Nauru has fewer species than surrounding archipelagos.

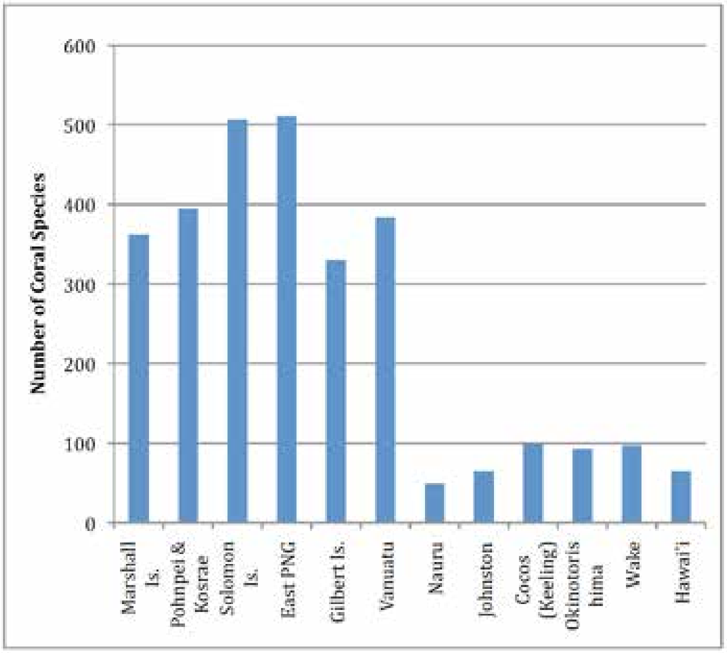

Figure 1. Total number of coral species known from Nauru and from surrounding archipelagos, and also five isolated areas in the Pacific (Johnston Is., Cocos (Keeling), Okinotorishima, Wake Is. and Hawai'i).

Data sources for locations are: Marshall Is.: Baker et al. (2011), Pohnpei: Turak and DeVantier (2005) updated by Veron et al. (2009), Solomon Is.: Veron and Turak (2006) updated by Veron et al. (2009), east Papua New Guinea: Fenner (2003) updated by Veron et al. (2009), Gilbert Islands of Kirbati and Vanuatu: Veron et al. (2009), Johnston: Maragos and Jokiel (1986) updated by Veron et al. (2009), Cocos (Keeling): Veron (1990) updated by Veron et al. (2009), Okinotorishima: Kayanne et al. (2012), Wake Is.: Kenyon et al. (2013), Hawaii: Fenner (2005).

The mean number of coral species found per site is more comparable between areas than the total number of corals found in a rapid assessment, because the amount of effort (one 60 minute dive) is more comparable than for the total species (number of dives, which varies greatly by study). A mean of 17.2 coral species was found per site in Nauru. This is similar to the mean of 18 species per site found in Hawaii (Fenner 2006), but much less than the 73.2 species per site found in New Caledonia (Fenner 2011), 70 per site found in Fiji (Fenner 2006), 71 in American Samoa (Fenner 2006), 71 in eastern Australia (Fenner 2006), 104 in Leyte, Philippines, and an average of 93.6 in 12 areas of the "Coral Triangle" area of highest diversity (Fenner 2006). Thus, comparing mean species per dive shows low diversity at Nauru just as shown by comparing the total number of species per area.

The sites with the greatest numbers of coral species were sites 19, 20, 12, and 4, and the sites with the fewest species were sites 14, 15, 16 and 3. The number of species found at each site is shown in Table 2. The species found at each site and their abundances at each site are shown in Appendix 10.

Table 2. The total number of coral species recorded at each site.

Site	Species	Site	Species	Site	Species
1.	15	8.	19	15.	9
2.	17	9.	15	16.	10
3.	11	10.	19	17.	15
4.	21	11.	20	18.	19
5.	21	12.	22	19.	27
6.	21	13.	18	20.	26
7.	18	14.	8		

The cumulative number of coral species found as a function of the number dives is shown in Figure 2. The cumulative number of species found increased rapidly at first, and then the rate decreased to low levels, until it increased again in the last few sites. Based on the data, the number of coral species found increases by about 7.25 species for each doubling of the number of dives, though it could be anywhere in a range from about 6 to 9 species. The total area of the island's reef is about 20–50 times larger than the surveyed area, so it would take 400–1000 dives to search the entire reef. Extrapolating from the present data, about 85–95 species would be found after 400–1000 dives, if additional species continued to be found at the rates found so far. If the actual total number of species around the island is less than 85-95 species, which is a real possibility, then additional species would not continue to be found with additional dives at some point. But 85–95 species appears to be about the most likely maximum number of species that might be found (though at an increment of 9 species per doubling that would be 96–105 species), while 51 is the minimum number since that number has already been found. Even105 species is well below the diversity of surrounding archipelagos.

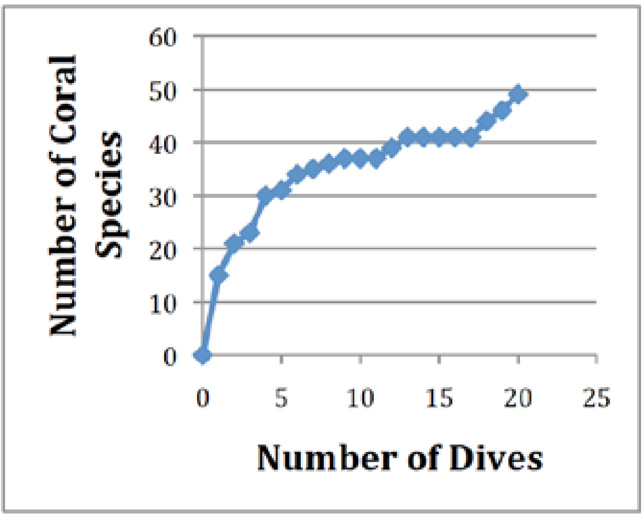

Figure 2. Cumulative number of coral species found with increasing numbers of dives.

The five reef flat sites had only a few scattered corals, and only one species of coral (*Acropora* sp. 4) was found that was not found on the slopes. Reef flats had an average of 2.4 species per site, much less than the 17.2 species per site on the reef slopes.

CORAL REPLENISHMENT AND CORAL RARITY INDEXES

The results for the Coral Replenishment Index for all sites are shown in Figure 3. The sites with the highest CI index were (in order starting from the largest) sites 5, 11, 10, and 13 and 19 (tied).

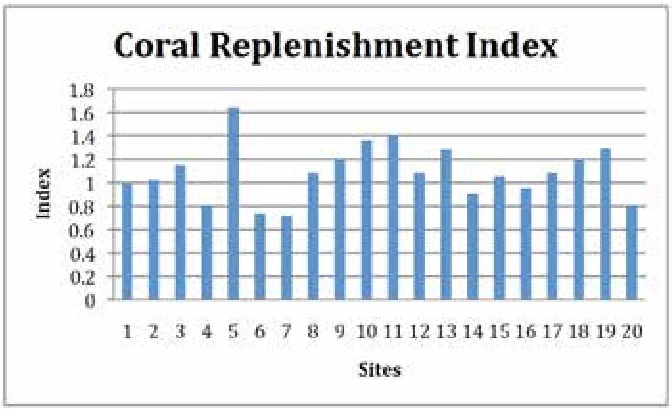

Figure 3. The coral replenishment index (CI) for each site using the method of DeVantier et al. (1998).

DeVantier et al. (1998) also used an index for evaluating reef sites for conservation, called the "rarity index" (RI). This is an index of how many relatively rare species are found on a site and how abundant they are. It is

$$RI = \sum Ai / 3Pi$$

Where Ai is the abundance rank and Pi is the proportion of sites in which the species was present. Figure 4 gives the values of the Coral Rarity Index calculated for each site. The highest values were found at sites 20, 19, 18 and 12 (in decreasing order).

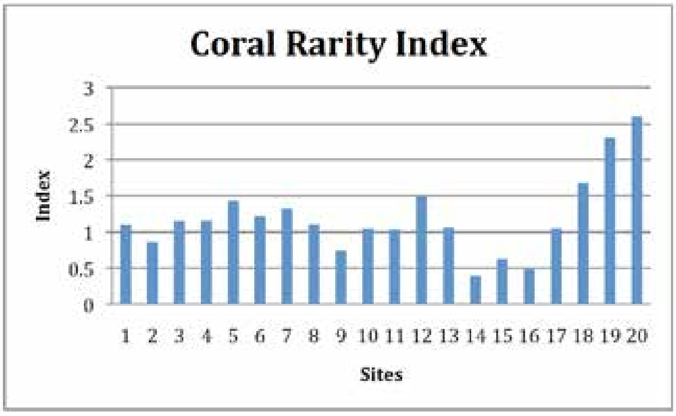

Figure 4. The coral rarity index (RI) for each site using the method of DeVantier et al. (1998).

The two indices, CI and RI, can be adding together to produce a single score for each site, which would provide a ranking of sites by both of these scores. Figure 5 presents the combined score for each site. The sites with the highest scores were 19, 20, 5 and 18, in descending order.

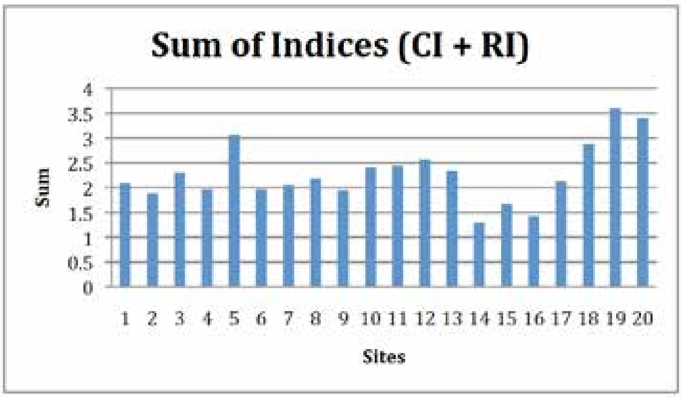

Figure 5. Combined index derived from adding the Coral Replenishment Index (CI) and the Rarity Index (RI), given by site.

GENERAL FAUNAL COMPOSITION

The coral fauna consists mainly of zooxanthellate Scleractinia with 46 species, and only five species that are not zooxanthellate Scleractinia (*Tubastraea* sp., *Heliopora coerulea*, *Distichopora violacea*, *Stylaster* sp. and *Millepora* cf. *platyphylla*). Zooxanthellate Scleractinia are the main reef builders, but *Millepora* and *Heliopora* are also significant reef builders because they are also zooxanthellate and have large skeletons. There were a total of 48 zooxanthellate species and just three species that are not zooxanthellate (*Tubastraea* sp., *Distichopora violacea* and *Stylaster* sp.). This pattern is typical of most reefs.

The genera with the most species were *Pavona* with eight species, *Montipora* with seven species, *Porites* with six species, *Acropora* with five species, and *Pocillopora* with four species. In the Indo-Pacific as a whole, *Acropora* has the most species, followed by *Montipora, Porites*, and *Fungia* in that order. However, *Acropora* was notable in Nauru for having few species and very few colonies. Resident observers noted that *Acropora* was more common in the past, though it was not among the dominant corals. The cause of the decline of *Acropora* is not known, though it is preferred prey of crown-of-thorns starfish (De'ath and Moran, 1998) and observers reported an outbreak of these starfish in the past. *Acropora* is also among the most sensitive genera to mass coral bleaching, hurricanes, and disease. Only a few small colonies of *Acropora hyacinthus* were observed, though one large table was reported by resident observers. *A. hyacinthus* is a common coral many places.

The most abundant species were *Porites rus*, *Pocillopora eydouxi*, *Distichopora violacea*, *Heliopora coerulea*, and *Montipora grisea*, in that order, as indicated by the mean abundance estimate ratings (Appendix 10). This is consistent with observations, particularly that *P. rus* is the most abundant coral by far, and completely dominates almost all reef slope sites. Interestingly, *D. violacea* is far more abundant in Nauru than anywhere else the author or Sheila McKenna has seen. Everywhere else it is restricted to shaded habitats, but in Nauru it is also in sunlit locations on vertical surfaces of coralline algae. It is not clear why it is so much more abundant in Nauru than elsewhere.

SPECIES OF INTEREST

A few colonies of *Pocillopora* had some branches that resembled branches of *P. eydouxi*, except that they were almost always cylindrical, and on some colonies were much shorter. About 1-2 dozen colonies were seen, on the upper reef slope, most commonly at about 5-7 m depth. However, the basal parts of the colonies were largely encrusting, and had narrow cracks that were unique. The development of the branches relative to the encrusting areas differed between colonies, but they always had some encrusting areas and always had the narrow cracks. This is consistent with the descriptions and photographs of *Pocillopora fungiformis*, described in Veron (2000) and Veron (2001). No other species in the genus *Pocillopora* has the combination of cylindrical branches, encrusting base, and cracks in the base (Veron 2000). Both the encrusting parts of colonies and the cracks can be seen in the illustrations in Veron (2000). *P. fungiformis* was photographed at five sites, but may well have been present at other sites as well, as it was not clear that it was a distinct species until after the survey was completed, in part because a copy of Veron (2000) was not available on site. The species is illustrated in Figures 6-9 below.

Figure. 6 A *Pocillopora fungiformis* colony illustrating branches resembling *P. eydouxi*, an encrusting base, and thin cracks. Some branches have been broken off.

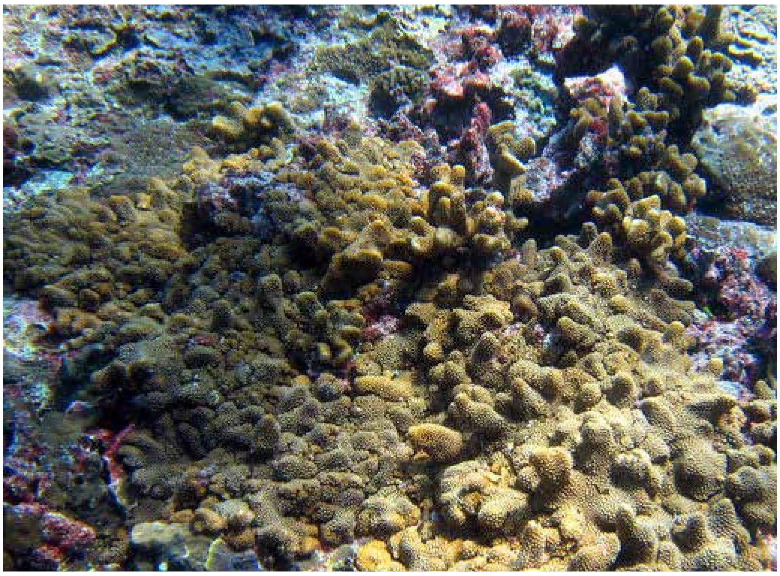

Figure 7. A colony of *P. fungiformis* that is mostly encrusting, with very stubby branches.

Figure 8. A photograph illustrating the cracks in *P. fungiformis*.

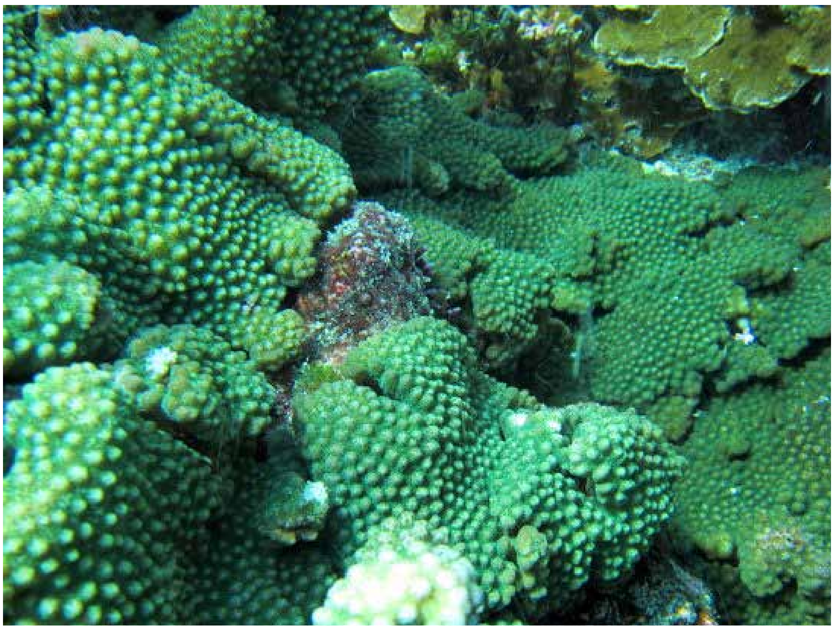

Figure 9. A photograph showing a *P. fungiformis* colony with an entirely encrusting portion on the right with cracks.

In Figure 10, a photograph of a colony in Madagascar, taken by J.E.N. "Charlie" Veron, who described the species, is presented. The encrusting base, irregular cylindrical branches, and the distinctive cracks in the encrusting base can be seen in this photograph.

Figure 10. A photograph of *P. fungiformis* in the type location in Madagascar.

One species that was observed has been listed by the IUCN Red List as endangered, and three species were observed that have been listed as vulnerable to global extinction. One species has been proposed for listing under the U.S. Endangered Species Act as "threatened" (Table 3).

Table 3. Species observed that have been assigned to categories for risk of global extinction.

Species	IUCN Red List Category	U.S. Endangered Species Act
Pocillopora fungiformis	Endangered	
Montipora caliculata	Vulnerable	Proposed: threatened
Heliopora coerulea	Vulnerable	
Pavona venosa	Vulnerable	

Extensions of known biogeographic ranges were found for seven species, *Pavona chiriquensis* , *Pavona gigantea*, *Pavona frondifera*, *Pocillopora setichelli*, *Porites arnaudi*, *Porites monticulosa*, and *Porites evermanni*. Known coral species ranges are presented in Hoeksema (1989), Wallace (1999) and Veron (2000). Additional details for each of these species is presented in Appendix 11.

All 51 coral species reported here (Appendix 10) except *Pocillopora eydouxi* are new records for Nauru. Lovell et al. (2004) reported that "The most common species were *Porites australiensis*, *P. heronis*, *Fungia* spp., *Pocillopora eydouxi* and *Millepora* sp. *Acropora specifera* and *A. palifera* were relatively common." Surprisingly, only *P. eydouxi* is still common, and *Porites australiensis*, *P. heronensis*, *A. spicifera* and *A. palifera* were not found in the present study at all. *P. heronensis*, *A. spicifera* and *A. palifera* are all relatively distinctive and easily recognized. They may be present in areas that were not searched in this study, though if they were common one would expect to find at least one colony. Another possibility is that somehow they were misidentified.

CANDIDATE LOCALLY ENDANGERED SPECIES

Table 4 presents the corals least frequently sighted in this survey, the total number of colonies seen, and the total estimated population.

Table 4. The coral species recorded least often in Nauru in this study. For each species only one colony was seen, as indicated in the table.

	Coral Species	Number of Sites Observed	Number of Colonies Observed	Total Estimated Population
1.	*Montipora caliculata*	1	1	20-50
2.	*Montipora* cf. *danae*	1	1	20-50
3.	*Pavona frondifera*	1	1	20-50
4.	*Cycloseris vaughani*	1	1	20-50

Table 5 below shows all the additional species with populations estimated at less than 250 individuals.

Table 5. Additional coral species estimated to have less than 250 individuals in Nauru. All species were rated "R" (Rare = 1-2 individuals) at all sites they were found at, and all but one were found at only one site.

	Coral Species	Number of Sites Observed	Number of Colonies Observed	Total Estimated Population
1.	*Acropora* sp. 1	1	1-2	20-100
2.	*Acropora* sp. 3	1	1-2	20-100
3.	*Leptoseris explanulata*	1	1-2	20-100
4.	*Leptoseris mycetoseroides*	1	1-2	20-100
5.	*Pavona venosa*	2	2-4	40-200
6.	*Leptastrea pruinosa*	1	1-2	20-100
7.	*Tubastraea* sp.	1	2	40-100

Discussion

The coral reef slopes of Nauru currently show several features that indicate healthy reefs, including very high coral cover, healthy corals, no macroalgae other than *Halimeda*, high cover of coralline algae in areas not covered by coral, and very high calcifying cover. However, there are previous reports of bleaching (King, 1992) low coral cover (Lovell, 2004) and lack of large coral colonies (King, 1992) and the loss of *Acropora* (King, 1992; Lovell, 2004). At the same time, the reefs show very low diversity for their geographic location, with much higher diversity in surrounding archipelagos (Figure 1). Also the island has a large amount of exposed phosphate, plus phosphate dust lost in loading ships. Reefs that have pollution impacts can have reduced coral diversity (Edinger et al. 1998), and/or reduced coral cover (Côté et al. 2005). However, cadmium levels in corals were low, there was no evidence of stimulation of algae growth by the phosphate, and coral cover and health were high. Reefs can also have low diversity due to their biogeographic location, such as in the Eastern Pacific (Glynn 1997; Veron, 2000), Caribbean (Veron, 2000; Humann and Deloach 2002), and Brazil (Veron, 2000; Castro and Pires 2001). However, Nauru is in a biogeographic location where high diversity is expected (Veron quoted in King, 1992; Veron et al. 2009; Veron et al. 2011) because all other archipelagos in the area have high diversity. Nauru is an outstanding example of the fact that a reef can have low diversity and be healthy. Low diversity does not necessarily mean a reef is degraded, even if it is in a biogeographic area where other reefs have high diversity.

Johnston Island is a small reef and island remote from other archipelagos much like Nauru, Hawaii at 800 km distance being the closest. Johnston has 33 species of corals (Maragos and Jokiel, 1986) updated to 65 species by Veron et al. (2009), and is surrounded by archipelagos with more coral species (Hawaii: 65 species (Fenner, 2005), Phoenix Is.: 189 species (Veron et al. 2009), Line Is.: 84 species (Williams et al. 2008) and the Marshall Islands: 362 species (Baker et al. 2011). Maragos and Jokiel (1986) attribute the depauperate coral fauna of Johnston to its small size and distance from other reefs and sea level changes that might have caused species extinctions. Veron (1990) studied the corals of Cocos (Keeling) Atoll in the northeast Indian Ocean. The larger atoll is about 10 by 15 km in size, and nearby North Keeling Island is about 1 by 2 km. They are 880 and 1830 km from the reefs of Java, Indonesia and Western Australia, respectively. Veron (1990) reported 99 species from Cocos (Keeling), and reports that Done (in prep.) found 85 coral species at Christmas Island, a small high island east of Cocos (Keeling). These were revised to 107 and 100 species, respectively by Veron et al. (2009). The nearest part of Indonesia, west Sumatra, has 386 species (Veron et al. 2009) and Western Australia has 318 species (Veron, 1990) with individual areas of Western Australia having 270-405 species (Veron et al. 2009), so the only reefs anywhere near these tiny islands have much higher diversity. Veron (1990) reviews disturbances that have reduced coral populations at Cocos (Keeling) and knowledge of currents that could bring larvae from elsewhere. Kayanne et al. (2012) describe a similar situation in the northwestern Pacific, in which a small Japanese reef, Okinotorishima (also called "Parece Vela"), has low diversity (93 coral species) even though it is nearly surrounded with archipelagos with much higher diversity, on the order of 250 species or more. The reef is 4.5 km by 1.7 km, so somewhat smaller than Nauru (though the reef area might be as large or larger than Nauru). It is 675-700 km from other archipelagos. They ascribe the low number of species on this reef to the fact that all the islands and archipelagoes with higher diversity that surround it are distant and currents do not flow to the reef, and so few of the coral larvae from those archipelagoes can reach this isolated reef. A fourth example is provided by Wake Island, a small remote island 546 km northeast of the nearest reef in the Marshall Islands, 1900 km southwest of Kure Atoll, the nearest reef in the Hawaiian archipelago, and 2260 km northeast of Guam (Kenyon et al. 2013). The island's longest axis is about 8 km. Kenyon et al. (2013) report a total of 97 species of hard coral species have been found at Wake Island. This is less than the northern Marshall Islands (168 species; Maragos, 1994), much less than the Mariana Islands (377 species, 281 of which are zooxanthellate; Randall, 2003) and the Marshall Islands as a whole (362 species: Baker et al. 2011), but more than Hawaii (65 species: Fenner, 2005). Kenyon et al. (2013) give no explanation for why the island has lower diversity than surrounding archipelagos. Johnston Is., Cocos (Keeling), Okinotorishima, and Wake Is. have the same pattern as Nauru: a small island or reef with low coral diversity, surrounded by distant archipelagos with higher coral diversity.

The diversity of fish, marine invertebrates and several groups of terrestrial fauna and flora are also low on Nauru (see other chapters in this report). This indicates that the cause of the low biodiversity is not due to something unique to corals or some other single group of organisms, but is rather a much more general process that affects both marine and terrestrial biota. The McArthur and Wilson (1967) Theory of Island Biogeography predicts that the terrestrial diversity of an island depends on the size of the island, the distance to a source of organisms, and the diversity of organisms at the source. The larger the island, the shorter the distance to a source of organisms is, and the higher the diversity of the source, the higher the diversity on the island. Those relationships are very likely to hold for marine organisms as well as terrestrial, in spite of differences in dispersal ability. Nauru is a very small island which is far from other sources of biota, as documented in the introduction. The majority of coral larvae probably drift a shorter distance than was recognized in the past (e.g., Ayre and Hughes, 2000); recruitment can decrease by an order of magnitude in just 600-1200 m from a source reef (Sammarco and Andrews, 1988; 1989). Thus, the Theory of Island Biogeography correctly predicts that Nauru should have low diversity, even if it is surrounded by archipelagos with much higher diversity.

The idea of "metapopulations" (e.g., Mumby 1999; van Woesik, 2000; Kritzer and Sale 2006; Mumby and Ditham 2006; Bay et al. 2008; Botsford et al. 2009;) is consistent with the Island Theory of Biogeography but goes further. It hypothesizes that when there is a group of habitat patches with intermediate levels of connectivity, the habitat patches support species diversity for each other. That is, when one habitat patch loses a species to local extinction, larvae from other habitat patches can re-colonize it. Islands and reefs are habitat patches for corals. This theory leads to the prediction that the larger the group of reefs, the more species it can maintain, a prediction supported by biogeographic studies of corals (Bellwood and Hughes, 2001). A good example is the Eastern Pacific where reefs are small and widely dispersed, coral diversity low, and local extinctions of corals have been documented (Glynn, 1997; 2011; Glynn and Ault, 2000). The low diversity of corals and other groups of organisms on Nauru is correctly predicted by the theory of metapopulations.

The only species of *Millepora* (commonly called "fire coral" because they sting) found in Nauru resembles *Millepora platyphylla*. The colony shapes found in Nauru are typical of those found in American Samoa, with an encrusting base and vertical paddles that are separated and thick. *M. platyphylla* has thin plates that are interconnected and rarely shows much of an encrusting base. The evidence from American Samoa indicates that it is a new species, and it will be described by the author from there. This species appears to be widespread, and present in Nauru. A small sample was collected to confirm the identification.

The taxonomy of *Pocillopora* is almost entirely based on colony morphology, because the corallites are almost featureless and do not provide a clear basis for identification. *Pocillopora fungiformis* was described from Madagascar, and as of 2000 known only from the type location. Thus, Nauru is a huge range extension from its previously known range. The author has not seen it before, and it is surprising to see it so far from the type location. *P. fungiformis* is listed (www.edgeofexistence.org/coral_reef/top_50.php) by the Edge of Existence program of the Zoological Society of London (www.edgeofexistence.org/index.php) as a top "EDGE" coral, where EDGE stands for "Evolutionarily Distinct & Globally Endangered" species. *P. fungiformis* is rated as "Endangered" on the IUCN Red List (www.iucnredlist.org), based on the evaluation reported in Carpenter et al. (2008). A formula is used to produce the EDGE score, by combing the IUCN Red List measure of how endangered a species is, with a quantitative measure of evolutionary distinctiveness. The rationale and formula are presented in Isaac et al. (2007). *P. fungiformis* is not listed among the 66 species of corals proposed by NOAA for protection under the endangered species act. It is not known from U.S. waters, and so was not petitioned for endangered status, however it is included in a new petition for protection under the U.S. Endangered Species Act. NOAA NMFS has subsequently decided that the information in the petition did not warrant further consideration of the species for endangered species status.

Although the corals illustrated have the colony morphology described for *P. fungiformis*, the fact that the only two known locations (Madagascar and Nauru) are very far apart suggests caution in interpreting this finding. In addition, the skeleton has not been examined yet. It is possible that there are populations of this species between the two locations that have not been recognized as this species, since the branches appear much like *P. eydouxi*. This is supported by the fact that the author found a single colony in the Northern Marianas soon after the present BIORAP. But if there are no populations between these three locations, the three populations would probably be completely genetically isolated from each other, and likely be genetically different. It may be that this coral population will prove to be a new species, distinct from *P. fungiformis* in Madagascar, though there is no evidence for that yet, and the species may well be found in intermediate locations in time.

The four species presented in Table 4 may meet the IUCN Red List criteria for locally Critically Endangered, based on criterion D, less than 50 mature individuals. The criteria for global extinction can be applied to Nauru because it is so isolated for corals that too few larvae are able to reach the island to establish most of the coral species found in surrounding archipelagos (Figure 1). This indicates that larvae from other locations cannot "rescue" a species that is going extinct on Nauru. For very isolated populations, the local populations behave like endemic species, and the IUCN Red List criteria for global species are applied to the local population. The IUCN Red List rules state that "Mature individuals that will never produce new recruits should not be counted (e.g. densities are too low for fertilization)." For some or many individuals in these species listed in Table 4 and 5 in Nauru, there are likely to be no other individuals of the same species within a distance (roughly 10 m) where fertilization success would be more than zero or very close to zero. The seven species listed in Table 5 meet the IUCN Red List criteria for locally Endangered, which is a population of less than 250 mature individuals. All coral species on Nauru fit the criteria for locally Vulnerable, since the total area of occupancy, the reefs, is an area of only about 1-2.5 km^2, and the criterion (D2) is "typically less than 20 km^2".

As in all reef systems, some species are rare. On a small island, species that are rare have small populations and are thus in more danger of local extinction (not global extinction) than species that are common and abundant. Because corals are fixed in location and must broadcast their sperm and/or eggs, colonies must be close together to achieve much fertilization success. If colonies are separated by more than a few meters, fertilization success drops off rapidly with distance. Thus, these species are subject to strong "Alee Effects" or "depensation" such that at low populations, the population becomes much harder to sustain (Courchamp et al. 2008).

Although the label "locally Critically Endangered" is appropriate for the species in Table 4, and although it sounds like a dire state of affairs, some perspective is warranted. First, while Table 4 presents the best currently available estimates of total populations of these species, they are only estimates. While a larger proportion of the total Nauru reef area was searched than is possible in larger countries, still, only one twentieth to one fiftieth of the total reef was searched, and searching a larger area would produce more accurate estimates. Also, estimates based on small numbers are subject to large random effects, so the accuracy of the estimates is low. Second, the loss of a species from Nauru would have no effect on the survival of the species as a whole, and the species in Tables 4 and 5 are not endangered globally. Third, the process of local extinctions and colonization from elsewhere is natural, and has been going on in Nauru for a long time. The problem is not a problem for the species, it is a problem for Nauru. The wait for larvae to arrive to re-colonize Nauru is likely to be a long one, so it is better for Nauru if the species don't go locally extinct in the first place. It is better to conserve Nauru's natural resources, than have to rebuild them.

Conservation Recommendations

Nauru has reefs that have coral cover that is among the highest on the planet, at a time in which most reefs are in decline, indicating they are exceptionally healthy. There are a variety of measures that can help protect the reefs and strengthen them. Regulations could be adopted making it illegal to take or kill any coral without a permit, or to make it illegal to take or kill a locally endangered coral. Marine Protected Areas can help with fisheries management (Fenner 2012), and strengthen protection of those areas to restore a more natural reef ecosystem with a full and functional fish community. A good herbivorous fish community helps protect from phase shifts from a coral-dominated reef that produces fish to an algae-dominated reef that produces few fish, and a good top predator community helps protect the herbivorous fish (by controlling the mid-size predators, Rupert et al. 2013). The large fish species often roam over large areas of reef, larger than MPAs. Restoring the largest species of fish, which are often the most impacted by fishing, can help reduce effects on the ecosystem that happen through trophic cascades (Fenner 2009). Fishing regulations can be used to completely protect the largest species of fish throughout the island's reefs, without closing them to fishing for other kinds of fish. Scuba spearfishing is a very efficient and powerful fishing method; banning it could reduce pressure on parrotfish (which are herbivores), which don't take bait on a hook. That would help provide security that parrotfish are abundant enough to keep the algae in control, and it also helps keep the reefs from being overfished. Spearfishing without scuba could continue. The government could also consider signing the CITES convention, which would help it to control any future trade in organisms that might threaten biodiversity on land and in the sea, while allowing trade that is not a threat. In addition, the government could consider protecting sea turtles, which are all endangered or threatened. Finally, the Fisheries department should begin a coral reef monitoring program, repeating our benthic transects each year. The Fisheries department has all the major equipment it needs plus a staff of good scuba divers and could easily do the benthic and fish transects. A monitoring program could provide early warnings of any problems with the reef that might develop.

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CHAPTER 6

MARINE NON-CRYPTIC MACRO INVERTEBRATE DIVERSITY OF NAURU

SCHANNEL VAN DIJKEN

Summary

- Over a period of 10 days in June 2013, 20 subtidal sites and four reef flat intertidal areas were surveyed around Nauru for non-cryptic macro invertebrate species. The survey involved approximately 32 hours of scuba diving to a maximum depth of 40m, and four hours of reef walks.
- The reefs of Nauru have relatively low diversity of marine invertebrates. The total number of non-cryptic invertebrate species identified to genus in this study was 79, representing 43 families, 18 orders, and 11 class groupings.
- First documentation of soft corals in Nauru (i.e. *Sacrophyton* sp. and *Cladialla* sp.). Colonies were sparse and observed at only two sites surveyed (sites seven and 13).
- Forty one new records for Nauru were found in this study. The total number of macro invertebrates recorded is 248, including 207 species that have been recorded in previous studies or museum collections.
- Species diversity per site ranged from 18 species at site 16 (northwestern side of Nauru) to one species at reef flat site 3 (northern part of Nauru). The average species per site was 10.6 (+/- 0.9 SE)
- Low diversity is most likely due to the paucity of habitat types and availability as well as the islands' small size and isolated locality.
- The invertebrate fauna is dominated by the family groups; Diadematidae (two species over 22 sites), Muricidae (seven species over 20 sites), Holothuridae (three species over 18 sites) and Trapeziidae (five species over 18 sites).
- The most common species per site were; *Echinothrix diadema* (20 sites), *Drupella cornus* (16 sites), *Trapezia rufopunctata* (16 sites), *Coralliophila neritoidea* (15 sites), *Actinopyga varians* (13 sites) and *Diadema setosum* (13 sites).
- Two *Tridacna maxima* were found during this study. These clams were previously thought to be locally extinct as they have not been recorded since the 1980s. No other giant clam species were observed.
- There was limited diversity and number of targeted marine invertebrates. Only five species of sea cucumber were observed; *Actinopyga palauensis, Actinopyga mauritiana, Bohadschia graeffei, Holothuria atra, and Thelenota ananas*. Observed densities of these species was very low. Very little *Turbo* spp were found and no *Trochus* was found despite habitat availability, which may suggest over exploitation.
- Over targeting of easily accessible gastropods and clams may have led to their relatively low abundances and diversity. Marine Managed Areas (MMAs) are recommended to help establish source populations and replenish low numbers for once abundant targeted invertebrates. Immediate action is required to save and nurture the only *Tridacna* clams recorded in recent history in Nauru.
- A Marine Managed Area with multiple use and restriction zones are recommended in the Anibare Bay of east coast of Nauru in conjunction with the district directly north of Anibare (Ijuw District – north east Nauru). A Marine Managed Area for the entire Anibare and Ijuw districts should be considered that would encompass the fringing terrestrial area for effective integrated coastal management and that would contribute to national commitments to the Convention on Biological Diversity (CBD) targets and Pacific Oceanscape Initiative.
- Nauru Traditional Environmental Knowledge (TEK) should be revived to reconnect Nauru people with their land, sea and resources. Past customary laws and practices governing resource use have been lost with the propagation of the mining industry, resulting in a tragedy of the commons attitude, effectively leading to over collecting. These customary practices can be revived. Together with updated legal policy and tighter legislation, TEK will be very important and effective in the longterm sustainable resource management in Nauru.

Introduction

In July 2013 the Secretariat of the Pacific Regional Environmental Program (SPREP) with assistance from Conservation International, conducted a Biodiversity Rapid Assessment Program (BIORAP) survey in Nauru. The aim of the expedition was to develop information on the biodiversity and ecosystem health of Nauru to help inform conservation status. This chapter presents the results of the non-cryptic macro-invertebrate diversity investigation conducted as part of the BIORAP.

The marine fauna of Nauru has been poorly documented. The earliest accounts on marine life were recorded by North et al. (1903), and by Whitley and Colefax (1938). These studies were brief and only covered a few species. Other past studies have included finfish work; Dalzell and Debao (1994), Petit-Skinner (1995). Reports from the Cousteau Society (King, 1992) and Jacobs (2000) noted that Nauru reefs had low diversity of corals and invertebrates. The most recent general survey of fish and targeted invertebrate communities was undertaken by the Pacific Regional Coastal Fisheries Development Programme (PROCFish, 2005) for the Secretariat of the Pacific Community (SPC). This project conducted a substantial survey of reef associated fisheries resources at 50 sites around Nauru in 2005.

There has been very little dedicated study of marine invertebrates in Nauru. Past studies have focused on general country profiles (Jacobs, 2000), coral and fisheries stock assessments (PROCFish, 2005). The only studies on species diversity have included specimen collections for museums (Australian Museum, Museum national d'Histoire naturelle (MNHN in New Caledonia), and the Florida Museum of Natural History), casual notes recorded on species presence and recordings of targeted and gleaned invertebrates during the 2005 PROCFish program. The PROCFish project concentrated on diversity, abundance and distribution of targeted invertebrate species, using broadscale (manta tows) and fine scale (transects, timed search periods) methods. The aim of the PROCFish study was to identify commercial feasibility of harvesting targeted invertebrates and conduct an up to date stock assessment of commercially and locally targeted invertebrate species.

In this current study the spectrum of research was broadened to survey and record significant and non-cryptic macro invertebrate species together with the commercial and targeted invertebrate species to complement and enhance the biodiversity information for Nauru. The objective of this chapter was to produce an up to date species diversity assessment and species list of the non-cryptic macro-invertebrate fauna (termed thereafter as 'macro-invertebrates') that can be used as a tool in guiding marine resource management and use in Nauru.

Methods

Non cryptic macro invertebrate species were assessed over a 10 day sampling period from 14th to 26th June, 2013. A total of 24 sites were examined, 20 subtidal and four intertidal. Attention was focused on the subtidal reef surge zone and slope down to 30m due to survey time constraints as reef top and intertidal zones had been extensively covered in previous PROCFish study.

All 20 subtidal sites were surveyed using SCUBA. Each site was examined using a "roving diver" technique starting at a depth of 35m and working up the reef slope in a slow meandering zig zag path to the shallows. This technique was used to sample as much habitat as possible in the time allowed within each dive, allowing access to deeper sites where previous survey data is poor. The approach involved the author covering the full range of depths and habitats during a single dive of 60 minutes. Most of the dive was spent in the shallow water (5m), where generally highest diversity of invertebrates occur (Wells & Kinch, 2003) and allowing for safe dive profile.

The four intertidal reef flat sites were also surveyed over a 60 minute period at low tide by walking in a roaming zig zag fashion starting at the high tide mark and making way seaward, recording or collecting species in the exposed habitats. Surveying all sites in 60 minutes allowed comparisons amongst sites to be made giving a better idea of species richness per site. There are however a number of limitations to this method such as macro cryptic, burrowing and nocturnal species unable to be observed.

All non-cryptic macro invertebrates that were encountered were recorded and identified *in situ* on an underwater slate and waterproof paper. However, if identification was unable to be made *in situ* a picture was taken and if possible a sample. These pictures and samples were analysed at the end of each day using reference material while images and memory was fresh. A number of up to date standard macro invertebrate field and identification guides and reports were available for referencing during the survey. Most species were identified with these references, which included; Colin and Arneson, 1997; Gosliner et al, 1996; Humann and DeLoach, 2010. Relative abundance data for each species was also recorded at each site.

For species that were unable to be identified in the field photos were sent off for identification with invertebrate specialists. Special thanks are given to Emmanuel Tardy for his time in identifying unknown invertebrate specimens from pictures sent. Species that were unable to be identified (from pictures or in the field) to the genus or family level were not included in this study. Many unidentified species specimens were unable to be taken away for identification due to lack of proper containment and logistical complications.

In order to provide the most comprehensive record of the macro invertebrate biodiversity in Nauru the report not only provides species recorded by the author, but also includes species recorded in previous reef invertebrate survey (PROCFish, 2005) and data obtained through research of databases from museums that hold type specimens of species collected from Nauru (www.gbif.org). In addition, this report also utilises the local knowledge of three experienced Nauruan fisheries department staff (and keen fishermen) over the survey time period. Data collection and species identification in this manner was achieved by interviewing the fisheries officers and allowing them to point out species from identification guides and resources (Colin and Arneson, 1997; Gosliner et al, 1996; Humann and DeLoach, 2010) that they had seen on their reefs. Only positive and definitive species were recorded. From these sources and methods a more current, broader and comprehensive species list for Nauru was compiled.

Results

A total of 79 species and 59 genera were recorded in this present study. This included representatives from 43 families, 18 orders, and 10 classes as outlined in Table 1. Please see Appendix 12 for full list of species identified in this study.

Table 1. Number of order, families, genera and species by class collected during Nauru survey

Class	Order	Family	Genera	Species
Anthozoa	1	1	1	3
Asteroidea	1	3	3	3
Bivalvia	2	4	4	4
Cephalopoda	1	1	1	1
Echinoidea	4	4	7	7
Echiuroidea	1	1	1	1
Gastropoda	4	10	14	23
Holothuroidea	1	2	4	5
Malacostraca	1	16	22	30
Polychaeta	2	1	2	2
Totals:	**18**	**43**	**59**	**79**

Given the large number of invertebrate species (over 95% of all animal species on earth are invertebrates) it would be presumptuous to try and identify all groups of invertebrates in the current study. As such the author focused on the following groups where knowledge was more accessible and for the ability to compare results with other work. Main groups included: holothurians, gastropods, bivalves, asteroids, and echinoids. Due to the limited time and limited specific knowledge groups such as crustaceans, sponges, cnidarians, brittle stars, feather stars, bryozoans or ascidians were not systematically targeted for survey. However, some species from these groups known to have an important role in the ecosystem (such as some crustaceans) or that was readily and easily identifiable were included and listed. Two species of soft corals were documented (Sacrophyton sp. and Cladialla sp) and included in the species list for Nauru but excluded from the non-cryptic macro invertebrate analysis done per site.

It is important to note that many species that could not be identified beyond the family level were not entered into the species list or used as data in this report. Over 40 species were excluded from the study analysis and thus record. However, most were crustaceans (at least 18 hermit crab species, eight coral crab species, four crab species, one mantis shrimp, one shrimp) as well as three brittle star species, one anemone, one bivalve and several cowry species.

To complement this study, comprehensive background research was done into past studies and surveys where it was found that there is at least 207 species recorded for Nauru (PROCFish 2005, Australian Museum, MNHN, Florida Museum of Natural History). Most of these recordings were biodiversity occurrence data from the Australian, New Caledonian and

Florida museum data bases and accessed through the GBIF Data Portal (http://www.gbif.org/country/NR/about/datasets), with the most recent recordings (59 species) from the 2005 fisheries surveys conducted in Nauru by SPC. Appendix 13 provides a current species list recorded for Nauru from all sources including this study.

SITE SPECIFIC INVERTEBRATE DIVERSITY

Table 2 compares invertebrate diversity amongst the 24 sites. The mean number of species (species diversity) per site was 10.7 (+ 0.91 SE). Species diversity ranged from 18 species at site 16 to one species at reef flat site 3. There does not seem to be a pattern of species diversity associated with the different sides and/or predominant weather exposure gradient of Nauru, where the east side (windward) has higher wave and swell energy in comparison to the west side. However, several sites that were in areas adjacent to large scale development did have the lowest species diversity. For example sites 1, 2, and 3 were situated next to the old cantilevers, and small boat launching harbour, and only had 5, 6, and 3 species per site respectively. Figure 1 illustrates site locations in Nauru.

Table 2. Total invertebrate diversity observed within each site surveyed with location on Nauru.

Site	Number species found	Percent (%) of total species recorded in 2013 Nauru Survey	Location on Nauru
16	18	22.8	West
17	16	20.3	Southwest
8	15	19.0	North
10	15	19.0	East
11	15	19.0	Southeast
13	14	17.7	North
20	14	17.7	West – active cantilever site
12	13	16.5	Southeast
18	13	16.5	South
4	12	15.2	Southeast
7	12	15.2	Northeast
9	12	15.2	North
15	12	15.2	Northwest
14	11	13.9	Northwest
19	11	13.9	East – fisheries harbour entrance
6	10	12.7	Northeast
Reef Flat 1	10	12.7	West
5	8	10.1	Southeast
2	6	7.6	Southwest
1	5	6.3	Southwest
Reef Flat 2	5	6.3	East
Reef Flat 4	5	6.3	East
3	3	3.8	South
Reef Flat 3	1	1.3	North

Figure 1. Map of Nauru with location of sites sampled, including fisheries department office and some predominant district names.

Table 3 outlines the total number of sites that the most common family groupings were recorded. The dominant invertebrate fauna by family was; Diadematidae (Urchins), with two species observed over 22 sites, Muricidae (Marine rock snails) with seven species over 20 sites, Holothuridae (sea cucumbers) with four species over 18 sites and Trapeziidae (coral crabs) with five species over 18 sites. Please refer to Appendix 14 for full listing of total number of sites for all families recorded.

Table 3. Most common families observed by number of sites (reef sites plus reef flats).

Family Grouping	Number of sites
Diadematidae	22
Muricidae	20
Holothuriidae	18
Trapeziidae	18
Serpulidae	13
Echinometridae	12

The most widespread species recorded throughout Nauru is outlined in Table 4. *Echinothrix diadema* was the most widely observed around Nauru being recorded at 19 sites, followed by *Drupella cornus* (recorded at 16 sites), *Trapezia rufopunctata* (recorded at 16 sites), *Coralliophila neritoidea* (recorded at 15 sites), *Actinopyga varians* (recorded at 13 sites) and *Diadema setosum* (13 sites).

Table 4. Most common occurring species during Nauru BIORAP.

Functional grouping	Species	Total number of sites observed
Urchin	*Echinothrix diadema*	19
Corallivorous snail	*Drupella cornus*	16
Coral crab	*Trapezia rufopunctata*	16
Corallivorous snail	*Coralliophila neritoidea*	15
Sea cucumber	*Actinopyga mauritiana*	13
Urchin	*Diadema setosum*	13
Christmas tree worm in coral	*Spirobranchus giganteus*	11
Urchin	*Echinostrephus* sp.	9
Coral crab	*Trapezia bidentata*	9
Shrimp	*Alpheus* sp. 1	8
Hermit crab	*Paguritta corallicola*	7
Urchin	*Tripneustes gratilla*	7
Urchin	*Echinometra mathaei*	6
Starfish	*Linckia laevigata*	6
Sea cucumber	*Bohadschia graeffei*	5
Sea cucumber	*Actinopyga palauensis*	4
Hermit crab	*Calcinus minutus*	4
Sea cucumber	*Holothuria atra*	4
Sea snail	*Turbo argyrostomus*	4
Hermit crab	*Calcinus haigae*	3

Asteriodea (starfish)

Only three species of starfish were observed during the survey. *Linckia laevigata* (the blue starfish) was the most commonly occuring being observed at 6 sites. The others were corallivore starfish such as the pincushion star *Culcita novaeguineae* and the crown of thorns starfish (cots) *Acanthaster planci*, but only occurring at 2 and 1 sites respectively. The rarity of these species was also observed in the PROCFish 2005 study.

Bivalves (clams)

Only four species of bivalves were recorded in this study, including *Acrosterigma elongata* (local cockle), *Periglypta reticulata* (reticulated venus shell), *Spondylus sp* (local scallop), and *Tridacna maxima* (giant clam).

Two *T. maxima* individuals were recorded in this study at sites reef flat 2 and reef flat 4. This is the only species of giant clams that have been recorded in Nauru in recent history. All past and most recent studies found and reported that *T. maxima* had become locally extinct or extirapated in Nauru waters (Jacobs, 2000, South and Skelton 2000, PROCFish 2005). This is not surprising as rapid declines in population densities and local extinctions of Tridacnids have been observed in recent history throughout their Pacific geographic range, which has largely been due to over harvesting and habitat degradation (Lucas, 1988; Othman et al., 2010). Throughout the 90's these specis were re-introduced throughout the Pacific region from Palau stock to help replenish declining numbers (. However, this has not seemed to have helped and as a consequence to aforementioned threats and current status they are listed in Appendix II of the Convention on International Trade in Endangered Species (CITES), and considered vulnerable under the International Union for Conservation of Nature (IUCN) Red List of threatened species (Waters et al, 2012).

Identifying two individuals of *T. maxima* at two separate sites is encouraging and provides evidence that the environmental conditions and habitat required for their successful rearing still exists in Nauru. Both these sites where the clams were found were on the eastern side (most exposed) of the island and in two different Intertidal reef front areas very close to the fisheries department office and boat ramp. There would be potential to use these sites in pilot studies to investigate

T. maxima growth and culture for the aquarium trade, as well as for local restocking programs. The location of these sites where the clams were found for protection would be ideal given the very close proximity to the Nauru fisheries office, allowing for more effective monitoring and enforcement.

Crustaceans (crabs and lobsters)

No lobsters or large crabs were observed in this survey, however they were identified by local fisherman and fisheries officers in meetings and discussions with identifications provided by looking through invertebrate reference identification books (Colin and Arneson, 1997; Gosliner et al, 1996; Humann and DeLoach, 2010). It has been reported that lobsters are normally fished at night to be sold in the restaurant trade, with anecdotal information to suggest that this stock is in decline (PROCFish 2005; Nauru Fisheries officers personal communication).

It was interesting to note the high abundance of coral crabs living amongst the branching *Acropora* coral. This may also be contributing to the high coral health that was observed throughout survey sites, with very limited disease, algae growth, and cots scarring being observed. Coral crabs are known to have symbiotic relationship with branching corals cleaning, gleaning and keeping the corals free from sediment and coralivorous predators such as cots and *Drupella* snails (Stewart et al, 2006; Rotjan and Lewis, 2008)

Echinoderms (urchins)

Urchins were abundant on all dives within the study as was observed with the widespread dominance of the Diadematidae family that was recorded at 22 out of the 24 sites. Given the apparent abundance of these species it is thought that this may contribute to limited diversity of other sedentary species illustrating a habitat dominated by urchins that are able to graze, feed and dislodge newly settled and growing invertebrate recruits and control cryptic spaces for shelter.

Gastropods (sea snails)

The large spider conch *Lambis truncata* was observed in only 2 sites (site 5 and 6). This apparent limited abundance is consistent with what was observed in past studies (PROCFish, 2005). Also, as observed in the PROCFish 2005 surveys, *Turbo argyrostomus*, *Conus* spp, *Cypraea*, *Nerita*, *Thais* and *Vasum* spp were recorded but in low numbers. There seems to be no obvious change in these species relative abundance over the past years. No trochus was recorded although suitable habitat does seem to be available.

Holothurians (sea cucumbers)

Only five sea cucumber species were recorded in this study. This limited number and diversity of seacucumbers is most likely due to the nature and habitat of the Nauru reef-scape. There are very limited protected shallow areas with sediment and/or sand. As reported in the PROCFish 2005 study the "the lack of sediment and high degree of exposure across reefs at Nauru makes them less than ideal for most deposit feeding sea cucumbers (which eat organic matter in upper few mm of bottom substrates). Even the reef platforms partially protected from swell, were generally exposed (to sun and wind) at low tides.

One species, the surf redfish (*Actinopyga mauritiana*), that was previously recorded in Nauru as "relatively common (recorded in 92% of broad-scale manta transects and 100% of reef-front searches)" (PROCFish, 2005) was found only in 54% of sites surveyed. In the PROCFish study it was suggested that there was some potential for a small scale fishery based on this species, and observed that locals were starting to consume more of it as other species become harder to find. This species is exploited throughout its range in the Pacific and as such is listed as Vulnerable on the 2013 IUCN RedList. Given this information and comparing to the present study, it appears that this species is in decline in Nauru and that urgent management steps are required.

Discussion

Nauru is small and isolated which is reflected in the limited diversity that was observed in this study. The level of geographic isolation from the Indo-Pacific marine biodiversity center and other Pacific and mainland countries is a major barrier limiting the influx of potential recruits. Also, there seems to be very limited endemism as you would normally expect with an isolated island archipelago, suggesting that many invertebrate species present in Nauru were transient in nature while colonising other island chains, but given the limited habitat types found in Nauru were unable to specialise, evolve or develop into additional niches, thus the limited habitat diversity playing a role in limiting the actual species diversity.

The small size and limited area of intertidal and subtidal reef habitats found in Nauru, compounded with small available intertidal reef habitats that are often exposed for extended periods of time, is not suitable to support a large number and diversity of macro invertebrates. As observed in the coral and fish diversity chapters, diversity is very limited, restricted by available habitat type that is usually dominated by a few species.

Other factors may also compound with habitat availability to limit diversity of macro invertebrates in Nauru, such as exposure (abiotic) and the present densities of urchins (biotic). Although these urchins can stop the build-up of algae and therefore are useful in the system, they may also have a negative influence on incoming recruitment. It would be interesting to conduct several studies that would exclude urchins from specific areas of inter-tidal and sub-tidal reefs and document the recruitment process. Urchin build up may also be a symptom of over fishing; whereas larger individual fish of given species that would normally predate on urchins are disappearing, as observed with the general smaller size classes of fishes (Dave Feary, pers comm)

Although species diversity seemed low the general health of the ecosystem seemed intact and healthy, despite some indications of over harvesting (e.g. no *Trochus* species found, declining numbers of *Turbo spp* and *Actinopyga mauritiana* the Surf Redfish). Live coral cover was high, present densities of corallivore starfish, such as the crown of thorn starfish were not a concern, and the presence of the IUCN Red Listed vulnerable (but locally extinct) giant clam *T. maxima* were positive signs. Anecdotal evidence had suggested that these clams were lost from Nauru as early as 1980, with few reports of sightings before this. The fact that there is a local name for this giant clam "earinbawo" suggests that it was significant in the past (PROCFish, 2005). Suitable habitat is available on Nauru for this and other species (e.g. *Trochus*) but over harvesting has led to drastic declines. Effective conservation and resource management is now required to preserve and help sustain the current marine macro invertebrate fauna for Nauru.

Conservation Recommendations

Although there is a lack of data on Nauru invertebrates, we have enough information to make educated decisions on sustaining, protecting and effectively managing the current macro invertebrate fauna and diversity of Nauru and the eco system services they underpin.

Before any concrete recommendations can be suggested it would be premature to suggest anything without first recommending and considering proper policy, laws and legislation are in place. Adequate Marine Protected Area (MPA) and conservation legislation needs to be established. From Jacobs 2000 report it was noted that "The Nauru Fisheries and Marine Resources Authority Act 1997, calls for the Authority to manage and sustainably utilise the fisheries and marine resources of Nauru. The Nauru Fisheries Act 1997 calls for the management, development, protection and conservation of the fisheries and marine resources of Nauru." The two legislation pieces only mention the requirements for management and conservation of marine resources, but are not adequate to address conservation programmes or issues in more detail. At the time of the Jacobs 2000 study, a draft marine conservation bill was proposed to be tabled in parliament, this was done but required widespread consultation before it became law. However, this situation has not changed since 2000 and the drafted bill has not made it through parliament to be law (Asterio Appi, pers comm). Now is the time to reinvigorate this, to protect Nauru's future food security, biodiversity and the ecosystem services that are important to a healthy sustainable living environment.

In addition to law and policy, community and government agencies can start looking at developing Marine Managed Areas (MMAs). These have also been recommended in recent past reports formulated for Nauru. Suggested sites have included establishing a MMA in the bay area of Anibare (east Nauru), as this site has been already proposed in the past report of Thaman and Hassall (1996) which at the time had the support of the local community. This site would also be ideal as it is very close to the fisheries department office and was the only district area that had the two sites where the *T. maxima* clam were found. Another area suggested is the northeast reef area of Nauru in Ijuw District (adjacent district north of Anibar) where PROCFish 2005 described the habitat as less impacted and the appearance of greater diversity. This study did not find greater diversity of non cryptic marine invertebrates at this site however the site was very healthy and appeared diverse. Both these sites would work very well as MMAs.

A recommendation from the author would be to create a MMA for the entire Anibare and Ijuw (northeast Nauru) districts that would also encompass the fringing terrestrial area. These areas would benefit from protecting and managing important habitats and species, further enhancing local populations of targeted marine invertebrates as well as other targeted species. It would be suggested that the districts would close off some areas to harvesting (no take zones), restrict certain fishing practices in places (eg hunting of fish and invertebrates with SCUBA, limiting gear types etc), create bylaws and adopt an integrated management view of restoring and protecting their terrestrial habitat. Such an endeavour would also attract outside funding, support and partnerships, as well as fulfil country CBD and Pacific Oceanscape commitments.

Protection is required of the reef top locations where the *Tridacna* were found or at the very least the restriction of gleaning in these areas should be pursued. There is potential to re-introduce more *T. maxima* at these sites once protected. The two adjacent sites where the clams were found (located right out front of the fisheries department office and harbour) would act as an ideal no take zone and be a constructive first step in designing a multi-use marine managed area as described above.

Effective management also requires more stock assessments for targeted macro invertebrates e.g. for lobsters, nocturnal sea cucumbers, high value sea cucumbers (e.g. red surf fish), crabs, and *Turbo* spp. Continual monitoring of catches of targeted species needs to be pursued. Based on the general observed low densities of targeted species a limitation on their take should be instigated as a precautionary approach with quotas established in conjunction with more accurate and consistent stock assessments.

Awareness and education programs on all fisheries regulations and issues should be targeted at communities, schools and the public at large. Funding should be sought for radio awareness programs. A meeting should be held with Provincial Police to discuss with them aspects relating to the enforcement of Fisheries Regulations.

All recommendations can be underpinned in the Nauru culture with the revival of Traditional Environmental Knowledge (TEK) and the clan tenure system that have been lost or unused. Informal discussions with local Nauruan fishermen and locals have shown that there is little evidence that such practices/traditions are occurring at present in Nauru. The loss of TEK has resulted in the lack and loss of Nauruan's connectivity to the land and sea and is a major problem in regards to their connection to their natural resources and traditional resource management. It has been documented that the small island used to have customary laws governing resource use of land and sea (Weeramantry, 1992), but with the proliferation of the mining industry this was lost, including a well-established traditional Marine Tenure system, which resulted in overharvesting of coastal areas over subsequent years. As evident in most Pacific Island countries, TEK is very important in sustainable and long-term resource management (Thaman, 1992) and this system and knowledge in Nauru should be revived so that any conservation and management decisions can be effective and sustainable into the future.

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CHAPTER 7

CORAL REEF FISH DIVERSITY OF NAURU

DAVID A. FEARY

Summary

- A list of fish species was compiled for 20 subtidal dive sites, and 4 reef flat areas surrounding Nauru Island. The survey involved approximately 29 hours of scuba diving to a maximum depth of 35m, and 4 hours of reef walks.
- Nauru has a relatively depauperate reef fish fauna, consisting of at least 407 species of which 231 (56%) were observed during the present study. The total reef fish fauna comprised here includes 280 new species records and 31 new family records for Nauru.
- Species diversity at sampled sites during the 2013 survey ranged in number from 88 species at Site 6 (north eastern side of Nauru) to 35 within the Fisheries boat launch harbour, with an average of 73.8 (+/- 3.2 SE)
- The reef fish fauna within Nauru is dominated by Labridae (34 species), Pomacentridae (30 species), Acanthuridae (21 spp), Chaetodontidae (21 spp), Balistidae (12 species), Serranidae (11 spp) and Scaridae (10 spp)
- A formula for predicting the total reef fish fauna based on the number of species in six key indicator families indicated that at least 406 species can be expected to occur within Nauru reefs.
- Mobile invertebrate feeders were the most common functional group found within the reef fish fauna (23.8%), while planktivorous fishes (19.2%), fishes that had a diet comprised of both invertebrates and fishes (12.8%) and piscivores (10.3%) were also relatively diverse.
- Although the abundance of the reef fish fauna within Nauruan reefs is relatively high, there were significant signs of overfishing, including a lack of large sized fishes (i.e. large Groupers and Snappers). Despite this, a high abundance of the white tip reef shark (*Triaenodon obesus*) was observed throughout all sites (excluding Site 16).
- The lack of early life stages for the majority of reef fishes observed during this survey suggests that Nauruan reefs may be distinctly isolated from source habitats (therefore only receiving sporadic new reef fish larvae). This distinct isolation from source regions will substantially diminish the resilience of the reef fish faunal community to any disturbance events that reduce biodiversity; such low resilience to change means that there is a distinct need for conservation or marine protected areas (MPA) to be established.

Introduction

This chapter presents the reef fish diversity investigation conducted as part of the Conservation International (CI) and the Secretariat of the Pacific Regional Environmental Program (SPREP) BIORAP survey of Nauru, June 2013. General information on the survey and survey site descriptions are provided elsewhere in this report. The objective of this work was to produce a comprehensive list of the reef fish fauna. This was achieved through observations completed by a scuba diver within safe recreational diving depths (to 35m). On a cost and time basis this method is generally perceived to give the best results. There are however a number of limitations to this method as deep water species and open water pelagic species generally such as flying fish, tuna and billfish are not observed.

Nauru has relatively little history of marine survey work. The earliest accounts of finfish species were recorded by North et al. (1903), and by Whitley and Colefax (1938). However, their lists were brief and only covered a few species. Dalzell and Debao (1994) compiled a scientific checklist for finfish within Nauru, which included updating previous reports on the finfish stocks. The most recent survey of fish communities (preceding the present work) was undertaken by the Pacific Regional Coastal Fisheries Development Programme (CoFish, 2005). The program undertook substantial visual surveys of reef associated fishes at 50 sites throughout Nauru within 2005. This work was the most complete survey of finfish since the early 1990's. This work found that Acanthuridae (surgeonfish) and Balistidae (triggerfish) dominated the fauna, with a numerical dominance of several genera, including *Acanthurus*, *Ctenochaetus*, *Naso*, *Zebrasoma*, *Melichthys*, *Balistapus* and *Sufflamen*. This work also showed that semi-pelagic species of trevallies, fusiliers, baitfishes and tunas appeared to be in relatively good numbers (discussed further in the proceeding fisheries chapter).

Despite being little studied, the history of marine studies within Nauru has increasingly highlighted reductions in the abundance and diversity of reef fish communities. Dalzell et al. (1992) reported anecdotal information which suggested that certain reef fish species were becoming scarce and the average size of fishes caught were also decreasing within Nauruan waters, while Jimwereiy (1999) observed that finfish species that were becoming rare included mullets (Mugilidae), Topsail Drummer (*Kyphosus cinerascens*), Coral Cod (*Cephalopholis miniata*) and the Humpheaded Maori Wrasse (*Cheilinus undulatus*) (reported in Jacob, 1998). The National Assessment Report (released in 2009) reported an increasing scarcity of several formerly common marine finfish within Nauru, including large reef cod, squirrelfish and drummers (Anon, 2009). The most recent assessment of reef associated fishes (CoFish, 2005) reported "alarmingly" low abundances of targeted and commercial species of groupers, snappers, emperors and scarids, while biomass of other less targeted edible species of parrotfish, now targeted by spearfishers (free diving and SCUBA), also appeared to be increasingly reduced.

Methods

The fish diversity method employed here closely follows the methods utilised in previous Conservation International rapid biodiversity surveys (Allen, 2002; Evans, 2006). The survey involved approximately 29 hours of scuba diving, with the maximum depth surveyed being 35m and 4 hours of reef walks. A list of all fish species observed was compiled for each site surveyed. 'Fish' in this survey encapsulated all Class Actinopterygii (i.e. bony teleosts) and all Class Elasmobranchii (i.e. sharks and rays) observed over the dive period. The first complete survey of reef associated fish species was undertaken by CoFish within 2005. To our knowledge, the present survey is only the second comprehensive survey of the Nauruan reef fish fauna ever completed. Details of the sites surveyed are presented in Appendix 9 and Figure 1.

The SCUBA survey approach involved the author covering the full range of depths and habitats during a single dive of 60–110 minutes duration at each site. The full scientific name of each observed species was recorded. The survey technique involved descending to the 35m level on the reef (NB. there was no reef edge at this depth, with no reef edge seen despite the author being able to see to a depth of ~50-60m within each site). All species surveyed were classified by their primary feeding guild (i.e. scraper, excavator, grazer, browser, mobile and benthic invertebrate feeders, piscivore, piscivore–invertivore and planktivore) (Froese and Pauly, 2013). Species were then classified according to their trophic use of coral resources (i.e. non-corallivore, facultative corallivore or obligate corallivore).

SCUBA survey effort was divided between the various depth zones of the reef with a larger amount of time devoted to the 1–12m zone, where typically the greatest abundance and diversity of reef fish species were located. The diver would move through the habitats in a slow meandering manner looking for free swimming species as well as spending as much time as possible searching for more cryptic species in amongst the reef substrate. Each dive included a representative sample of all major bottom types and habitat situations present at the site. Examples of the typical habitats encountered were moderate slopes, small under hangs, rubble and sand patches. The majority of sites surveyed were subtidal reef slopes, however the harbour in which the Nauruan Fisheries Centre launch their boats, as well as 4 reef flat areas were also surveyed.

DATA USED WITHIN THIS REPORT

To develop the most comprehensive record of the reef fish biodiversity with Nauruan waters this report utilises the data recorded by the author, but also encapsulates the results of a previous reef fish surveys (CoFish, 2005) and a species list of reef fish species collated during a survey of aquarium fishes by Franck Magron and Collette Wabnitz during June 2013 (Secretariat of the Pacific Regional Environment Program, SPREP). In addition, this report also utilises local knowledge of reef fish biodiversity. This data was collected by undertaking a verbal assessment of reef fish diversity with two experienced Nauruan fishermen over the survey time period (June 2013). This data collection encompassed sitting with the two fishermen and allowing them to point out species (within Allen, G., R. Steene, P. Humann, and N. Deloch. 2003. Reef Fish Identification Tropical Pacific. New World Publications Inc., Jacksonville, FL, pp 431) that they had seen on their reefs. This method provided a substantial oversight to the wider diversity of fishes found within Nauruan reefs.

Site specific details are given in this report (solely based on diversity counts undertaken by the author). However, the majority of the report uses the full list of species developed through the various sources listed above (see Appendix 15 for full list of species). The survey method used within the present survey precluded the collection of quantitative data on the size structure and abundance of reef fish species data. However, to develop the most comprehensive survey of the Nauruan reef fish fauna, the author provides his personal observations on the reef fish community size structure and the abundance of different species and families.

Results and Discussion

SITE SPECIFIC REEF FISH DIVERSITY

Comparing reef fish diversity between the 20 sites surveyed (Figure 1), the median species diversity was 79.5 species, with an average species diversity of 73.8 (+ 3.2 SE) within sites (Table 1). Although there was relatively similar species diversity across the majority of sites surveyed, several sites were distinct in holding substantially lower species diversity (Table 1). There was a relatively weak pattern in species diversity associated with different sides of Nauru, with the majority of highly speciose sites being found on the eastern side of Nauru (Figure 1). However, species diversity between sites was relatively independent of the side of the island surveyed, but was highly related to the degree of large scale development (Figure 1). For example, sites 1, 2 and 3, which held some of the lowest species diversity, were situated next to the Nauru Port and the Phosphate Cantilevers, while Site 19 encapsulated the Fisheries boat launch harbour and adjacent reefal area (Figure 1). This harbour out of which fisheries launch their boats is a human-made harbour, which had been constructed by dredging/blasting coral reef to make a sandy area close to shore, and then surrounding it with a large rocky breakwater (~7-8m in height). Within the harbour the available benthic habitat was predominantly composed of relatively featureless shallow sand (~4m in depth). In addition, anthropogenic refuse covered the site (including car/truck tires, can and bottles, rope etc.). However, this refuse also provided some 3-dimensional structure, and was used by a number of small damselfish species as habitat (author pers obs).

Table 1. Total diversity within each surveyed site, and the sites location on Nauru

Site	Total Diversity	Location on Nauru
Site 6	88	North east
Site 11	85	South east
Site 8	84	North
Site 7	83	North east
Site 9	83	North
Site 16	82	West
Site 18	82	South
Site 12	81	South east
Site 14	80	North west
Site 5	80	South east
Site 15	79	North west
Site 20	79	South west
Site 17	78	South west
Site 4	78	South east
Site 13	74	North
Site 10	70	East
Site 3	54	South
Site 2	52	South west
Site 1	49	South west
Site 19	35	East

Figure 1. Numbered survey sites utilised within the present BIORAP survey.

There were a range of families and species that were found within a high number of sites surveyed. Of these species, *Zanclus cornutus* (Family Zanclidae) was apparent throughout every site surveyed (20 sites, 100% occurrence), while *Chaetodon meyeri* (Family Chaetodontidae), *Centropyge flavissimus*, *C. loricula* (Family Pomacanthidae), *Chromis margaritifer* and *Plectroglyphidodon dickii* (Family Pomacentridae) were found within 19 of the 20 sites (95 % occurrence).

There were several families that had species occurring in at least 90% of sites (18 of 20 sites) (Figure 2). Of these species, 20% comprised species within the Labridae, 16% were damselfish species (Pomacentridae), while species within the Balistidae and Chaetodontidae both comprised 12% of the species found within 85% of the sites surveyed (Figure 2).

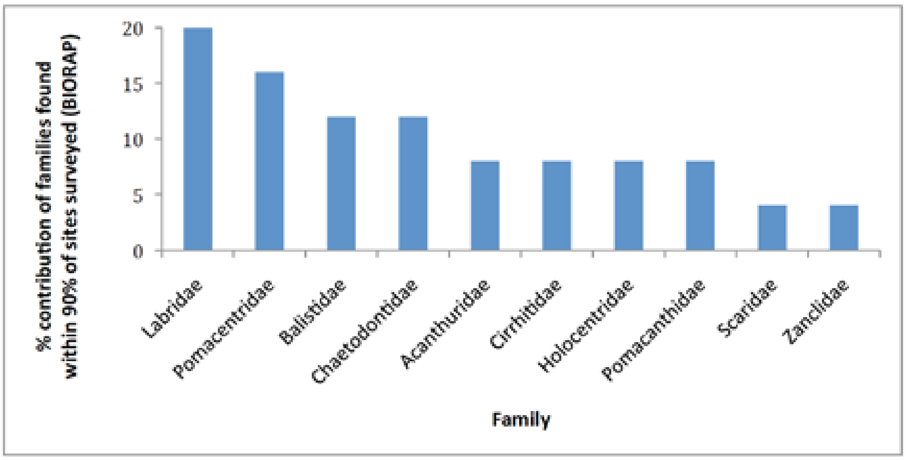

Figure 2. Percent (%) contribution of families found within at least 90% of sites surveyed (18 out of the possible 20 sites)

CORAL FISH DIVERSITY INDEX (CFDI)

The method developed by Allen (1998) to assess and compare the overall reef fish diversity was applied to Nauru waters. Methods follow that explained in Allen (2002). This technique involves using the inventory of six key families surveyed within reef habitats: Chaetodontidae (butterflyfish), Pomacanthidae (angelfish), Pomacentridae (damselfish), Labridae (wrasse), Scaridae (parrotfish) and the Acanthuridae (surgeonfish). The number of species in each of these families is totalled from surveys (NB. in this report this number is taken only from the present BIORAP surveys; no other survey counts were used in this analysis). 'Surveys' within the present report encapsulated all 20 sites surveyed within Nauru.

As previously stated within Allen (2002), CFDI values are used to develop an accurate estimate of the total reef fish fauna of a particular locality by the use of a simple regression formula. As the reef fish diversity measure was taken from a 'large' area (surrounding seas encompassing more than 50,000km^2) the formula (4.234*CFDI (– 114.446)) was used. This regression can be used to gauge the thoroughness of a particularly short-term survey (as in the present study). In addition, this regression can provide a useful estimate of an entire reef fish fauna.

The total CFDI for Nauru had the following components: Labridae (34), Pomacentridae (30), Chaetodontidae (21), Acanthuridae (21), Scaridae (10), and Pomacanthidae (7). The CFDI for Nauru then was calculated as ((4.234*123) – 114.446), which gave an estimated number of reef fishes for this island of 406 species. This is in concordance with estimates of reef fish diversity when totalling that found within the present study (407 species, which includes data from SPREP, local fishermen and previous reef fish diversity counts CoFish, 2005).

Following the table presented in Allen (2002), Table 2 presents a ranking of Indo-Pacific areas that have been surveyed to date based on CFDI values (to 2013). This table also includes the number of reef fishes that have recorded for each locality, as well as the total reef fish fauna predicted by the CFDI regression formula. Nauru has a relatively low reef fish diversity, much akin to that found within relatively isolated island systems (i.e. Lord Howe Island), tropical areas geographically distant from the coral reef triangle (i.e. Western Australia, Central Pacific), or areas that have high levels of sedimentation and are surrounded by anthropogenic disturbances (i.e. Bintan, Indonesia – which is approximately 36 km distant from Singapore Harbour).

Table 2. Locality/country where reef fish surveys have been undertaken, including present study location

Locality	CFDI	No. reef fishes observed	Estimate reef fishes
Milne Bay, Papua New Guinea	337	1109	1313
Maumere Bay, Flores, Indonesia	333	1111	1107
Raja Ampat Islands, Indonesia	326	972	1084
Togean and Banggai Islands, Indonesia	308	819	1023
Komodo Islands, Indonesia	280	722	928
Madang, Papua New Guinea	257	787	850
Mont Panié, New Caledonia	255	597	844
Kimbe Bay, Papua New Guinea	254	687	840
Manado, Sulawesi, Indonesia	249	624	823
Northwestern Lagoon of Grande-Terre, New Caledonia	234	526	773*
Capricorn Group, Great Barrier Reef	232	803	765
Ashmore/Cartier Reefs, Timor Sea	225	669	742
Kashiwa-Jima Island, Japan	224	768	738
Scott/Seringapatam Reefs, Western Australia	220	593	725
Samoa Islands, Polynesia	211	852	694
Chesterfield Islands, Coral Sea	210	699	691
Sangalakki Island, Kalimantan, Indonesia	201	461	660
Bodgaya Islands, Sabah, Indonesia	197	516	647
Pulau Weh, Sumatra, Indonesia	196	533	644
Izu Islands, Japan	190	464	623
Christmas Island, Indian Ocean	185	560	606
Sipadan Island, Sabah, Malaysia	184	492	603
Northwest Madagascar	176	463	576
Rowley Shoals, Western Australia	176	505	576
Cocos-Keeling Atoll, Indian Ocean	167	528	545
North-West Cape, Western Australia	164	527	535
Tunku Abdul Rahman Island, Sabah, Malaysia	139	357	450
Lord Howe Island, Australia	139	395	450
Nauru Island	**123**	**231**	**406**
Monto Bello Islands, Western Australia	119	447	382
Bintan Island, Indonesia	97	304	308
Kimberley Coast, Western Australia	89	367	281
Cassini Island, Western Australia	78	249	243
Johnston Island, Central Pacific	78	227	243
Midway Atoll, Pacific, USA	77	250	240
Rapa Polynesia	77	209	240
Norfolk Island, Australia	72	220	223

* Kerr (2009) reported that 1019 reef associated fish species are known from this region. Data sources: Allen 1998, 2002a, 2002b, 2005; Evans 2006; Kerr 2009

FUNCTIONAL COMPOSITION OF FULL REEF FISH FAUNA

Fishes feeding on mobile invertebrates were the predominant functional group (comprising 23.8% of the fish fauna), while planktivorous fishes (those feeding on pelagic phytoplankton and/or zooplankton) were also relatively speciose (comprising 19.2% of the fish fauna) (Figure 3). Fishes that have a diet comprised of both invertebrates and fishes ('Pisc-Invert') and feed solely on fishes ('Piscivore') were also relatively diverse, comprising 12.8% and 10.3% of the fish fauna (Figure 3). In addition, fishes that fed by grazing on turf algal resources ('Grazer/Cropper': comprising 9.6% of the fish fauna), benthic invertebrates (comprising 7.6% of the fish fauna) and species that utilised both algal and animal resources ('Omnivore': 6.6%) were also relatively common (Figure 3).

There were a number of functional groups that were relatively uncommon, and were predominantly associated with feeding on macroalgal algal resources and the detritus associated with it (Browser: 2.7%; Detritivore: 2.5%), or utilising coral resources (Scraper: 3.4%; Excavator: 1.2% and Scraper/Excavator: 0.2%) (Figure 3).

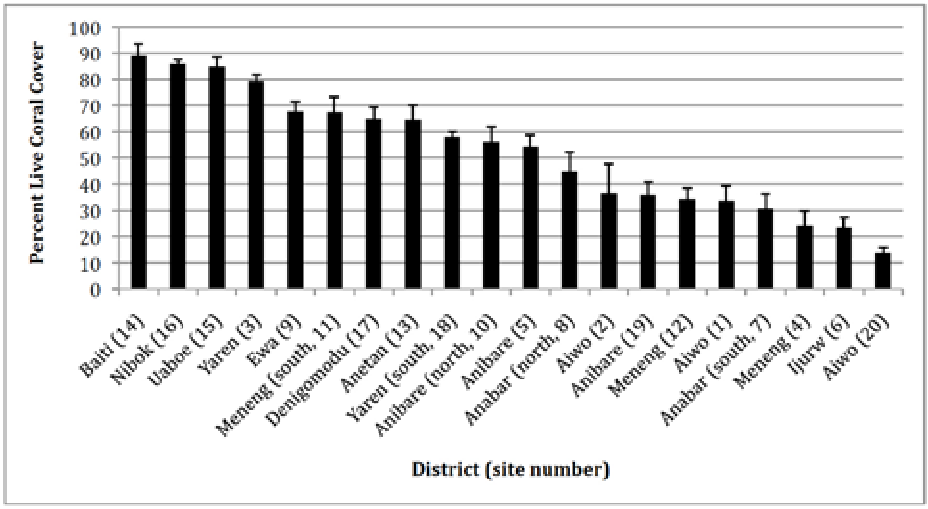

Figure 3 Percent (%) functional composition of the Nauru reef fish fauna (using data from the current survey by the author, data from SPREP, experienced Nauruan fishermen and the previous CoFish 2005 survey)

We then examined the functional composition of the Nauruan fish community in terms of their trophic use of live coral (Figure 4). This analysis showed that the overwhelming majority of fish species had little association with live coral as a trophic resource (97.4% of fish species), with only 1.7% and 0.9% of the fish species showing a facultative or obligate association with live coral as a trophic resource, respectively (Figure 4). Of the species that had either a facultative or obligate association with coral as a trophic resource, all were Chaetodontidae (composed of 63.6% facultative feeders and 36.4 obligate feeders)).

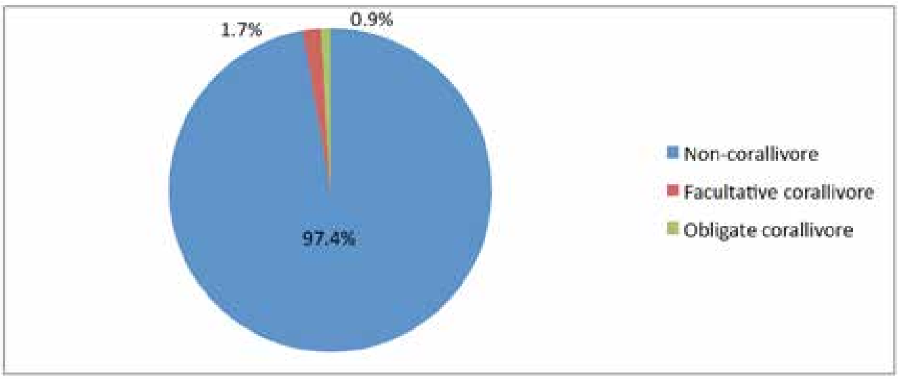

Figure 4. Percent (%) live coral trophic composition of the Nauru reef fish fauna (using in situ data from surveys by the author, data from SPREP, experienced Nauruan fishermen and the previous CoFish 2005 survey)

We then examined whether fishes identified by local Nauruan fishermen differed considerably from those surveyed within the present study by the author, or encapsulated within previous (CoFish, 2005) or recent reef fish surveys (using a species list of reef fish species collated during a survey of aquarium fishes by Franck Magron and Collette Wabnitz during June 2013). Discarding all fishes identified within the present or past surveys (as above) the range of species identified by Nauruan fishermen encapsulated a number of large bodied, fisheries important species (Figure 5). Although some of the species identified by Nauruan fishermen may be relatively rare in the type of visual survey methods used in the present work (i.e. large pelagic fishes, or relatively cryptic species), there were a number of species highlighted that are reef associated (i.e. Serranidae) or non-cryptic (i.e. Mullidae). In addition, despite no quantitative data collected on the size structure of the reef fish fauna, the author did not observe a high abundance of large sized individuals throughout Nauruan reefs. Such a reduced size structure suggests that the Nauruan reef fish fauna may be relatively overfished. In concordance with this observation, the verbal assessment of reef fish diversity by local fishermen was composed of a range of large finfish, including Carangidae, Serranidae and moray eels (Muraenidae) (Figure 5).

Using the same verbal data set, we then examined the functional group composition of the fishes highlighted by local fishermen (Figure 6). This analysis showed that fishes identified by Nauruan fishermen (and not identified in previous or the present surveys) comprised a range of piscivore-invertebrate feeding fishes (17%), mobile invertebrate feeders (11%) and benthic invertebrate feeders (6%). Interestingly, the local fishermen involved in this study indicated the majority of species that they identified (not identified in previous or the present surveys) were predominantly found within depths below safe diving limits (Please note – Nauruan fishermen stated that they would typically dive to depths deeper than ~50m to collect fish). As the depth of all surveys undertaken with the present survey, and in previous surveys excluded excessively deep dives (all dives were shallower than 40m), species found predominantly in deeper waters did not form part of the present or past surveys.

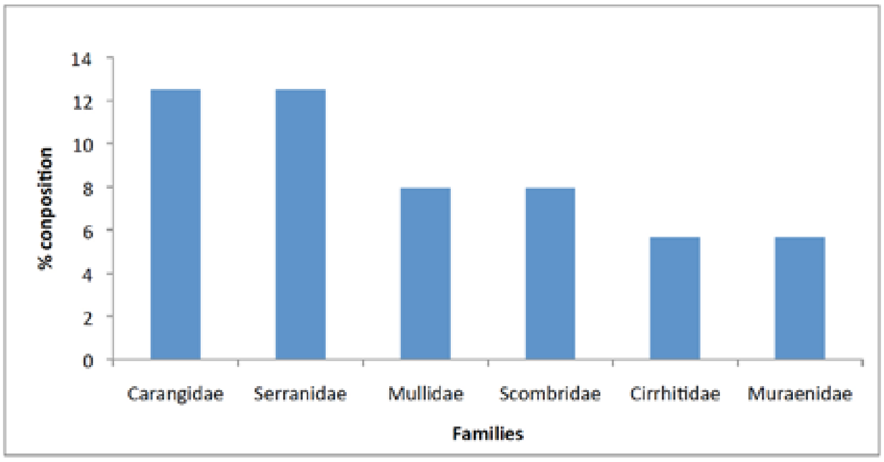

Figure 5. Percent(%) composition of families highlighted by local fishermen (that were not listed within CoFish. 2005. Nauru Country Report: Profile and Results From In-Country Survey Work. Noumea, Pacific Regional Coastal Fisheries Development Programme (CoFish), Secretariat of the Pacific Community", a species list of reef fish species collated during a survey of aquarium fishes by Franck Magron and Collette Wabnitz during June 2013, or the survey results of the present work. Families not included in this graph had % values less than 6%).

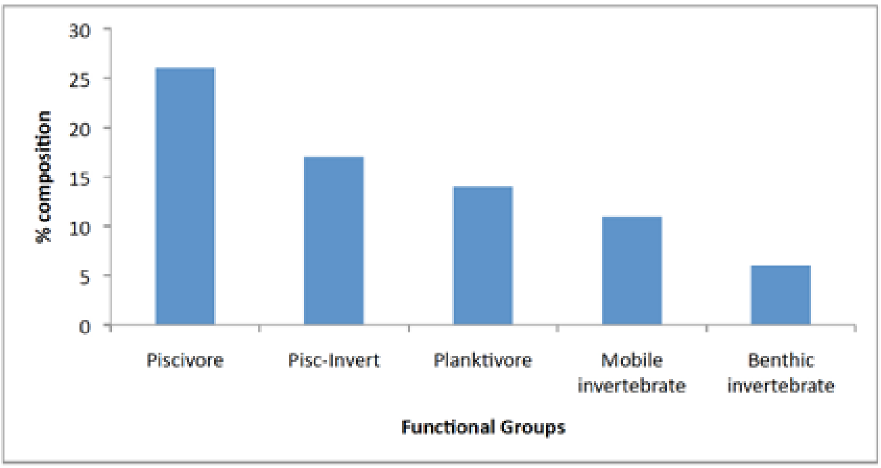

Figure 6. Percent (%) composition of functional groups highlighted by local fishermen (that were not listed within CoFish. 2005. Nauru Country Report: Profile and Results From In-Country Survey Work. Noumea, Pacific Regional Coastal Fisheries Development Programme (CoFish), Secretariat of the Pacific Community", a species list of reef fish species collated during a survey of aquarium fishes by Franck Magron and Collette Wabnitz during June 2013, or the survey results of the present work. Families not included in this graph had % values less than 6%)

BIOGEOGRAPHIC INFLUENCES ON FULL REEF FISH DIVERSITY

Nauru is part of the western Pacific, belonging to the overall Indo-west Pacific fauna community. The reef fish fauna within Nauru are very similar to those inhabiting other areas within this region, which stretches from East Africa and the Red Sea to the islands of Micronesia and Polynesia. Although there is general concordance of genera and species across the Indo-West region, the species composition and diversity varies markedly across this vast region.

Nauru reef fish fauna is part of the relatively depauperate Western Pacific region, which holds a large number of relatively isolated reef islands, and relatively low fauna diversity within the tropical belt. This low reef fish fauna diversity is predominantly associated with relatively high levels of isolation between reef regions, as well as distance from the Coral Triangle; which holds the richest tropical faunal diversity globally, encapsulating Indonesia, the Philippines and Paua New Guinea. Such decline in diversity from the Coral Triangle is apparent when comparing the diversity of particular reef fish families (Allen 2002). For example, Indonesia has the world's highest number of damselfish (Family Pomacentridae) with 138 species recorded from this region, which declines with distance from this region: Papua New Guinea (109 species), northern Australia (95 species), west Thailand (60), Fiji Islands (60), Maldives (43), Red Sea (34), Society Islands (30) and the Hawaiian Islands (15). The total number of damselfishes known from Nauru (30; encapsulating the present survey, a species list of reef fish species collated during a survey of aquarium fishes by Franck Magron and Collette Wabnitz during June 2013 [Secretariat of the Pacific Regional Environment Program] and local fishermen knowledge, as well as the previous CoFish 2005 survey) is indicative of the relatively high geographical distance of Nauru from the Coral Triangle, but also the isolation of Nauru from other island regions.

OVERALL STRUCTURE OF THE REEF FISH FAUNA OF NAURU

Due to the short temporal nature of the present study (10 days diving), there was a range of quantitative data that were excluded from the present survey methods. Such data included the size structure of the reef fish fauna, but also the relative abundance (and in concordance, the rarity) of different species and families. Such data is important as it gives an overall impression of the structure and function of a reef fish fauna. Therefore, below I succinctly discuss several personal observations. This has been included in this report to primarily aid managers and researchers in understanding the complexities of the Nauruan reef fish fauna.

Throughout each of the dives completed within the present study survey, there was a relatively high abundance of white tip reef sharks (*Triaenondon obesus* [Family Carcharhinidae]). Within the majority of sites surveyed (only within one site [site 16] were no white tip reef sharks observed) between 4 to 8 individuals (up to 12 individuals) were observed. This species is a relatively common inhabitant of coral reefs, and a high abundance of this species is indicative of a relatively healthy fauna, but also one that is not overfished (Robbins et al 2006). However, as *T. obesus* is not actively fished within Nauru (both commercially or recreationally), and utilises a varied diet predominantly consisting small reef fishes and invertebrates, the abundance of this species may be more indicative of a low direct fishing pressure combined with a relatively high abundance of potential prey for *T. obesus* within Nauruan reefs.

Throughout all sites surveyed both the squirrelfish and soldierfish (Family Holocentridae) were one of the most numerically dominant families observed (average abundances per site of ~200-300 individuals were observed by the author). This high abundance is despite the diversity of this family being relatively low within the reefs (9 species surveyed within the present study, with a total of 19 species known to occur in Nauru, see Appendix 15). The numerical dominance of this family within the Nauruan reefs was interesting, as these species are also the preferred reef – associated fisheries species for Nauruan spearfishermen. In fact, catches of between 10-15 Holocentrid individuals per spearfishermen were continually observed by the author throughout the survey period; this fishing pressure was stated by local fishermen as being "normal" for this reef fish family. Although such a high fishing pressure on this family would be expected to substantially reduce the abundance of individuals within reefs, there was no evidence (collected by talking with local fishermen about the recent history of fishing pressure and stock abundance of reef fish in Nauru) to suggest that stocks of Holocentrids have substantially reduced in recent history.

Despite completing 20 dives, encapsulating all habitats available within Nauru reefs (approximately 29 hours underwater), only a single cardinalfish individual (*Pristiapogon kallopterus*, Family Apogonidae) was surveyed within the present study. In addition, this individual was found within the local harbour, with no other individuals found throughout all reefs surveyed. Although this family is relatively cryptic in its habitat use, using small caves and overhangs (Gardiner and Jones, 2005), all surveys undertaken by the author were thorough in searching throughout all habitats within each site, including in small caves and over hangs and within holes in the reef. The rarity of this species (and this family) is in direct opposition to the abundance and diversity of this family within Indo-Pacific reefs (Gardiner and Jones, 2005). As this species is known to have a low preponderance for vagrant behaviour, and are not predominantly found within surveys of tropical vagrant species (Feary et al. 2012), the isolation of the Nauru reefs may preclude substantial recruitment of this family into the reef system.

Within the present survey no quantitative data was collected by the author on species size structure. However, when an early life stage of a species was observed this was recorded (using data available on tropical reef fish body size within Fishbase [Froese and Pauly, 2013] and the authors experience with juvenile sizes and colours of Indo-Pacific reef fishes). This work found relatively few early life stages within the reef fish fauna of Nauru. Of the species able to be taxonomically identified, early life stages of only 6 species were found: *Acanthurus olivaceus* (Family Acanthuridae), *Bodianus axillaris*, *Thalassoma amblycephylum* (Family Labridae), *Chrysiptera rollandi* (Family Pomacentridae), *Chlorurus microrhinos*, *C. sordidus* (Family Scaridae). Such low numbers of early life stages surveyed within the present work is relatively unusual for an Indo-Pacific reef, with the majority of regions surveyed by the author (including Indonesia, Papua New Guinea, and Singapore) predominantly holding a much higher percentage of early life stages (~30-40% of the species surveyed within an area will have early life stages within the reef system). Although there is no data on settlement or recruitment of fishes into Nauruan reefs, such low abundances of early life stages within surveys suggests that non-natal recruitment into this fauna may be relatively intermittent, and may be substantially associated with the high isolation of Nauru from other coral reef regions (e.g. Marshall Islands, Kiribati islands etc.).

Conservation Recommendations

There is a distinct need to decrease the interval between assessments of the biodiversity of the reef fish fauna within Nauru. As marine resources (and the diversity inherent within these resources) are so important in the health and welfare of Nauruan people, there is a need to develop surveys more often so the health of these resources is known.

There is a need to restrain SCUBA spearfishing, as the efficiency of this gear outweighs all the more traditional means of fishing, and if not properly controlled will have a drastic effect on targeted fish stocks. The abundant Holocentrids may be sustainably targeted by local fishing activities instead of parrotfish, groupers, snappers and emperors; the latter fish groups are most probably being impacted by fishing activities at present

There is a need for marine protected areas to be developed within Nauruan waters. Although little ongoing marine conservation exists within Nauruan waters, there is some history of fishing restrictions (National Assessment Report 2009). Such practise include temporary or seasonal taboos or bans on species or fishing grounds, restrictions on the consumption of certain species (for example, some species such as turtles or giant clams were reserved for chiefs or priests), fines or penalties for resource abuses, and clan tenure or limited access to reef and lagoon areas. However, through informal discussions with local Nauruan fishermen there is little evidence that such practices are occurring at present. The potentially low resilience of the reef fish fauna to habitat change (with hypothesised low levels of larval input), in addition to a reef fish size structure skewed to one dominated by small body-size individuals may be leading Nauruan fishing practices to levels that are unsustainable over the long term.

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CHAPTER 8

TARGETED AND COMMERCIAL FISH SPECIES ASSESSMENT

MAËL IMIRIZALDU

Summary

- A rapid assessment of targeted and commercial fish was conducted around the island of Nauru on the outer-reef slopes.
- A total of 129 species (of which 25 were not previously recorded) belonging to 63 genera and 27 families were identified over 20 study sites. Book surveys conducted with the fisheries' officers added 36 more targeted species, for a total of 154 species for this study. Combining this study's total of 154 with the findings of the 2005 PROCfish survey of 170 targeted species, brings an overall total of 324 targeted and commercial species potentially exisitng in Nauru.
- Targeted fish population of Nauru appear to represent a composition quite common and representative of healthy coral reefs ecosystems.
- Fish communities were highly dominated by the families of surgeonfishes (Acanthuridae) and triggerfishes (Balistidae) while families of groupers (Serranidae), snappers (Lutjanidae), emperors (Lethrinidae) and parrotfishes (Scaridae) were underrepresented.
- Fish communities' structure was unbalanced with a high rate of herbivores species and a very low rate of predators such as large carnivores' species and piscivores species.
- At least five species were under the minimum maturity size
- Strong signs of heavy overfishing were observed and there is an urgent need for management measures to ensure sustainable stock exploitation and food security overtime.
- The reef area along the districts of Anibare, Ijuw and Anabar were identified as a high priority conservation site.

Introduction

This chapter presents the targeted and commercial fish species diversity and status that was investigated in Nauru Island – Naoero "Pleasant island" during the Conservation International (CI) and the Secretariat of the Pacific Regional Environmental Program (SPREP) BIORAP survey, June 2013. The objective of this work was to produce a rapid assessment of the composition and structure of the fish species that are of interest for sale and consumption. Based on collected information, the main aim of this study is to provide reliable recommendations for the Nauruan government and Nauru Fisheries and Marine Resources Authority to develop and implement efficient management measures. This was achieved through standardized Underwater Visual Census method frequently used in studies of this type and known to be efficient when focusing on the main group of species that are found and fished on reefs in general.

Species of finfish in Nauru and fishing practices were documented since the early 20th century in several books and articles: North et al. (1903), Whitley & Colefax (1938). However, their lists were brief and only covered a few species. In 1994, Dalzell and Debao updated the scientific knowledge of Nauru's fisheries with a complete article focusing on fishing techniques, catch composition and annual production. This work presented the first exhausted checklist of fishes observed and reported to be present in waters around Nauru. A review of the existing bibliography and description of the global status of marine resources and corals reefs of Nauru was produced by Jacob in 2000. As useful as all this studies were, providing guidance for resources management, none of them proposed a complete survey of the reef fish species community structure. In 2003, the Pacific Regional Coastal Fisheries Development Programme from the Secretariat of the Pacific Community (SPC) proposed the first finfish resource assessment that was completed with a socioeconomic assessment. This study was the first to provide reliable information on the Nauruan fisheries dynamic and its potential impacts on the reef fish species community structure from an ecosystem perspective.

Since the early 1990's, several points of concern were expressed about fishing pressure and its impact on fish stocks. Observations suggested that snapper and groupers stocks were being depleted while larger fishes were becoming rare and mainly found in deeper water. In 2003, the PROCFish program from the SPC was alarmed by the low rate of targeted and commercial species populations such as the groupers, snappers, emperors and parrotfishes. Moreover, the survey suggested that stocks sizes had exceeded sustainable and optimum levels. The results of this 2013 BIORAP survey draw the same conclusions. Several usually common groups of fishes are underrepresented, the global fish population's structure is unbalanced and the numbers of fishes are small-sized and under the minimum maturity size.

As the use of marine resources is not only a matter of the environment but also a matter of food security for the Nauruan people, it is becoming necessary and urgent for the Nauruan Government and Nauru Fisheries and Marine Resources Authority to engage strong management strategies and ensure sustainable resource use overtime.

Methods

The Biodiversity Rapid Assessment Program (BIORAP) conducted in Nauru over the 10 day period from June 17th to June 27th 2013, was conducted on the outer-reef surrounding Nauru. The sampling effort consists of 20 sites in the 12 Districts of Nauru (Table 1).The underwater survey methods used for this survey are supported by Samoylis and Carlos (2000) and were used in previous BIORAPs (Cornuet 2006, Grace 2009, Imirizaldu 2011).

Table 1. Sites distribution by districts (BR=BIORAP, the present survey and PF = ProcFish previously surveyed site either of corresponding or nearby location to BIORAP site)

District	Stations	Districts	Stations
Aiwo	BR01(PF23), BR02(PF25)	Ewa	BR09(PF12/13)
Anabar	BR07(PF08), BR08(PF10)	Ijuw	BR06
Anetan	BR13	Meneng	BR04(PF30),BR11, BR12
Anibare	BR05(PF28), BR10, BR19	Nibok	BR16
Baiti	BR14	Uaboe	BR15
Denigomodu	BR17	Yaren	BR03(PF20), BR18, BR20

This standardized method is frequently used in studies of this type and allows for comparison of results from one study to another. Species of interest for consumption or marketing are those that are found near coral reefs and likely to be targeted by commercial, recreational or subsistence fishing. Fishing pressure thus is not applied equally among all species and differs depending on the type of fishing practiced and the geographical area. It is thus difficult to accurately define a list of "targeted" species. As the BIORAPs implemented by the Secretariat of the Pacific Regional Environment Program aim at assessing the biodiversity of an area, the list of species considered was accordingly set to be exhaustive and was defined accordingly to: a) a review of reef fish identification's books with local fishermen and fisheries' officers; b) in agreement with D. Feary in charge of surveying coral reef fish; c) and based on lists previously established by the Secretariat of the Pacific Community (PROCFish/CiCoFish program, 2005). Since the surveyed species are likely to be caught, they may risk fleeing when facing the diver even more so in Nauru where fishing while scuba diving is a common practice. To minimize this risk of sampling bias, the fish experts enter the water before the rest of the team. The 50 meters long tape is quickly unwound and then the diver leaves the station for a few minutes before coming back. Surveying takes place along a belt transect with a length of 50m and a width of 10m. An area of 500m² is thus sampled. Only individuals in front of the diver and already present in the area are counted, while individuals arriving from behind the diver are not taken into account to avoid counting the same fish twice. However, some exceptions are made for uncommon and easily recognizable species. This distinction is sometimes difficult to assess and the count may be slightly overestimated. The fish are counted individually and their size is estimated (to the nearest 1 cm for fish ≤ 10 cm; to the nearest 2cm for fish ≤ 30cm; to the nearest 5cm for fish ≤ 60cm; and to the nearest 10cm for fish ≥ 60 cm). When a group of over 50 individuals is seen, an estimate of the number is given (in increments of 10 to 50 individuals) and an average size is allotted. On each transect, counting time, depth and visibility are systematically recorded (Table 2).

Table 2. Descriptive statistical parameters of transects

	Time (min)	Depth (meters)	Visibility (meters)
Average	34	8.4	14.3
Minimum	20	4	5
Maximum	52	12.6	20

A single count was performed on each site, however probably as an overfishing consequence, numerous species that are usually common in shallow waters on reefs from other countries are found on Nauru's reefs at greater depths and/ or quickly avoid divers. To obtain a more accurate representation of the communities present at each site, a five minutes random swim was systematically carried out at the beginning and at the end of each count both in depth and shallow waters to record species that had not been observed on the transect but were present in the sampling area. Only the species name is then noted, as estimate of the number or size cannot be compared with data obtained during the counting. This method yields significant results on the number of species, genera and families observed at end of mission. Counting was carried out on all sites visited during this mission.

From the data collected, species richness was defined and indices of abundance, density and biomass were calculated. Species richness is defined by the number of taxa identified during counts. Abundance is the number of individuals recorded for a sampling site whereas Density corresponds to this abundance reported to a standard surface area. Density is expressed in number of fishes per square metres (fish/m^2) and is converted from the original expression in number of fish for 500m^2. Biomass represents the overall quantity of fish available on a site and is estimated from the number of fish counted and their individual weight. Biomass is also reported to a standard surface area. This weight is determined from the length of the fish according to the following equation (Letourneur & al. 1998):

$$W = aLb$$

Where, W is the weight, L the estimated fork length in cm and the coefficients *a* and *b* are species specific and defined by the works of Letourneur & al. (1998). The old cubic formula (W = 0.05 L3) has a tendency to overestimate the weight of the majority of species and to provide less accurate results so was not used in the analysis of the results. This biomass is expressed in tons per square kilometres (t/km^2), converted from the original expression in gram for 500m^2.

To better fit with the BIORAP objectives (biodiversity inventory, rapid assessment of stocks, use of resources by local communities), a quick survey was made with the fisheries' officers. The aim of such a survey was to identify through an identification book's review, species that are present in Nauru but weren't previously recorded from past studies (PROCFish/ SPC, 2005; Dazell & Debao, 1994) or during this BIORAP. This approach can be reliable as local knowledge is usually strong when communities rely on fish resources and people involved in the survey are fishermen. When identification of a species was questionable and fisheries' officers weren't sure if the fish was found in Nauru, then, information wasn't recorded. This survey also allowed us to identify among the targeted species, the favoured fish species that are preferentially caught. These species are called "Highly Targeted Species" (HTS) in this document. A part of the analysis is focused on these species, specific management actions should be applied to ensure sustainable use.

To better understand the fish community structure from an ecosystem perspective and identify the existing balance on Nauru's reefs, part of the analysis will focus on diet groups.

Five diets groups were also defined (Table 3) (Randall 2005, Lieske & Myers, 2005).

Table 3. Classification of targeted fish families by diet.

Diet	Families	Common names
Carnivore	Carangidae	Jacks
	Carcharhinidae	Sharks
	Holocentridae	Soldiers & Squirrels
	Labridae	Wrasses
	Lethrinidae	Emperors
	Lutjanidae	Snappers
	Mullidae	Goatfishes
	Serranidae	Groupers
	Chaetodontidae	Butterflyfishes
	Muraenidae	Morays
	Fistulariidae	Cornet fishes
	Monacanthidae	Filefishes
	Priacanthidae	Big eyes
	Diodontidae	Porcupine fishes
Herbivore	Acanthuridae	Surgeonfishes
	Kyphosidae	Chubs
	Scaridae	Parrotfishes
	Siganidae	Rabbitfishes
Omnivore	Acanthuridae	Surgeonfishes
	Balistidae	Triggerfishes
Omnivore *(cont.)*	Ephippidae	Spade fishes
	Kyphosidae	Chubs
	Chaetodontidae	Butterflyfishes
	Monacanthidae	Filefishes
	Mugilidae	Mullets
Piscivore	Carangidae	Jacks
	Lutjanidae	Snappers
	Serranidae	Groupers
	Sphyraenidae	Barracudas
	Aulostomidae	Trumpet fishes
	Belonidae	Needle fishes
	Muraenidae	Morays
Planktivore	Acanthuridae	Surgeonfishes
	Balistidae	Triggerfishes
	Caesionidae	Fusiliers
	Holocentridae	Soldiers & Squirrels
	Lutjanidae	Snappers
	Chaetodontidae	Butterflyfishes
	Pempheridae	Sweepers
Spongivore	Zanclidae	Moorish idol
Corallivore	Chaetodontidae	Butterflyfishes

Since observations of low percentage occurrence could be either due to rarity or low detectability, the main focus of this this report is the 15 most frequently observed families (Table 4) for which the survey method is an efficient resource assessment method. This choice was made accordingly to the previous assessment conducted by the PROCFish program from the SPC and will allow further comparison.

Results

GENERAL CHARACTERISTICS

Species richness and composition

A total of 129 targeted species belonging to 63 genera and 27 families were observed during the survey with 7,718 individuals sighted. In addition, the survey conducted with fisheries officer and fishermen permit to reference 36 other species that weren't previously recorded in past studies. Of this, a mean of 13 families, 26 genus, 40 fish species and 386 individual fish were observed and recorded in each transect in Nauru. The survey conducted via book review with the fisheries officers showed that among this species, 45 (27.3%) HTS species are potentially subject to higher fishing pressure. A complete list of commercial species compiling data from this BIORAP (including both underwater survey and book survey with fisheries officer) and the previous PROCFish survey is presented in Annexe 1 of this document. The 10 minute random swim performed routinely before and after each counting allowed to record a large number of species not observed on transects and to significantly increase the total species richness (Student's test significant, P <0.01) (Table 4).

Table 4. Number of genera, species and individuals identified by targeted families (decreasing rank by number of species). A distinction is made between genera and species recorded only on transects (transect counts) and the total number of records including the systematic random swim (Total). Families in bold correspond to the dominant families in the region.

Families	No. of genera (transect counts)	No. of genera (Total)	No. of species (transect counts)	No. of species (Total)	No. of individuals (transect counts)
Acanthuridae	5	5	14	19	3009
Chaetodontidae	3	4	8	17	710
Serranidae	2	5	6	11	221
Balistidae	5	7	5	9	1710
Lutjanidae	2	4	4	9	76
Carangidae	1	4	1	8	33
Mullidae	1	2	5	8	260
Holocentridae	3	3	4	7	181
Scaridae	2	3	6	7	143
Labridae	1	4	1	4	1
Lethrinidae	1	3	1	4	295
Caesionidae	1	2	2	3	200
Muraenidae	0	2	0	3	1
Monacanthidae	2	2	3	3	-
Kyphosidae	1	1	1	2	10
Carcharhinidae	1	1	1	1	18
Ephippidae	0	1	0	1	-
Siganidae	1	1	1	1	-
Sphyraenidae	0	1	0	1	571
Zanclidae	1	1	1	1	173
Aulostomidae	1	1	1	1	-
Belonidae	0	1	0	1	-
Fistulariidae	1	1	1	1	1
Priacanthidae	0	1	0	1	-
Mugilidae	0	1	0	1	18
Diodontidae	1	1	1	1	9
Pempheridae	1	1	1	1	78
Total: 27	**37**	**63**	**67**	**126**	**7718**

The structure of fish family for the whole island of Nauru is relatively similar to other study sites with the presence of 14 of the 15 most dominant families in coral reef ecosystems (Table 4). Only the Breams (Nemipteridae) family wasn't observed during this survey. However, at the district level, only 9 to 12 of these dominant families were recorded. The most diverse families observed were the surgeonfishes (Acanthuridae; 19 species), butterflyfishes (Chaetodontidae; 17 species) and groupers (Serranidae; 11 species). Families of parrotfishes (Scaridae), Emperors (Lethrinidae) and rabbitfishes (Siganidae) were observed at the opposite end with relatively low diversity with only seven, four and one species respectively.

Much of the total species richness (S) is composed of species observed on less than 10 of the 20 sites surveyed (76.7% of the S) with 22.5% of the total S observed on a maximum of five sites. Only 12.4% of the total S, corresponding to 16 species were observed on more than 15 sites. These species belong to the families of surgeonfishes (Acanthuridae; seven species), triggerfishes (Balistidae, three species), butterflyfishes (Chaetodontidae, three species), moorish Idol (Zanclidae, one species), parrotfishes (Scaridae; one species) and groupers (Serranidae, one species). A total of 30 HTS species was recorded during this survey corresponding to 23.3% of the total S. Among these species, 43.3% were observed on more than 10 sites and seven species (20% of HTS S) were recorded on more than 15 sites in 10 to 12 districts of Nauru: *Acanthurus lineatus* (Acanthuridae, Lined surgeonfish, (**Nauruan name given in bold**), **Iwiyi**: 16 sites), *Acanthurus nigricans* (Acanthuridae, whitecheek surgeonfish: 19 sites), *Acanthurus triostegus* (Acanthuridae, convict surgeonfish, **eweo**: 15 sites), *Ctenochaetus marginatus* (Acanthuridae, striped-fin surgeonfish: 16 sites), *Naso lituratus* (Acanthuridae, orangespine unicornfish, **Irer**: 20 sites), *Melichthys vidua* (Balistidae, pinktail triggerfish: 20 sites), *Chaetodon lunula* (Chaetodontidae, raccoon butterflyfish: 19 sites). At the opposite end, nine HTS species (23.3% of HTS species) were recorded only on a maximum of five sites in one to four districts of Nauru (excluding species that are hardly seen during underwater surveys such as moray eels): *Pterocaesio tile* (Caesionidae, neon fusilier: three sites), *Hemitaurichthys thompsoni* (Chaetodontidae, thompson's butterflyfish: four sites), *Kyphosus cinerascens* (Kyphosidae, blue sea chub, **Iyibawo**: one site), *Kyphosus vaigiensis* (Kyphosidae, brassy chub, **Iyibawo**: one site), *Macolor macularis* (Lutjanidae, midnight snapper: one site), *Mulloidichthys mimicus* (Mullidae, mimic goatfish: four sites, *Priacanthus hamrur* (Priacanthidae, moontail bullseye: one site), *Aethaloperca rogaa* (Serranidae, redmouth grouper: two sites), *Cephalopholis miniata* (Serranidae, coral hind, **Eanit**: two sites).

Only one species listed as endangered (EN) on the IUCN red list was observed: The humphread wrasse (Labridae, C*heilinus undulatus*). Only one fish was observed at depth of approximately 50 meters during a random swim on one station in the district of Yaren. The white-tip shark (Carcharhinidae, *Triaenodon obesus*) listed as Nearly Threatened (NT) was frequently observed as individuals were recorded on 12 stations in eight districts but were observed by other divers on other sites. However, no other shark species was observed.

The analysis of these results should take into account several items regarding methodological bias and Nauru's fishing context. As the survey is conducted in shallow waters on the reef, several species are difficult to observe when counting. These includes pelagic fishes such as the Fusiliers that stay in the water column. Also, cryptic species that hide in caves or holes such as moray eels or soldiers & squirrels fishes that are hardly seen. This results in an underestimation of the real species richness. As explained in the methodology part of this report and probably as a result of the fishing by scuba-diving activity, several species that are usually common on reefs in shallow water were found in deep water and/or quickly avoided the presence of divers. This contributes to a reduction of the species richness recorded on every site surveyed.

Overall Quantitative Results

The means for abundance and biomass recorded over the entire mission are given in Table 5 for all families surveyed. The contribution of HTS species in relation to the complete community is expressed as a percentage in the column "contribution of HTS species". The percentage of each family for total biomass and abundance is shown graphically in Figure 1 and Figure 2. A mean biomass of 162.05 t/km^2 (PROCFish survey 2005, Total mean biomass = 212.85 t/k m^2) and a mean density of 0.76 fish/m^2 (PROCFish survey 2005, Total mean biomass = 1.49 fish/m^2) were identified per site where HTS species contribute to 29.6% of this biomass and 42.1% of the fishes' density.

Table 5. Mean biomass and density of targeted families (in decreasing rank of mean biomasses and decreasing rank of mean density). The contribution of Highly Targeted Species (HTS) species to mean biomass and density of families is expressed as a percent

Families	Mean BIOMASS (t/km^2)	Contribution of HTS species to mean biomass (%)	Rank	Families	Mean density (fish/m^2)	Contribution of HTS species to mean biomass (%)	Rank
Acanthuridae	35.16	60.8%	1	Acanthuridae	0.30	51.3%	1
Carcharhinidae	25.84	0%	2	Balistidae	0.16	57.2%	2
Siganidae	24.83	0%	3	Chaetodontidae	0.071	39.4%	3
Balistidae	18.56	77.7%	4	Siganidae	0.057	0%	4
Scaridae	12.16	0%	5	Lethrinidae	0.029	0%	5
Zanclidae	9.18	0%	6	Mullidae	0.026	96.9%	6
Lethrinidae	7.51	0%	7	Serranidae	0.022	6.3%	7
Mullidae	6.73	96.7%	8	Caesionidae	0.02	0%	8
Caesionidae	5.63	0%	9	Holocentridae	0.018	60.2%	9
Diodontidae	4.03	0%	10	Zanclidae	0.017	0%	10
Chaetodontidae	3.63	53.8%	11	Scaridae	0.014	0%	11
Lutjanidae	2.02	93.9%	12	Pempheridae	0.0078	0%	12
Carangidae	1.96	0%	13	Lutjanidae	0.0076	98.7%	13
Serranidae	1.55	25%	14	Carangidae	0.0033	0%	14
Holocentridae	1.41	57.3%	15	Carcharhinidae	0.0018	0%	15
Pempheridae	0.90	0%	16	Monacanthidae	0.0018	0%	15
Kyphosidae	0.72	100%	17	Kyphosidae	0.001	100%	17
Monacanthidae	0.19	0%	18	Diodontidae	0.0009	0%	18
Labridae	0.03	0%	19	Aulostomidae	0.0001	0%	19
Aulostomidae	0.01	0%	20	Fistulariidae	0.0001	0%	19
Fistulariidae	0.00	0%	21	Labridae	0.0001	0%	19
Total fish fauna	**162.05**	**29.6%**	-	-	**0.76**	**42.1%**	-

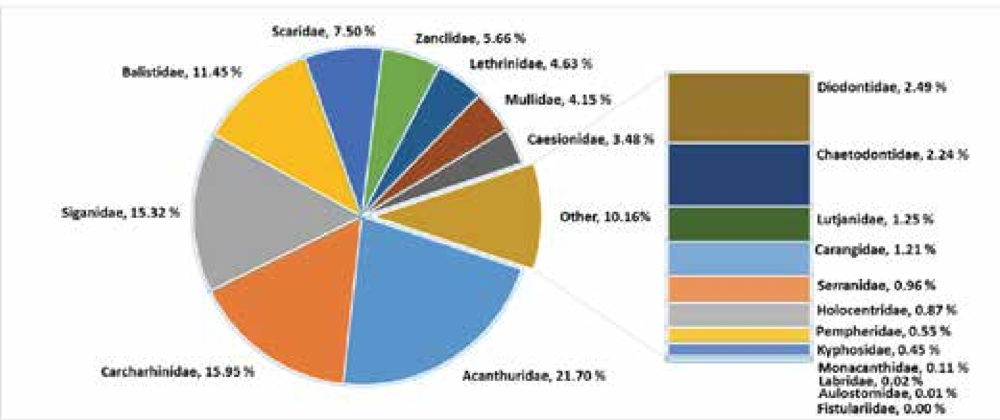

Figure 1. Contribution (in percentage) of targeted families to the total biomass.

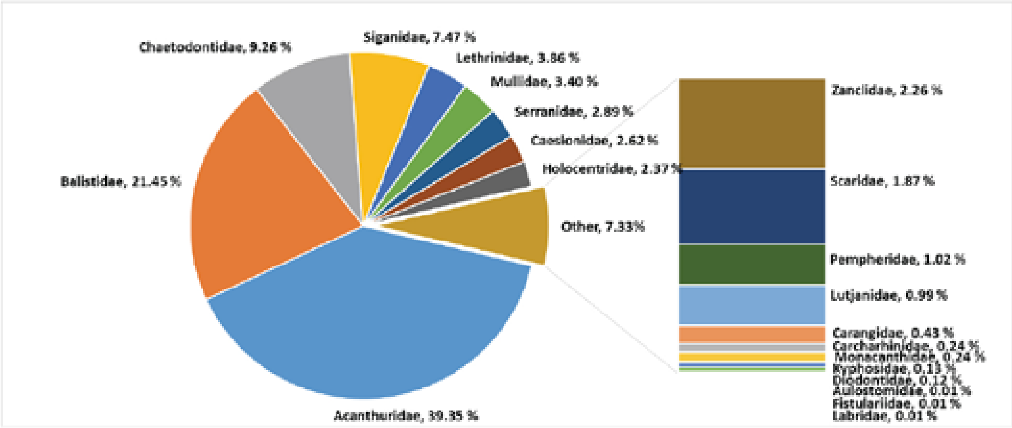

Figure 2. Contribution (in percentage) of targeted families to the total density.

The Family of Acanthuridae including surgeonfishes and unicornfishes represents a set of species with varying diets (herbivores, omnivores, planktivores), found over a wide range of habitats where some species are relatively common and abundant. Therefore they largely dominated this group of species, representing over 39.3% of the total mean biomass (35.16 t/km^2) and 21.7% of the total mean density (0.3 fish/m^2) with a predominance in density of fish genera *Acanthurus*, *Ctenochaetus* then *Zebrasoma* and *Naso* noted. Within this family, two herbivores species were particularly present in high densities: *Ctenochaetus striatus* (striated surgeonfish, **iubwiya**) and *Acanthurus nigricans* (HTS; whitecheek surgeonfish). These were followed by: *Zebrasoma scopas* (two tone tang), *Acanthurus triostegus* (HTS, convict surgeonfish, **eweo**) and *Ctenochaetus marginatus* (HTS, striped-fin surgeonfish). All herbivores presented important biomass and densities as shown in the Table 6. The mean size was 17.3cm for HTS species and 15.5cm for other species.

Table 6. Mean biomasses, mean densities and mean/maximum sizes of main Acanthuridae species. The values found for biomass and density during the PROCFish study in 2005 is presented as a comparisons. The Maturity length (Database IRD-Nouméa – M.Kulbicki, personal communication) and Maximum size (Kulbicki 2005; FishBase) are presented as a comparison. The dash symbol "-" means that no data or value were available.

Species	Mean Densities recorded in 2005 (PROCFish)	Mean Densities recorded in 2013 (BIORAP) (fish/m^2)	Mean Biomass recorded in 2005 (PROCFish	Mean Biomass recorded in 2013 (BIORAP) (t/km^2)	Mean / Max Fork Length (cm)	Maturity length / Max size (Reference)
Ctenochaetus striatus	0.22	0.0825	19.7	9.52	14.9/22	12/26
Acanthurus nigricans(HTS)	0.32	0.0613	31	5.54	14.4/19	-/21.3
Zebrasoma scopas	0.1	0.0496	4.74	1.07	8.3/11	-/-
Acanthurus triostegus (HTS)	0.06	0.0264	4.02	1.31	11.2/15	7.5/27
Ctenochaetus marginatus (HTS)	0.22	0.0252	0.45	2.96	16.1/19	-/27

The Family Balistidae including the triggerfishes represent a set of species that are solitary diurnal carnivores, feeding on a wide variety of invertebrates including hard-shelled molluscs and echinoderms while some also feed on algae or zooplankton. This is the second most dominant family observed and recorded, representing 11.45% of the total mean biomass (18.55 t/km^2) and 21.44% of the total mean density (0.16 fish/m^2) with a predominance in density of fish genera *Melichthys*, *Balistapus* and *Odonus*. The highest densities and biomasses were recorded for the two species of omnivores, *Melichthys vidua* (HTS, pinktail triggerfish) and *Balistapus undulates* (orange-lined triggerfish) and the two species of planktivores, *Melichthys niger* (HTS, black triggerfish) and *Odonus* niger (red-toothed triggerfish). The *Sufflamen* genus was present in lower density and biomass. Individuals from the large species *Pseudobalistes flavimarginatus* (yellowmargin triggerfish, **kumum**) were observed only outside the transects at several stations. On one site in the Anetan district, a group of 10 individuals were observed displaying mating behaviours. The mean size was 17.1cm for HTS species and 15.5cm for other species.

Table 7. Mean biomasses, mean densities and mean/maximum sizes of main Balistidae species. The values found for biomass and density during the PROCFish study in 2005 is presented as a comparisons. The Maturity length (Database IRD-Nouméa – M.Kulbicki, personal communication) and Maximum size (Kulbicki 2005; FishBase) are presented as a comparison. The dash symbol "-" means that no data or value were available.

Species	Mean Densities recorded in 2005 (PROCFish)	Mean Densities recorded in 2013 (BIORAP) (fish/m²)	Mean Biomass recorded in 2005 (PROCFish	Mean Biomass recorded in 2013 (BIORAP) (t/km²)	Mean / Max Fork Length (cm)	Maturity length / Max size (Reference)
Melichthys vidua (HTS)	0.12	0.056	14.7	7.87	16.7/20	-/40
Melichthys niger (HTS)	0.007	0.0378	1.06	6.53	17.8/25	-/50
Balistapus undulatus	0.05	0.0169	9.96	2.17	14.6/23	-/30
Odonus niger	0.0176	0.052	0.9	1.35	12.7/30	-/50
Balistoides viridescens	-	0.0004	-	1.06	50/60	47/75
Sufflamen bursa	0.02	0.0049	2.34	0.28	13.5/16	-/25
Sufflamen chrysopterum	0.02	0.0022	2.48	0.14	13.8/17	-/30

The Siganidae family including the rabbitfishes is another dominant group of herbivores observed in Nauru. They are diurnal herbivores that feed on benthic algae in large schools or small groups. They represent the third most abundant family with 0.057 fish/m² (7.47% of the total mean biomass) and the fourth largest biomass with 24.83 t/km² (15.32%). Only one species, *Siganus argenteus* was found during this survey and only on 10 sites. However, because this species can form large groups (from 100 to 300 fishes recorded within the same school), it can significantly contribute to high densities and biomass records. The mean size was 27cm.

The Scaridae family including the parrotfishes is one of the main herbivores family of coral reefs (Randall 2005), include species that can be found from coastal waters (which are sometimes turbid) up to the outer reef slope affected by oceanic influences. While some species are solitary, others form groups, sometimes of large size. parrotfishes weren't found abundant in Nauru. Despite the low number of species recorded, fishes were only observed individually or forming small groups and the global mean density recorded was low with only 0.014 fish/m² (1.87% of the total mean density). The recorded biomass of 12.16t/km² which represent 7.5% of the total mean biomass is mostly due to one more abundant species (*Scarus rubroviolaceus,* ember parrotfish*; Total mean Density = 0.008 fish/*m² Versus 0.002 fish/m² recorded in 2005; Total mean Biomass = 8.27 t/km² Versus 1.71 t/km² recorded in 2005) were large individuals can be observed (max Fork Length recorded = 50cm; Max size FishBase = 70cm). The mean size was 32.8cm.

The Chaetodontidae including butterflyfishes is a family of fishes commonly found on reefs. Typically diurnal, it is constituted with a large number of species belonging to different diet groups (corallivore, omnivore, planktivore). They're found in great density as they represent 9.25% of the total mean density (0.07 fish/m²) but because of their low size, they represent only 2.24% of the total mean biomass (3.63 t/km²). The main genera *Chaetodon* is dominant. The highest densities and biomasses were recorded for the two corallivore species *Chaetodon lunula* (HTS, raccoon butterflyfish) and *Chaetodon meyeri* (scrawled butterflyfish) as shown in the table. The mean size was 13.75cm for HTS species and 11.8cm for other species.

Table 8. Mean biomass, mean densities and mean/maximum sizes of the main Chaetodontidae species. The values found for biomass and density during the PROCFish study in 2005 is presented as a comparisons. The Maturity length (Database IRD-Nouméa – M.Kulbicki, personal communication) and Maximum size (Kulbicki 2005; FishBase) are presented as a comparison. The dash symbol "-" means that no data or value were available.

Species	Mean Densities recorded in 2005 (PROCFish)	Mean Densities recorded in 2013 (BIORAP) (fish/ m^2)	Means Biomass recorded in 2005 (PROCFish)	Means Biomass recorded in 2013 (BIORAP) (t/km^2)	Mean / Max Fork Length (cm)	Maturity length / Max size (Reference)
Chaetodon lunula (HTS)	0.007	0.0217	0.31	1.67	14.5/17	-/20
Chaetodon meyeri	0.017	0.0197	0.52	0.80	11.3/14	-/20
Chaetodon auriga	0.001	0.0044	0.03	0.32	14.1/15	10/23
Chaetodon vagabundus	0.0054	0.0033	0.19	0.19	13/15	12/23
Hemitaurichthys thompsoni (HTS)	-	0.004	-	0.15	11.5/12	-/18
Chaetodon kleinii	0.003	0.0045	0.07	0.12	9.8/12	7/15
Forcipiger flavissimus	0.0002	0.0096	0	0.12	10.1/12	-/22
Chaetodon ornatissimus (HTS)	0.0115	0.0022	0.4	0.12	12.4/14	-/20

The Holocentridae family including the squirrels and soldiers is a group of fish that are mostly nocturnal. Usually cryptic during the day, they hide in crevices or beneath ledges of reefs. It is thus difficult to be exhaustive and record all the squirrel and soldiers fishes that can be on transects. However, random swim in greater depth allowed to observed great abundances of squirrels and soldierfishes. Soldierfishes feed mainly on large zooplankton whereas squirrelfish feed on benthic invertebrates and small fishes. The family contribute to 2.36% of the total mean density with 0.018 fish/m^2 and only 0.86% of the total mean biomass with 1.4 t/km^2 but these numbers might be slightly underestimated. A predominance in density of fish genera *Sargocentron* and *Myripristis* was noted. The highest densities and biomass were recorded for the three carnivores' species *Sargocentron caudimaculatum* (HTS, silverspot squirrelfish), *Sargocentron tiere* (HTS, blue-lined squirrelfish, **Ebo**) and *Neoniphon sammara (*sammara squirrelfish and the two planktivores species *Myripristis berndti* (big-scale soldierfish, **Emwan**) and *Myripristis vittata* (HTS, whitetip soldierfish) as shown in the Table 9. The mean size was 14.46cm for HTS species and 14.8cm for other species

Table 9. Mean biomasses, mean densities and mean/maximum sizes of main Holocentridae species. The values found for biomass and density during the PROCFish study in 2005 is presented as a comparisons. The Maturity length (Database IRD-Nouméa – M.Kulbicki, personal communication) and Maximum size (Kulbicki 2005; FishBase) are presented as a comparison. The dash symbol "-" means that no data or value were available

Species	Mean Densities recorded in 2005 (PROCFish)	Mean Densities recorded in 2013 (BIORAP) (fish/m^2)	Means Biomass recorded in 2005 (PROCFish))	Means Biomass recorded in 2013 (BIORAP) (t/km^2)	Mean / Max Fork Length (cm)	Maturity length / Max size (Reference)
Sargocentron caudimaculatum (HTS)	0.004	0.0092	0.49	0.73	14.3/22	-/25
Myripristis berndti	0.0034	0.007	0.53	0.57	14.4/17	12/30
Sargocentron tiere (HTS)	0.0002	0.0016	0.01	0.06	14.8/17	-/33
Neoniphon Sammara	0.0004	0.0002	0.03	0.02	19/19	15/32
Myripristis vittata (HTS)	0.0001	0.0001	0.03	0.007	13/13	-

The Lethrinidae family including emperors represent a set of species that are bottom-feeding, carnivores, coastal fishes, ranging primarily on or near reefs. They typically feed primarily at night on benthic invertebrates, fishes or on hard-shelled invertebrates. They can be solitary or schooling and do not appear to be territorial.

The Lutjanidae family including snappers represent a set of species that mostly feed on crustaceans and fishes but can also be planktivores. Generally demersal they can be found down to depths of about 450 m.

The Serranidae family including groupers represent a set of species that are bottom-dwelling predators and highly commercial food fish that feed on crustaceans and fishes.

Families such as Lethrinidae, Lutjanidae or Serranidae were found at very low density and biomass as they respectively represent 3.8%, 0.9%, 2.9% of the total mean density (with 0.03 fish/m², 0.007 fish/m² and 0.02 fish/m²) and 4.6%, 1.2% and 0.9% of the total mean biomass (7.51 t/km², 2.02 t/km² and 1.55 t/km²). Even if some species were more abundant, the observed trend in Nauru for these families was low abundances of small sized fish on the transect. Bigger fishes as well as some species were only found out of transects in greater depth.

Only two species of emperors (Lethrinidae) were recorded on transects with a large predominance of the species *Gnathodentex aureolineatus* (striped large-eye bream) that were always found in groups. Only few specimens of *Monotaxis grandoculis* (humpnose big-eye bream) were observed. The mean size was 24.45cm.

Four species of snappers (Lutjanidae) were recorded on transects with a predominance of the HTS species *Aphareus furca* (small toothed jobfish). Fishes were usually observed individually or by pair but on two stations in the districts of Ijuw and Anabar, schools of 12 to 14 individuals were recorded. The HTS species *Lutjanus fulvus* (red-tail snapper, **Iniame**) was the second more frequently observed but for the other snappers, only individuals were seen occasionally or out of transects. Other HTS species such as *Lutjanus kasmira* (yellow and blue-lined snapper, **Earata**) or *Lutjanus Bohar* (red snapper, **Eanurum** / **Irum**) were usually observed out of transects, in greater depth and rapidly fleeing. The mean size was 22.3cm for HTS species and 40cm for other species.

The groupers (Serranidae) were more frequently observed with a predominance of the genera *Cephalopholis* and *Epinephelus*. The highest densities and biomasses were recorded for the two species *Cephalopholis urodeta* (darkfin hind) and *Epinephelus hexagonatus* (orange rock-cod, **Iwuro**). Small sized fishes were mostly observed. The HTS specie *Cephalopholis argus* (peacock rock-cod, **Etom**) was found in lower abundance but as it can reach greater size, it contributes significantly to an increase in the total mean biomass of Serranidae family. The mean size was 25.28cm for HTS species and 13.8cm for other species

Table 10. Mean biomass, mean densities and mean/maximum sizes of main Serranidae, Lutjanidae and Lethrinidae species. The values found for biomass and density during the PROCFish study in 2005 is presented as a comparisons. The Maturity length (Database IRD-Nouméa – M.Kulbicki, personal communication) and Maximum size (Kulbicki 2005; FishBase) are presented as a comparison. The dash symbol "-" means that no data or value were available.

Families / Species	Mean Densities recorded in 2005 (PROCFish)	Mean Densities recorded in 2013 (BIORAP) (fish/m²)	Means Biomass recorded in 2005 (PROCFish)	Means Biomass recorded in 2013 (BIORAP) (t/km²)	Mean / Max Fork Length (cm)	Maturity length / Max size (Reference)
Serranidae						
Cephalopholis urodeta	0.0163	0.013	1.4	0.79	13.2/23	17/28
Cephalopholis argus (HTS)	0.0032	0.0013	0.52	0.38	26/37	31/60
Epinephelus hexagonatus	-	0.005	-	0.22	15.7/28	19/27.5
Cephalopholis leopardus	0.0007	0.0027	0.05	0.11	12.3/17	-/24
Epinephelus spilotoceps	0.0006	0.0002	0.05	0.03	22.5/30	19/35
Aethaloperca rogaa (HTS)	0.0001	0.0001	0.01	0.006	21/21	34/60
Lutjanidae						
Aphareus furca (HTS)	0.0005	0.0041	0.41	1.07	23.5/33	-/70
Lutjanus fulvus (HTS)	0.0131	0.0028	3.26	0.71	22.6/30	19/40
Lutjanus semicinctus	0	0.0001	0	0.12	35/35	24/35
Lutjanus monostigma (HTS)	0.0022	0.0005	0.8	0.10	23/23	26/60
Lutjanus bohar (HTS)	0.0004	0.0001	0.17	0.0003	50/50	45/90
Lethrinidae						
Gnathodentex aureolineatus	0.0111	0.0265	3.38	5.37	20.8/30	-/30
Monotaxis grandoculis	0.0005	0.003	0.41	2.13	28.7/42	23/60

Apex predators are large size piscivore species with slow growth rate at the top of the food web and have a very low rate of predation. Very few of them were observed during this BIORAP. No large groupers, only one jobfish, and few barracudas were observed.

The Carangidae family including jacks wasn't found really abundant in Nauru as it contributed to 0.43% of the total mean density with 0.0033 fish/m² and to 1.2% of the total mean biomass with 1.96 t/km². The genera *Caranx* was dominant followed by the *Carangoides* genera. The species, *Caranx lugubris* (black jack, **Apwe**) was the most abundant and was usually following divers during surveys. Only small individuals were observed. The two species *Carangoides ferdau* (blue trevally) and *Caranx melampygus* (bluefin trevally, **Ikwidada**) were less abundant but larger specimens were observed that contributed to a higher biomass. The rainbow runner (Carangidae, *Elagatis bippinulata,* **Eokwoe**) seemed to be quite abundant, but as they usually stay swimming in the water column and stay distant from the reef, they weren't recorded on transects. The mean size was 29.25cm.

White tip sharks (Carcharhinidae, *Triaenodon obesus)* were the most abundant apex predators found in Nauru's reef as they were observed almost in every dive contributing to 0.24% of the total density with 0.0018 fish/m² and to 15.95% of the total mean biomass with 25.84 t/km² as they can reach a length of 120cm. Spearfishing while scuba-diving being allowed in Nauru, shark might be attracted by divers.

Table 11. Mean biomass, mean densities and mean/maximum sizes of main Carangidae species. The values found for biomass and density during the PROCFish study in 2005 is presented as a comparisons. The maturity length (Database IRD-Nouméa – M.Kulbicki, personal communication) and maximum size (Kulbicki 2005; FishBase) are presented as a comparison. The dash symbol "-" means that no data or value were available.

Species	Mean Densities recorded in 2005 (PROCFish)	Mean Densities recorded in 2013 (BIORAP) (fish/m²)	Means Biomass recorded in 2005 (PROCFish)	Means Biomass recorded in 2013 (BIORAP) (t/km²)	Mean / Max Fork Length (cm)	Maturity length / Max size (Reference)
Caranx melampygus	0	0.008	0.04	0.74	50/55	35/128.7
Carangoides ferdau	-	0.018	-	0.70	33/35	30/70
Caranx lugubris	-	0.036	-	0.35	21.3/25	36.5/100
Carangoides orthogrammus	-	0.004	-	0.15	36/55	33/75

Size Analysis

The existing information in reference databases concerning the maturity size are still very limited even if this parameter is critical in regards of conservation strategies. Indeed, as fishermen usually first target bigger specimens, one obvious sign of overfishing is the decrease overtime of Mean and Maximum size of species recorded. When the global mean size of a particular species recorded during a survey become lower than its maturity length, we can assume that the stock may be endangered and may collapse soon if no action is undertaken. This is even more worrying when the bigger fish observed (Maximum size) is under this maturity length.

The existing data in the PROCFish report doesn't allow any comparison of sizes between 2005 and 2013. However, data on maturity length for a limited number of species provided by the fish specialist M.Kulbicki, and presented in the previous tabs allow to highlight some important results. These results only focus on abundant species with enough individual registered for the analysis to be relevant.

Five species belonging to the families of surgeonfishes (Acanthuridae), jacks (Carangidae) and groupers (Serranidae) show values of Mean size under the minimum maturity length. For three of these species, the number of individuals recorded is quite small and further investigations should be undertaken to confirm the trends observed: *Naso hexacanthus* (Acanthuridae, sleek unicorn fish, 23 individuals, Mean size = 41.8cm, Maturity length = 45cm, HTS), *Cephalopholis argus* (Serranidae, peacock rock-cod, **Etom**, 13 individuals, Mean size = 26cm, Maturity length = 31cm, HTS), *Caranx lugubris* (Carangidae, black jack, **Apwe,** 18 individuals, Mean size = 21.3cm, Maturity length = 36.5cm). Regarding the black jack, even the maximum size recorded (25cm) was under the maturity length. More worrying, two species of grouper (Serranidae) presented mean size under the maturity length despite a higher number of fish recorded: *Cephalopholis urodeta* (Serranidae, darkfin hind, 130 individuals, Mean size = 13.2cm, Maturity length = 17cm, HTS) and *Epinephelus hexagonatus* (Serranidae, orange rock-cod, **Iwuro**, 50 individuals, Mean size = 15.7cm, Maturity length = 19cm, HTS).

Trophic Structure analysis

To better understand the existing balance in fish communities from an ecosystem perspective and understand further conservation recommendations, the following results **are presented through trophic groups.**

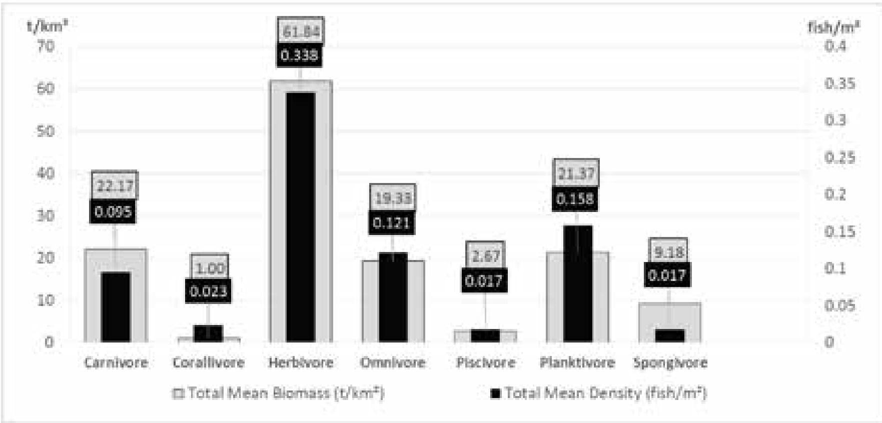

Figure 3. Total mean biomasses and densities of main diet groups.

Herbivores fishes (surgeonfishes, parrotfishes, rabbitfishes and chubs) feed on algae turf, macro-algae and cyanobacteria. As shown in the Figure 3, they are from far the most abundant group found all over Nauru's reefs. It represents 44.9% of the total mean biomass with 61.8 t/km² and 43.8% of the total mean density with 0.3 fish/m². The planktivores fish (surgeonfishes, triggerfishes, fusiliers, soldiers, squirrels, snappers, butterflyfishes and sweepers) feed on plankton in the water column. They form the second more important groups observed during this survey. It represents 15.53% of the total mean biomass with 21.3 t/km² and 20.5% of the total mean density with 0.15 fish/m². Carnivorous fishes (trevallies, soldier, squirrels, emperors, snappers, goatfishes, groupers and others) are predators that feed on crustaceans, shells and fishes. Their mean density is slightly lower than planktivores as they represent 12.38% of the total mean density with 0.09 fish/m² but as some larger sized-species are included in this group, their mean biomass is bigger and represents 16.12% of the total mean biomass with 22.16 fish/m². The piscivores group includes larger predators (trevallies, snappers, groupers, sharks and others) that exclusively feed on other species of fish. As shown in the Figure 3, this group is largely unrepresented as only 1.94% of the total mean biomass with 2.66 t/km² and 2.26% of the total mean density with 0.017 fish/m².

COMPARATIVE STUDY

Table 12 provides a ranking of the 20 sites surveyed based on the values for species richness, biomass and density. The *Caesionidae* were excluded from this analysis, their high numbers in certain areas (with a limited consumption interest) largely biased comparisons between sites. Carcharhinidae family was also excluded as their large size can largely biase the comparison of biomass between sites.

Table 12. Ranking of the 20 sites for each of the indices measured (species richness, density and biomass). For each site, the corresponding district is presented (BR=BIORAP, the present survey and PF = ProcFish previously surveyed site either of corresponding or nearby location to BIORAP site).

Districts	Stations	Species Richness	Districts	Stations	Density (fish/m^2)	District	Stations	Biomass (t/km^2)
Ijuw	BR06	54	**Anibare**	BR19	1.526	**Ijuw**	BR06	493.243
Anabar	BR08(PF10)	49	**Yaren**	BR20	1.428	**Anibare**	BR19	308.909
Meneng	BR12	47	**Ijuw**	BR06	1.42	**Aiwo**	BR01	278.393
Anabar	BR07(PF08)	47	**Baiti**	BR14	1.268	**Yaren**	BR20	257.478
Anibare	BR10	45	**Denigomodu**	BR17	1.136	**Yaren**	BR18	234.587
Anetan	BR13	45	**Anibare**	BR05	0.842	**Anabar**	BR08	215.782
Anibare	BR05(PF28)	44	**Anabar**	BR07	0.798	**Baiti**	BR14	188.295
Yaren	BR20	44	**Meneng**	BR04	0.74	**Anibare**	BR05	176.157
Yaren	BR18	44	**Anabar**	BR08	0.696	**Anabar**	BR07	151.971
Anibare	BR19	42	**Aiwo**	BR01	0.642	**Meneng**	BR04	127.250
Ewa	BR09(PF12/13)	41	**Nibok**	BR16	0.622	**Uaboe**	BR15	127.062
Baiti	BR14	39	**Uaboe**	BR15	0.606	**Ewa**	BR09	117.505
Denigomodu	BR17	39	**Aiwo**	BR02	0.6	**Denigomodu**	BR17	113.139
Nibok	BR16	37	**Anetan**	BR13	0.564	**Anibare**	BR10	109.122
Meneng	BR04(PF30)	36	**Yaren**	BR18	0.542	**Anetan**	BR13	105.998
Meneng	BR11	35	**Ewa**	BR09	0.454	**Nibok**	BR16	86.484
Aiwo	BR02(PF25)	35	**Meneng**	BR12	0.448	**Meneng**	BR12	66.940
Uaboe	BR15	32	**Meneng**	BR11	0.446	**Meneng**	BR11	49.305
Yaren	BR03(PF20)	25	**Anibare**	BR10	0.4	**Aiwo**	BR02	47.236
Aiwo	BR01(PF23)	19	**Yaren**	BR03	0.262	**Yaren**	BR03	15.404

Table 13 provides a ranking of the 12 Districts surveyed based on the values for species richness, biomass and density.

Table 13. Ranking of the 12 Districts for each of the indices measured (species richness, density and biomass)

Rank	Districts	Specific Richness	Districts	Total Mean Density (fish/m^2)	Districts	Total Mean Biomass (t/km^2)
1	**Anibare**	77	**Ijuw**	1.42	**Ijuw**	493.243
2	**Yaren**	73	**Baiti**	1.27	**Anibare**	198.063
3	**Anabar**	69	**Denigomodu**	1.14	**Baiti**	188.295
4	**Meneng**	61	**Anibare**	0.92	**Anabar**	183.877
5	**Ijuw**	54	**Anabar**	0.75	**Yaren**	169.156
6	**Anetan**	45	**Yaren**	0.74	**Aiwo**	162.815
7	**Ewa**	41	**Nibok**	0.62	**Uaboe**	127.062
8	**Baiti**	39	**Aiwo**	0.62	**Ewa**	117.505
8	**Denigomodu**	39	**Uaboe**	0.61	**Denigomodu**	113.139
10	**Aiwo**	38	**Anetan**	0.56	**Anetan**	105.998
11	**Nibok**	37	**Meneng**	0.54	**Nibok**	86.484
12	**Uaboe**	32	**Ewa**	0.45	**Meneng**	81.165

The reefs located from the Yaren district to the Anabar districts stand out from this analysis as the most diverse and abundant area for finfishes observed during this survey in Nauru. Indeed, districts of Anibare, Yaren, Anabar and Meneng are respectively the first, second, third and fourth most diverse districts of Nauru with the highest species richness values. These four districts also presented the highest diversity of HTS species. The highest species richness per station were found on station 6 (Ijuw), 7 and 8 (Anabar) and 12 (Meneng). A more restricted area including the districts of Anibare, Ijuw and Anabar presented the highest values of density and biomass, more specifically on stations 19 (Anibare) and 6 (Ijuw). The first, third and fourth highest values of density for HTS species were found in the districts of Ijuw, Anibare and Anabar. Also, two of the three highest densities of piscivores and two of the three highest densities of carnivores were found in the same restricted area. High values for density and biomass were found on stations 20 and a high biomass value on station 18 in the district of Yaren. However, one of the four lowest density values for HTS species was also found in this district (Yaren). Similarly, despite a high species richness, the district of Meneng had the lowest biomass and density, one of the four lowest values for density of HTS species and a low rate of piscivores species.

The reefs located from the Aiwo District to the Baiti District stand out from this analysis due to the low diversity of finfish observed. Indeed, the Districts of Baiti, Uaboe, Nibok, Denigomodu and Aiwo present the lowest values recorded both for specifies richness and HTS species richness. High densities mainly due to large number of surgeonfishes (Acanthuridae) including HTS species and large schools of rabbitfishes (Siganidae) were found on stations 14 (Baiti) and 17 (Denigomodu). Apart from the District of Denigomodu where higher density of piscivores was found, the Districts of Baiti and Nibok, presented respectively low densities of piscivores and carnivores. Low rates for both carnivores and piscivores were recorded in the District of Aiwo. Also observed in this district, a very low density of HTS species. The two districts of Ewa and Anetan located in the northern part of the island, with the Meneng District, located in the southeast part of Nauru, were observed to have the lowest quantities of fishes (including both indices of density and biomass) recorded during this survey. The Ebua District had the lowest density of HTS species observed.

Discussion

FINFISH COMPOSITION

Findings indicate that the targeted fish population of Nauru have a common composition that is representative of healthy coral reefs ecosystems. Most of the dominant fish families generally found on reefs in other study Pacific reef sites were found during this survey. However, the biodiversity of finfish is slightly lower than other Pacific reef sites within the region. This can be partly explained as a result of biogeography. Nauru is a small island geographically isolated from any other bigger islands or continents. This has resulted in a low probability for fish larvae to be supplied from other reefs in the region to settle on Nauru's reef. Consequently, Nauru's isolation needs to be critically considered for successful conservation and management actions.

Despite the classic composition of Nauru's population of fishes, several signs suggest the strong influence of several factors. The coexistence of multiple species within a trophic level can be the result of numerous components, including competition for space and food, predatory, resource availability, and environmental conditions (Tilman, 1977; Emery & al., 2001; Gross & al., 2001; del-Val and Crawley, 2005). In near shore marine communities, patterns of species coexistence are temporally and spatially dynamic, with fluctuations in species composition often occurring following ecosystem-level changes. These include natural disturbances like storms (Fourqurean and Rutten 2004) and anthropogenic impacts such as overfishing of top consumers (Jackson & al., 2001) and coastal nutrient enrichment (Cardoso & al., 2004). As it will be further discussed, overfishing seems to be the main factor impacting the fish communities of Nauru.

DECLINE IN FISHES' ABUNDANCE AND PREDICABLE CONSEQUENCES

With a circumference of 18km, Nauru is quite a small island. Nevertheless, a large proportion of fish species were found on only half of the sites surveyed. Only the most abundant species were observed on all the sites surveyed (located around the island) and those abundant species where in a very small number (i.e. n = 12). As limited as comparisons with the previous study by PROCFish (2005) are, the general trend shows important changes overtime. Comparing the two studies (present one and PROCfish 2005) suggests a decline between 2005 and 2013 in the density and biomass of important fish species. This results in a reduction of the quantity of resources available for fishing. Except for few species, surgeonfishes (A*canthuridae*), triggerfishes (Balistidae), groupers (Serranidae*)* and snappers (Lutjanidae) globally observed a decline of density and biomass between 2005 and 2013 while families of butterflyfishes (Chaetodontidae), soldier & squirrelfishes (Holocentridae) and Emperors (Lethrinidae) observed an increase.

As shown in other chapters of this BIORAP, reefs in Nauru were found to be healthy. The reef morphology consists of a rapid 45° angle slope to the ocean floor to a 4000m depth (Jacobs, 2000). This outer reef is characterized by oceanic water, strong hydrodynamic energy and currents that appear to create good conditions for coral habitats and associated benthic organisms. Coastal influences (wastewater, sewage and runoff) are largely limited to the intertidal sheltered coastal reefs and rapidly flushed. Butterflyfishes (Chaetodontidae), considered good indicators of reef's health, were found abundant. Moreover, families of fishes that feed on plankton, on small reefs organisms (crustaceans, shells…) or on algae such as surgeonfishes (Acanthuridae) and triggerfishes (Balistidae) as well as soldiers & squirrelfishes (Holocentridae) (not observed during UVC transects, but present in most of the reef's crevices) were largely dominant in the overall fish population. This observation is consistent with the previous study (PROCFish, 2005). However, these families were only represented by a small number of species that were the most abundant. In this case, herbivorous species are by far the most abundant fish observed. Herbivorous fishes are those that feed mainly or entirely on algae. In coral reef environments, the relationship between algae and corals is characterized by intense competition for space (Knowlton 2001). The grazing action of herbivores curbs algal development and promotes growth and occupation of space by corals (Crossman et al. 2001, Wismer et al. 2009). Nutrient enhancement due to coastal influence may influence algae development on the fringing reefs. This may result in bottom-up effects whereby nutrients enhance algal growth thereby providing a food source to support a high level of herbivorous fishes.

On the other hand, predation is a well-known factor playing an important role in structuring assemblages through top-down effects (direct and indirect). Apex predators and top predators such as sharks, large groupers, large snappers and jacks feed on the animals below them in the food web. They help to regulate and maintain the balance of marine ecosystems as they directly limit the populations of their prey, which in turn affects the prey species abundance and distribution and ultimately influences the community structure (Griffin et al., 2008). Piscivores and low-level carnivores such as the groupers (Serranidae), snappers (Lutjanidae), jacks (Carangidae) or emperors (Lethrinidae) were observed at a very low densities, biomass and species richness on Nauru's reefs. Only a few species in each of these families was noted. Most of the species were observed in deep waters and observed to rapidly flee when facing the diver. These families are commonly found in greater abundance on remote or protected reefs and their food source appears not to be a limiting factor in Nauru. These observations may suggest a strong influence of fishing pressure over these fish families.

A growing body of work suggests that fishing can have strong effects on the ecology of target species, especially top predators. General ecological theory predicts that reductions in abundances of top predators should lead first to an increase in prey populations following reductions of predator density (Jennings et al. 2001; Sandin et al. 2010) that may result in a classic trophic cascade. As top predators on coral reefs tend to be generalists and are likely feeding on a variety of fishes and invertebrates from several lower trophic groups, the cumulative effects of removing top predators are not clear. This is particularly true in highly diverse and trophically complex coral reef ecosystems. However, overfishing predators may alter community structure in complex and non-intuitive ways. Therefore, indirect demographic effects should be considered more broadly in ecosystem-based management. Studies have shown that by preventing one species from monopolizing a limited resource, predators increase the species diversity of the ecosystem. (Paine1966).

Comparisons of areas with and without apex predators show that apex predators provide greater biodiversity and higher densities of fishes, while areas without apex predators experience species absences (Sergio et al. 2006). As these species usually have a slow growth and a low reproductive rate when compared to smaller species, overfishing effects can quickly impact their structure and can be easily detected.

Sharks are the larger apex predators on reefs. Throughout all sites surveyed, the white-tip shark (*Triaenodon obesus)* was observed with four to eight individuals observed on some sites. As these sharks seem to be targeted only occasionally, their abundance might be due to a large abundance of potential prey (as they can feed both on small reef fishes and invertebrates) as well as a low fishing pressure. This may contribute to the fishes' community structure. However, the white-tip shark was the only species of sharks found in Nauru. No other common reef sharks, such as the grey shark, the black-tip shark or the silver-tip shark were observed during this survey or during the previous ones.

MEAN SIZE REDUCTION

Fishing pressure in Nauru appears to be impacting the size of a wide variety of fish species. Given the lack of comparative data, trends cannot be determined. However the mean sizes recorded for the majority of the species belonging to the family of surgeonfishes (Acanthuridae), triggerfishes (Balistidae), soldier & squirrelfishes (Holocentridae), groupers (Serranidae*)*, snappers (Lutjanidae), and jacks (Carangidae) are quite small. Of particular concern were five species with sizes systematically lower than the maturity length. This means that most of the fish observed and belonging to these species, were under the size where they can reproduce. As maturity size data doesn't exist for all the species observed, this status could cover more species. As the monitoring surveys are conducted in shallow water, these observations have to be interpreted with cautious as larger individuals may be found in deeper water. However, these conclusions still mean that part of the stocks easily accessible to fishermen are impacted in their reproduction (and even more heavily impacted for some species).

OVERFISHING IN NAURU

The effects of intensive exploitation of fishing stocks are well documented (Gell and Roberts 2003) and leads to major threats such as:

- The decrease in densities of fishes resulting in a decline in the number of catch by unit effort for fishermen.
- The decrease of mean sizes of catches, as a result of selective fishing (such as scuba diving spearfishing).
- The depletion of the genetic stock and reduced fertility.
- The loss of species and a decline of biodiversity when overfishing pressure continues to affect the fish communities.

Rapid assessments programs including the methodology used here, do not allow and are not intended: to accurately determine the status of the resource stocks in the area sampled, to properly understand the fishes' population dynamics and how it is affected by external factors. However, these surveys do provide a fairly accurate representation of biodiversity and help to understand the global status of organisms surveyed. Indeed, the observations previously discussed highlight strong signs of intense fishing pressure in Nauru, confirming observations in previous reports.

Although there appears to be a trend of intense fishing pressure on Nauru's reef, the finfish community doesn't seem to be affected in the same way around the whole island. This is probably due to high hydrodynamics and access difficulties. Fishing pressure seems to be less along the districts of Anibare, Ijuw and Anibare. In these districts, a higher abundance of fishes were found (both for HTS and other targeted species) as well as more balanced fish communities (higher abundance of piscivores and carnivores). This may have further implications for management strategies.

Conservation Recommendations

"*We shall not exploit our land or marine environment for food or resources beyond what is needed by ourselves or our family*." (Republic of Nauru – National environmental strategy and National environmental action plan, 1996)

Fishes are clearly one of the most important marine resources on coral reef ecosystems, particularly for developing countries and Pacific Island nations as they provide both food and economical incomes and ensure the health and welfare of islands communities. Marine resources were estimated in 2007 (SPC, Bulletin n°16) to be the main protein source, 98% of Nauruan houses. Managing the marine resources in Nauru is not only a matter of environment conservation but it is even more a matter of food security and economical balance. Management has to be undertaken in a way that ensures a sustainable livelihood for local communities' overtime.

HISTORIC

As father A. Kayser wrote a hundred years ago in his ethnography book series, "*Of all the Pacific Islands […], the small island Nauru (Naoero, Pleasant Island) […] deserves its pre-eminence as the main fishing island*". Due to their solitary position surrounded by ocean and the small size of their island with limited land resources, Nauruan people always have relied on marine resources. "*All of the Islanders, both men and women, go fishing*". Detailed throughout the 133 pages book of A. Kayser is a large number of tools and fishing practices that were developed overtime by the fishermen to catch various resources such as shells and crustaceans on the fringing reef, reef fishes on the outer reef, grow milkfish or flyingfishes in the Buada lagoon as well as catch great white sharks on the open ocean. These traditional fishing practices were part of a strong cultural heritage that was linked to the social structure of communities at the same time ensuring sustainable use of resources. Since then, the population has grown from 1,400 peoples in 1900 to 12,000 peoples in 2000 (Caldwell & al., 2001). This implies a necessary increase in fishing pressure on the limited 18km long surrounding reef ecosystem. This fishing exploitation that was primarily undertaken on an artisanal level and on a moderate basis (Dalzell 1994), became progressively a professional sector that started to increase. By the year 2000, fishing contributed about 30% of the gross domestic product. Additionally, the use of more efficient fishing tools (seine and cast nets with small mesh size, scuba diving equipment, "Christmas trees" - *Which is a T shaped or cruciform wire framework to which are attached several hooks and which is used as a long-line*-…) largely contributed to the increase in fishing pressure on the fish population bringing it to an unsustainable level. The effects of this overfishing have been documented for 20 years.

In 1994, P. Dalzell and A. Debao spent eight months working on coastal fisheries production on Nauru and expressed several points of concern:

- Stocks of snappers and groupers have been depleted and are not as plentiful as in the past
- Most large snappers and groupers have disappeared and spear fishermen are taking smaller specimens than in the past
- To escape the spear fishermen, snappers and grouper populations have retreated into deeper water.

In 2003, the PROCFish program also reported several strong signs of overfishing:

- Alarmingly low populations of targeted and commercial species of grouper, snapper, emperor and parrotfish.
- Stock sizes are currently at, or have already exceeded sustainable and optimum levels. Similarly, stock biomass of other less targeted species of parrotfish that are now targeted spear fishers appear to be increasingly affected as well.

EXISTING PLAN AND STRATEGIES

Coordination of policies and approaches to the management of fisheries was already identified as a priority in the early 2000 (NAURU – EUROPEAN COMMUNITY country Strategy Paper and National Indicative Programme for the period 2001-2007). Several projects were then undertaken more or less successfully involving both professional fishermen and communities with a aim to diversify fisheries types (FAD, Aquaculture, Tuna stocks) and reduce pressure on the reef's resources (Offshore Canoe Fishing, East Coast Escarpment Conservation Area Project). However, several constraints and challenges were faced. These included lack of funds to implement strategies/plans, misidentification of proper milestones to reach identified goals, land ownership disputes, lack of knowledge, gaps in existing rules and regulations from the fisheries act 1997 all leading to unachieved objectives (*Nauru National Assessment Report on the Mauritius Strategy Implementation*, 2009). With these lessons learned, the Nauruan Government is trying to align its National Biodiversity Strategic Action Plan with the Convention on Biological Diversity Strategic Plan & Aichi targets. The following recommendations will try to suggest realistic management measures to move forward.

Recommendations for further management options

The very productive reef fisheries of Nauru Island changed greatly in recent decades as human development and both intensive fishing and reef gleaning increased. Nauru typifies the increasingly common condition of resource depletion and marine community structure change with expanding human activities and population growth. Even if it's difficult to evaluate the proportion and importance of the decline in fish resources, the data analyses described here and in previous studies strongly suggest declines of specific groups or species and a collapsing fishery around Nauru Island. As the population is largely dependent on the marine resources for both subsistence and economical incomes, there is a strong need for the Nauruan Government to take action and adopt strategies to ensure resource maintenance and improvement as well as sustainable exploitation. The following recommendations for management options aim to provide reasonable and relevant guidelines that should be applied overtime

Immediately reduce fishing pressure and encourage good practices

Fishing gears restriction are usually the easiest way for a government body to reduce fishing pressure as it is easy to control and has no need for strong baseline studies and scientific guidance. Previous studies suggested a ban on Scuba diving spearfishing as the practice leads to selective fishing that target the bigger fishes and allow the fishermen to catch individuals at depth. Even if the practice finally seems to concern only a small number of fishermen, it should be prohibited to avoid any risk of increase. Spearfishing at night can also have greater impact even if practiced while free diving as most of the fish are sleeping and very easy to catch. This practice should be prohibited as well.

Spearfishing is limited to the outer reef area. Meanwhile most of the fishing in Nauru actually occurs on the sheltered coastal reef or close to the breakers and harbour entrances (PROCFish, 2005) where cast nets, handlines and gillnets are the principal gears used. Another gear restriction could be applied to cast nets and gillnets. Prohibiting the use of small-sized mesh (under 45mm) may be a means to avoid catching the juveniles of several species found on the reefs (e.g. snappers, surgeonfishes, parrotfishes). Usually, smaller mesh sized nets are only allowed for the catch of species such as mackerels or mullets (32mm min), and sardines or anchovies (5mm min). A maximum length and width restriction could also be applied for the use of gillnets to reduce the quantity of fishes caught per trip.

As several species are mainly found in greater depth, Nauruan fishermen have developed really efficient long-line fishing technics. More specifically, the use of the "Christmas tree" was described by Jacobs, (2000) as a particularly efficient technic that allows the fishermen to catch 60-70kg of snappers in three hours of fishing. This gear and technic were already described in A. Kayser ethnography book series and are part of the Nauruan cultural heritage that has to be preserved. However, the efficiency of such a tool should be controlled with the total number of hooks (currently between 18 and 50) attached to the apparatus being officially reduced. As this gear is usually used by fishermen who own a boat, awareness and control shouldn't be too difficult as only two channels exist around the island.

The following recommendations should be applied all over Nauru's reefs:

Rapidly create protected areas that will allow resource recovery while benefitting adjacent fisheries through the spill over effect

Marine Protected Areas (MPAs) are well known as an efficient management tool for their contribution to food security and sustainable livelihoods while protecting resources and restocking adjacent fisheries. The benefits of MPAs are well documented, including an increase in the diversity, density, biomass, body size and reproductive potential of many species (particularly key fisheries species) within their boundaries (Babcock, 2010; Lester, 2009; Halpern, 2003; Palumbi, 2004; Russ, 2002). MPAs can also provide conservation and fisheries benefits to surrounding areas through the export of eggs, larvae and adults to other reserves and fished areas. However, to be effective, MPAs have to be correctly designed and developed from an ecosystem perspective integrating adjacent communities in its implementation and monitoring.

A usual principle in designing MPA is to consider an area large enough to include 20-40% of the fishing stock and to ensure the species' home range pattern is protected. For some species of snappers and jacks, the home range can be over a length of 10km (Green et al. 2013). With an 18km reef's circumference, it won't be realistic to consider implementing such a large MPA in Nauru. However, one permanent MPA could focus on protecting Nauru's largest and healthiest reef segments based on the BIORAP survey while other smaller temporary MPAs could be implemented to protect critical habitats as discussed below.

In 2000, the East Coast Escarpment Conservation Area (ECECA) Project for a proposed conservation area that included the districts of Anibare, Ijuw and Anabar was developed. . At this time, the "ECECA Project" was considered to be the highest priority for conservation due to its unique ecological importance (e.g. coastal vegetation, mangrove ecosystem, wetlands areas, habitats for noddies and presence of endemic vascular plants). Also this area is adjacent to the Meneng Hotel thereby opening opportunities for ecotourism. At this time, little was known of the marine component and few management options were suggested. However, findings of this BIORAP survey confirmed that this specific area (including the districts of Anibare, Ijuw and Anabar) is of particular interest for conservation due to the comparatively higher abundance of fish and better balanced fish community structure. In this area, a large permanent marine protected area could be implemented with an aim to protect groupers (Serranidae), snappers, (Lutjanidae) emperors (Lethrinidae), jacks (Carangidae) and parrotfishes (Scaridae). In addition to the previously suggested gear restrictions, the fishing of theses listed families could be prohibited within this area. The MPA should be designed from both a permanent and long term perspective.

Indeed, MPA's primary benefits such as an increase in size of fish, offspring production and spill-over effects can be realized within a short period (>0-5 years). However, as the Nauruan fisheries are heavily overfished, long term protections should be considered (20 years at least) to ensure effective stock recovery and benefit to adjacent fisheries overtime. The area should extend from the beach to the open ocean at least 100 meters beyond the reef edge. In this way, the reef flat as well as the slope and the sea bottom with the associated species will be fully protected.

Utilizing these guidelines to design the MPAs, several community consultations should be conducted within the concerned districts to ensure acceptance of the project. Moreover, communities have to be involved in the planning and monitoring activities to ensure the effectiveness of this MPA. As implementation of this MPA with fishing restriction may directly impact the fishing ground of three districts, strong incentives have to be developed to provide new alternatives for local communities' livelihood. As examples, such alternatives could include:

- The MPA monitoring to ensure that rules and regulations are respected. This implies mediation, communication and awareness trainings as part of a capacity building project.
- The monitoring the protected resources overtime to evaluate the efficiency of the MPA. This implies underwater visual census, organism identification and data collection as trainings for part of a capacity building project.
- The development of touristic and educational activities. As an example, the *Ingi* is a traditional practice that aims to build artificial reefs on the reef flat where very few corals manage to grow. These *Ingis,* provide habitats to a great number of juvenile reef fishes. Traditionally used to teach the kids how to fish, *Ingis* could be also an efficient tool used for fish stock reconstitution and for educational or tourist awareness. Guides from local communities could be trained and involved.

These are only few examples of what can be developed within such a MPA. A comprehensive guide "economic incentives for marine conservation" was developed by Conservation International to help better understanding how to motivate sustainable behaviour by constructing economic alternatives. This approach may help in understanding how to distribute cost and benefits from conservation. The Locally Managed Marine Areas (LMMA) Network established in 12 Pacific Island countries could also represent an efficient help for the Nauruan Government in implementing and developing a community-based management strategy and help identifying important milestones for a sustainable locally managed MPA.

Protect reproduction as a critical ecological process to ensure stock recovery overtime

Protecting early life stage and reproduction is essential when considering stock recovery. Sustainable fishing means allowing adult fish to live long enough, and protecting the habitats on which the fish species rely during their different life stages. As previously stated in the discussion, as a result of biogeography, Nauru can't rely on other islands or countries to help bring back resources through fish larvae migrations. However, numerous species recorded during this survey were under or barely the minimum maturity size. In other words, this means that each fish caught under minimum maturity size never had a chance to produce offspring to be caught in future years. To protect this critical ecological process, several options can be considered.

The first measure to consider is the minimum size limit. Some of these sizes are presented in this report while others can be found on the online database FishBase or asked to the Secretariat of the Pacific Community. Typically, such measurements should be applied for highly targeted species and main species in finfish catch composition as highlighted in the PROCFish survey. Priority should be given to the five species presented in this report with mean sizes under the maturity length limit. Further investigation should be undertaken for species from the groupers (Serranidae), snappers (Lutjanidae), jacks (Carangidae), emperors (Lethrinidae) and parrotfishes (Scaridae). More data are needed to efficiently monitor the sizes trends of finfish. As discussed later in this report, if monitoring survey were undertaken on a regular basis, special attention should be paid to the evolution of mean and maximum sizes overtime. Also, participative survey involving professional fishermen could help recording periods of the year when eggs are found in fish's body and size of mature fish. This will help to define seasonal enclosure and minimum size limits.

Another strategic measure should be to identify and protect breeding and spawning aggregation sites. A fish spawning aggregation is a grouping of a single species of fish that has gathered together in greater densities than normal with the specific purpose of reproducing. Typically such aggregations form at the same place at approximately the same times each year. On a small island like Nauru where so many people fishing, local knowledge from fishermen could be used to identify where and when fish breed and help protect these critical habitats. As an example during this BIORAP, one officer from the fisheries mentioned that once a year hundreds of groupers (from the species *Cephalopholis leopardus*) could be found on a specific area from the reef (assuming this was a spawning aggregation)and that it was easier to fish them as only few of them were found the rest of the year. This testimony highlights the need of communication and awareness for the Nauruan people to better understand how their reef and resources work, it is also illustrates that local knowledge exists on such events and can be used for management purpose. Once identified and confirmed, marine protected areas could be implemented temporarily every year to protect sites where this critical ecological process (i.e. spawning aggregation) occurs. Following a survey on the local knowledge of fishers, further scientific underwater surveys would be needed to confirm and better characterize the composition and length of these events. Meanwhile, communication and awareness campaign could help to inform people and promote good practices.

SUPPORTING MEASURES

Making decisions on possible management options isn't that easy giving the facts:

- Most of the fishing is for subsistence purpose as 89.8% of Nauruan households eat fish almost four times a week (fresh fish they've fished) (PROCFish, 2005)
- Most of the fishing pressure (78.6%) occurs on the sheltered coastal reef area as most of the fishermen can't afford the price of a boat or fuel for outer reef fishing (PROCFish, 2005)
- Most of the fish families (Lutjanidae, Serranidae, Carangidae) observed to be in decline are fished on sheltered coastal reef or close to the breakers and harbour entrances. Individuals caught are usually small sized and often below minimum maturity size.

Indeed, any management options that will be adopted will necessarily have short-term impacts on households and on livelihoods by limiting the quantity of fish available for fishing. These restrictions should be offset overtime by the recovery of stocks if management options are efficiently applied. To ensure an efficient conservation of reef resources, rules and regulations aren't sufficient by themselves. People need to understand why management measures are undertaken, how their reef and resources work, what affects them and why the adopted measures will help the reef to produce more resources overtime. **Raising awareness and involving communities in the management of their resources** are essential. This can be done through simple actions such as billboards, posters, radio communications or public meeting as well as more complex actions such as including environmental awareness as part of in the school program, developing participative resources monitoring activities with communities or professional fishermen. As mentioned earlier in this document, resource users need to see tangible rewards from changing behaviour if sustainable management and conservation of marine biodiversity is to be achieved. Indeed, since people are facing pressing socio-economic needs in many priority areas for conservation, such a potential loss can hamper the acceptance and sustainability of conservation interventions. This is usually the case, unless conservation programs address economic needs and **propose good incentives for alternative livelihoods.** The Nauruan government can be only encouraged to continue its effort in developing alternative fisheries and aquaculture projects even though several attempts may be needed. Besides rules and regulations, endorsement and acceptance by Nauruan people won't be sufficient by itself to **ensure compliance and enforcement.** Nauruan government including the fisheries office will have to ensure that rules and regulations are respected overtime through effective control in a long term perspective. In the case of locally managed marine areas, this duty can be shared with local community. One of the greater challenges commonly faced by environmental managers is to raise sufficient funds in order to reach the initially fixed conservation objectives. Nauru is no exception to the rule, even the contrary, it symbolises how hard it can be to implement conservation strategies when the country's economy is unbalanced and development is a true necessity. However, sustainable financing mechanisms is a topic that has been widely studied in recent years. The Nauruan government should easily find support with NGO's and other available programs to help build such mechanisms and raise funds for conservation.

To conclude, protecting the fish resources in Nauru is as urgent as it is delicate given the economic situation of the island. Whatever measures to be adopted, will necessarily affect the local communities by limiting the quantity of fish available for fishing. However, overfishing has been occurring for over 20 years so urgent compulsory action is needed. More than an environmental matter, managing the fish stocks around the island has become more and more a matter of food security. As a Micronesian Pacific Island country, Nauru can find the support to face this challenge.

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CHAPTER 9

REEF CONDITION

SHEILA A. MCKENNA

Summary

- Although coral diversity is low, the reefs are very healthy with some of the world's highest live coral cover recorded. Live coral cover of 91.2% was observed at site 14 (Baiti District) at depth less than 11m (<11m) and 88.7% at site 16 (Nibok District) with a depth greater than 12m (>12m). The lowest coral cover was 16.9% (depth <11m) and 11.2% (depth >20m) at site 20 (Aiwo District).
- The most frequently observed threat or disturbance to the reefs surveyed was from fishing related activity that occurred on 75% of the reef sites surveyed. Debris on the reefs that was non-related to fishing (e.g. clothes, cans, plastic bags etc.) was noted on 60% of the reef sites. Two sites (17 and 18) had extensive debris such as clothing and plastic, aluminum cans, etc.
- No evidence of bleaching was observed on any of the reef sites surveyed. Symptoms consistent with white band disease were rarely noted, only one to two colonies of *Pocillipora* on four of the 20 sites surveyed.
- No outbreaks of the large corallivore, *Acanthaster plancii* were noted. However, the small molluscan corallivore, *Drupella* sp was frequently observed.
- Numerous red listed species were spotted on all the reef sites assessed. These included corals, the white tip shark, bony fishes, and sea turtles.

Introduction

The single island country of Nauru is a raised coral atoll with a total land area of 21 km^2 and a circumference of 19km. Well known for its phosphate mining, the interior of the island has had 70% of the natural vegetation and topsoil removed. The population of Nauru according to 2011 census is 10,084 with residents concentrated along the coastal areas. The island is divided into 14 districts with only one of the districts having no coastal area. With no rivers and streams, Nauru has no permanent freshwater. Rainwater is directly drained into the ground water table due to a highly porous soil (Jacob 2000). The brackish or anchialine pool, Buada Lagoon occurs in the "landlocked" district of Buada. A continuous fringing reef (predominantly having a 45° slope, but varying to 90° in some sections) with a reef flat up to 300m wide surrounds the island. Reef area has been estimated to be 10km^2 (Burke et al. 2011). The total intertidal reef area down to the 200m isobaths was estimated to be 7.4km^2 by Dalzell and Debao (1994). The reefs are mainly used for subsistence fishing including reef gleaning for invertebrates. The inshore marine resources have no customary or community management regimes and are open access (Vunisea et al 2008).

In comparison to other localities with coral reefs in the world, Nauru's reefs have not received as much attention. However there are some studies, reports and anecdotal evidence on the coral reefs including noted threats and other disturbances. Nauru Coral Reef Monitoring Network surveyed seven sites in 2004 and recorded live coral coverage between 44% to 78% with sites near the districts of Nibok and Yaren having a high percent of dead coral and alga growth. Like other small island countries, the reefs of Nauru are highly threatened by climate change (Chin et al. 2011). Widespread bleaching and dead coral was noted by the Cousteau Nauru expedition in May to June 1991 (King 1992). From 2002 to 2004, another bleaching event was reported with high mortality of *Acropora* in early 2004 by NCRMN (Deiye in Sulu 2004). Additionally, a massive fish kill occurred in September 2003 hypothesized to be a result of elevated sea surface temperatures with warm water upwelling that led to major drop in dissolved oxygen concentration (Deiye 2004, Lovell 2004)). Localized threats from dredging were documented with the installation of the harbor in the Anibare District (Maharj 2003). Overfishing has been identified as a major threat to the reef resources of Nauru (Jacob 2000, Procfish 2007, Vunisea et al. 2008).

Here, the condition of 20 reef sites off the 13 coastal districts is described to provide a snapshot of reef "health" as observed during the period of the survey. Information is presented on the benthic community structure of the reefs surveyed and on incidence or evidence of stress or threats to those sites. This information is meant to serve as an initial snapshot of the health of the reefs surveyed and to provide an indication of what factors appear to be influencing the reef that suggest further research, monitoring, management and subsequent mitigation activities may be needed. In many cases there are enough observations (without further study needed) that readily indicate immediate mitigation activities are needed.

Methods

At each survey site substrata/biota data of the benthos were collected. Transects were used to sample the benthos as described in English et al. (2000). The following is a brief description of the transects: a 100 meter transect tape was placed along the bottom of the reef as close as possible to the biota/substrata. Two 100m transects were placed at two possible depth zones depending on the reef structure and topography. The two depth zones included <11 m (shallow) and >18m (deep). At some sites it was not possible to place and sample transects along two different depth zones either due to high hydrodynamic energy (e.g. surge in shallow reef areas) or limited reef topography. In those cases, one depth zone was sampled. The biota/substrata were sampled at selected 0.5 m intervals (for 40 sample points) along 20 m segments of the 100 m transect. Below each sampling point, the type of substrata/biota is identified or characterized as follows: hard coral (hc), soft coral (sc), sponge (sp), macro algae (ma), crustose coralline algae (cca), turf algae (ta), cyano-bacteria (cyano), rubble (rb), other, dead coral (dc) and bare substrata (bs). The category turf algae included filamentous and turf algae. The "other" category includes invertebrates such as tunicates, sea stars, sea cucumbers, etc. After the first 20 of the 100 m was sampled, the diver would skip 5 m and then continue sampling another 20 m (40 points) along the transect. This allowed for replication during sampling, with four 20 m segments of each transect sampled at half-meter intervals per depth.

Any visible signs of damage, threats, or disturbance at each reef site were noted. The divers looked for evidence of damage from fishing (nets, spear guns, lines,), boating activities (anchor damage, grounding scars, fin marks from snorkelers), and storms or cyclones. Damage from the coral predators *Acanthaster plancii* and *Drupella cornus* on the reef was detected by the presence and number of individuals seen or by feeding scars on the coral. Other divers of the RAP team supplemented observations on reef condition after the site survey dive had been completed. Charismatic marine fauna and other marine related red-listed species were also noted at each reef site. These include sharks, manta rays, turtles, etc.

Bleaching refers to the discoloration of coral tissue color—the more discolored the coral tissue, the more severe the bleaching. Light (or early stages of) bleaching is indicated by a slight discoloration of the coral tissue. Moderate or extreme bleaching is usually indicated by the coral tissue being transparent, opaque, or clear in color with the coral skeleton visible. The number of colonies showing signs of bleaching and the level of tissue discoloration indicates the extent of the bleaching on the reef.

In addition to bleaching, coral pathogens or diseases may be observed on the reef and have been identified to occur on hard and soft coral. Some diseases are identifiable by a distinctive banding or pattern of discoloration on the surface of hard and soft coral. For example, black band disease on hard corals is evident by an obvious black band across the coral head—behind the band the coral skeleton is visible and the coral tissue is dead and gone. On the other side of the band the coral surface looks normal. The incidence of diseases and other pathogens has been more frequently observed and studied in the Caribbean than in the Indo-Pacific (Sutherland et al. 2004). Any symptoms of disease or pathogens observed during the survey were classified according to the Coral Disease Handbook: Guidelines for Assessment, Monitoring and Management (http://gefcoral.org/LinkClick.aspx?fileticket=BshMDpVe%2blk%3d&tabid=3260&language=en-US).

Evidence suggesting threat or pressure from pollution/eutrophication, fishing pressure, siltation, and freshwater runoff may be taking place on the reef can be observed, however further testing, monitoring, or experimentation is needed for quantitative data. In some cases, freshwater run-off or siltation may be a "natural" occurrence for a reef site because of its location next to a river mouth where the watershed has not been altered. In other cases theses occurrence are not "natural" and have been altered due to human activities. For example, the source of the damage (e.g., sewage outfall pipe, deforested area along the shoreline, mining activities coastal development, and river outfall) can be seen from the reef site, thereby providing qualitative evidence. An abundance of algae with low coral cover can be an anecdotal indicator of pollution/eutrophication on reefs. However, the population of herbivores and type of algae (macro-algae, turf or filamentous, or calcareous) need to be considered. The presence of fishers actively fishing or a low abundance of target biota (e.g., sea cucumbers or groupers) on the reef site indicates extractive pressure from fishers, but the frequency and extent of marine resource use and abundance of stocks need to be further investigated and monitored to obtain quantitative data. High percent cover of mud or silt on the reef benthos indicates siltation.

These types of threats or disturbance need to be characterized further by direct measurements of specific parameters (e.g., nutrients in the water column, stock abundance and fishers activity, sediments, and percent cover of biota/substrata) over a long sampling period of at least one year or more. The nature of the rapid assessment only allows for initial observations that suggest eutrophication/pollution, fishing pressure, siltation, or runoff is taking place and the relative extent of its impact on the reef site. This provides an important first step in determining stress or threat presence on the reefs sites and what follow up is needed in terms of further study, threat mitigation, monitoring and effective management. In some cases, observations identify a major threat that warrants or signals that immediate action is needed to mitigate a threat. Sites where evidence of these threats is noted are indicated in the text and summarized in Table 1. The summary table synthesizes the key indicators for state or health of the reef based on biodiversity of the fish and coral species, average percent coral cover and consideration of presence or absence and extent of human impact.

Table 1 Summary of parameters measured and observations by district with site number. An asterisk (*) next to the value denotes one of the five highest values for that parameter (i.e. percent coral cover pooled across depth as in Figure 3 , number (#) of fish and coral species, and mean density and biomass of targeted and commercial fish). Fishing line observed on the reef is noted by (line) and the occurrence of white band disease noted by WB.

District (site #)	Percent Live coral cover (pooled across depths)	Species Richness		Targeted and Commercial Fish Indices		Observation of Threat or Disturbance				Comments
		# Coral	# Fish	Mean Density (fish/m)	Biomass (t/km)	Fishing (extractive activity or fishing related debris seen)	Debris	Corallivores (no population outbreaks noted)	Disease (rare on isolated one or two colonies of Pocillopora)	
Aiwo (1)	33.7	15	49	0.6	278*	x		*Drupella* sp.	WB	
Aiwo (2)	36.6	17	52	0.6	47	x				
Yaren (3)	79.2	11	54	0.3	15	x				
Meneng (4)	24.4	21*	78	0.7	127	x				
Anibare (5)	54.4	21*	80	0.8	176	x (line)	x	*Drupella* sp.		
Ijurw (6)	23.7	21*	88*	1.4*	493*		x			
Anabar (south, 7)	30.6	18	83*	0.8	152	x (line)	x	*Drupella* sp.	WB	Extensive debris
Anabar (north, 8)	45	19	84*	0.7	216	x (line and spear gun)	x	*Drupella* sp.		
Ewa (9)	67.8	15	83*	0.4	117			*Drupella* sp.		Hawksbill turtle
Anibare (north, 10)	56.2	19	70	0.4	109	x (line)	x	*Drupella* sp.		
Meneng (south 11)	67.5	20	85*	0.5	49	x		*Drupella* sp		Soft coral (Cladialla sp.)
Meneng (south,12)	34.4	22*	81	0.4	67	x (line)	x			fishing hook stuck in mouth of white tip reef shark *Triaenodon obesus*
Anetan (13)	64.7	18	74	0.6	106	X (line)	x		WB	Unidentified sea turtle Soft coral *(Sacrophytan* sp.) Recent anchor damage
Baiti (14)*	89*	8	80	1.3*	188	x (line)	x	*Drupella* sp	WB	
Uaboe (15)*	85*	9	79	0.6	79			*Drupella* sp		
Nibok (16)*	86*	10	82	0.6	86	x (line)	x	*Drupella* sp		
Denigomodu (17)	65	15	78	1.1	113	x (line)	x	*Drupella* sp		Extensive debris
Yaren (south, 18)	58	19	82	0.5	235		x			Extensive debris Clothing tangled in *Acropora* colony
Anibare (19)	36	27*	35	1.5*	309*					
Aiwo (20)	14	26*	79	1.4*	267*					

Results

BENTHIC COVER

Percent coverage by hard coral at shallow depths (<11m) was high and equal to or over 40% for all sites except two (4 and 20). Percent hard coral cover (% + standard error) ranged from 16.9%+ 2.8 at site 20 to 91.2% + 3.1 at site 15 (depths <11m, Figure 1). In deeper depths (>12m), percent coverage by hard coral ranged from 11.2% + 2.4 at site 20 to 88.7+ 8.7 at site 14 (Figure 2). Crustose coralline algae were also observed dominating the substrate at several sites especially at the deeper sampling depth. Percent cover with standard error for all types of substrate/biota observed at each site by depth is given in Appendix 17. No sponges, soft coral, dead coral, bare substrate and sediment was recorded on transects at any sites. However, sponges and soft coral were observed outside of transects. The genus and species of the few colonies of sponges seen (approximately four colonies per all 20 sites surveyed) were not identified taxonomically as no tissue samples were taken, only photographs. Soft corals were rarely observed (approximately two or three colonies at most per all 20 sites surveyed). The genus of the individuals observed with site is: *Cladialla* sp at sites 7 and 11 and *Sacrophytan* sp. at site 13. The dominant macroalgae observed was *Halimeda* sp. No mud or silt was noted on any transect.

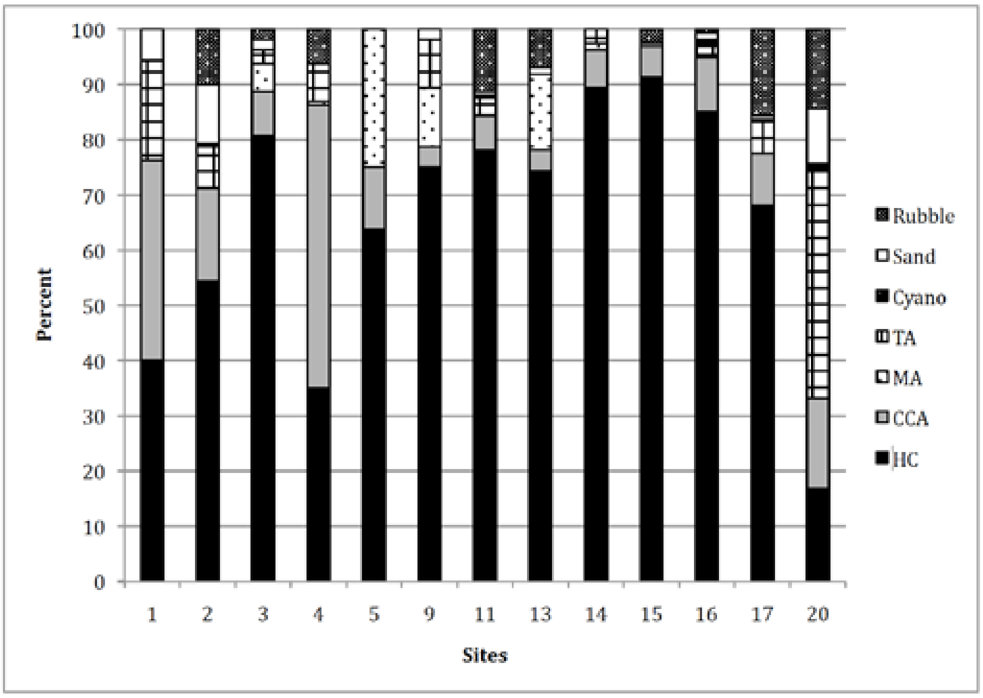

Figure 1. Percent benthic cover for sites at depths of less than 11m (shallow) as determined by the point intercept transect method. For each site four 20m length transects (n=4) were sampled. Biota/substrate were categorized as: Hard Coral (HC), Crustose Coralline Algae (CCA), Macro Algae (MA), Turf Algae (TA), Cyanobacteria (Cyano), Sand and Rubble.

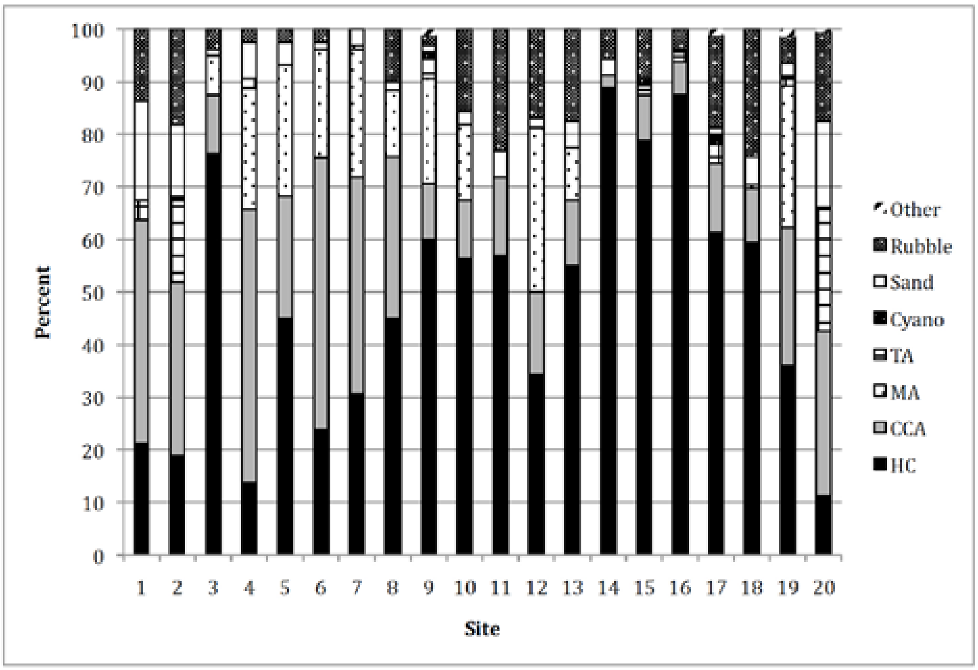

Figure 2. Percent benthic cover for sites at depths of greater than 12m (deep) as determined by the point intercept transect method. For each site four 20m length transects (n=4) were sampled except for sites 1 and 2 where n=2 and site 8 where n=3 . Biota/substrate were categorized as: Hard Coral (HC), Crustose Coralline Algae (CCA), Macro Algae (MA), Turf Algae (TA), Cyanobacteria (Cyano), Sand and Rubble.

CORAL BLEACHING AND PATHOGENS

No evidence of bleaching was observed in any of the hard corals across the 20 sites surveyed. Symptoms consistent with coral disease however were noted at four (1, 7, 13 and 14) sites or 20% of the sites surveyed. Symptoms consistent with white band disease were noted on only one to two colonies of *Pocillopora* sp. No other evidence of disease on crustose coralline algae (i.e. coralline lethal orange disease or CLOD) was noted.

CORALLIVORES

No outbreaks of the large corallivore, *Acanthaster planci* were noted on any of the reefs surveyed. In fact, only one individual was seen during the entire survey. However, the small molluscan corallivore, *Drupella* sp. were frequently observed at 11 sites (1, 5, 7, 8, 9, 10, 11, 14, 15, 16, and 17) or 55% of the sites surveyed.

FISHING

The most frequently observed threat or disturbance to the reefs surveyed was from fishing related activity observed at 13 sites (1, 2, 3, 4, 8, 10, 11, 12, 13, 14, 16, 17 and 20) or 65% of the sites surveyed. This included actual observations of individuals fishing or reef gleaning from shore or boat as well fishing related items on the reefs sites. Fishing line was observed at six sites (8, 10, 13, 14, 16, and 17) while a spear was noted at one site (site 8).

DEBRIS

Debris on the reefs was noted on 11 sites (6, 7, 8, 12, 13, 14, 16, 17, and 18) or 60% of the reef sites surveyed. Two sites (17 and 18) had extensive debris such as clothing and plastic, aluminum cans, etc.

RED-LISTED SPECIES SIGHTINGS

Red-listed species were observed at all 20 of the sites assessed and included corals, fishes, sharks as well as sea turtles. For detailed information on red-listed species of: coral see chapter 5, fish and sharks see Chapters 7 and 8. For sea turtles, only two individuals were seen, one *Eretmochelys imbricate* (hawksbill turtle) at site 9 and another that could not be identified with certainty at site 13.

SYNTHESIS OF FACTORS

A compilation and synthesis of the key indicators measured for coral reef health are summarized in Table 1. As percent live coral coverage is a critical indicator of reef health, the values for each district by site (pooled across depths in some instances) are presented in Figure3.

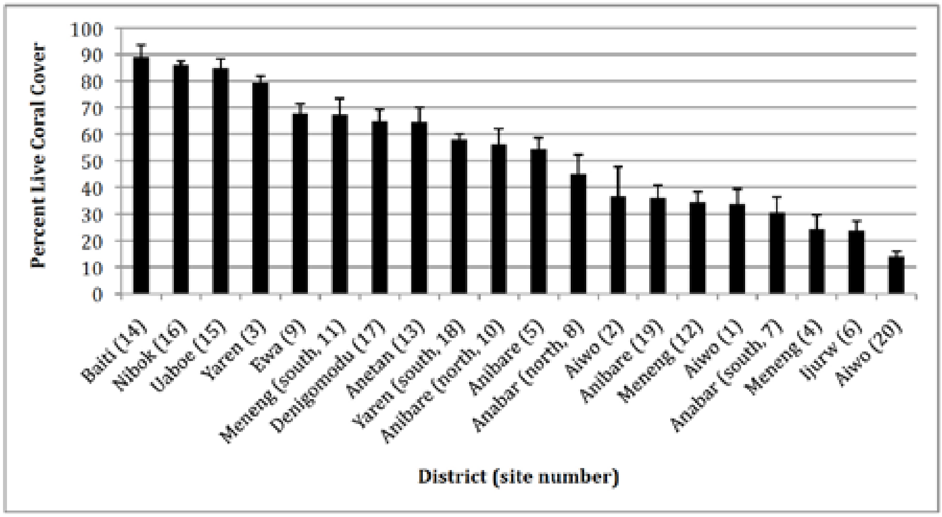

Figure 3. Percent coral cover by site and district pooled across depth. Number of 20 m transects sampled across shallow (<11m) and deep (>12m) depths is: n= 8 for sites 2, 4, 5, 8, 11, 13, 14, 15, 16, 17, and 20; n=6 for sites 1 and 3; n= 4 for sites 6, 7, 10, 12, 18, 19; n = 3 for site 8.

Discussion

In general the results indicates that the reefs are healthy as indicated by the high coral cover (some of the highest percent cover recorded in the world) with little to no coral disease, no bleaching and no outbreaks of corallivores. The percent live coral cover recorded off the districts of Nibok (site 16) and Yaren (site 3) were high and in fact among the top five highest for all sites surveyed. This is in direct contrast to the findings of the NCRMN who reported that these two districts (Nibok and Yaren) had the highest percent cover of dead coral and alga growth and live coral cover was 0-20% in areas from Uaboe ditrict to Gabab channel (Sulu 2004). The high live coral cover findings in this region from our survey suggest that recovery has taken place. The coral *Porites rus* dominates the reefs off the districts of Nibok (site 16) and Yaren (site 3) as well as other sites 2, 5, 10–15, 17 and 18 (see Chapter 5)and perhaps colonized following the bleaching and coral mortality. This species is known for being less prone to bleaching, but susceptible to disease (Shepard et al. 2013). Since mono-specific strands of *P. rus* dominate several sites, a major outbreak of a disease affecting *P.rus* would have devastating consequences (e.g. dead reef). It is important to note that increases in sea surface temperatures have been linked to increase in pathogens causing disease among corals (Bruno et al. 2007).

Given there are no rivers or streams in Nauru the lack of mud or silt being recorded on any transect is not surprising and is consistent with observations by Jacob 2000. Similarly the observation of only one *Acanthaster planci* is consistent with that of Procfish (2007) previous survey. Although *Drupella* sp can be of concern on some reefs (Cumming 2009), no observations consistent with population outbreaks were noted in this survey.

Disturbance or threats observed during this survey that are of primary concern stem from human activities that can be managed or mitigated. Overfishing is a severe problem as indicated in this chapter and even more so from the fish chapters of this report (see Chapters 7 and 8) and a previous survey conducted in Nauru by ProcFish/CoFish (2007). An in depth discussion on fish communities and fishing impacts is beyond the scope of this chapter, but the reader can found such information in Chapters 7 and 8.

The other major threat observed was debris mainly from fishing activity (e.g. monofilament line) or land based solid waste (e.g. cans, plastic bags, clothes etc.) seen at more than half of the sites surveyed. Debris is a known contaminant that can entangle and kill coral and other wildlife (Donohue et al. 2001, Allsopp et al. 2007). Debris or solid waste in general appears to be a serious problem on land as well as in the ocean for Nauru. On the positive side, this problem can be addressed through awareness, clean up and debris removal activities and at the country – wide government level with legislation and re-evaluation of their current waste disposal "system".

Observations of sea turtles (one hawksbill sea turtle, *Eretmochelys imbricata* and one unidentified individual) are consistent with other reports of their occurrence in Nauru (e.g. Hambruch 1915, Buden 2008). In addition to hawskbill, the green turtle, *Chelonia mydas*, has also been noted in Nauru.

As in all rapid assessments caution is warranted in interpretation of the results given the limited temporal and spatial scale of this survey. However it is evident that based on observations in this chapter and the rest of this report with the past literature that Nauru is long over-due to establish a marine managed area including no-take zone. Vitally important is to address the overfishing and debris problem through mitigation and to set up a monitoring program for the reefs and other marine resources. Conservation recommendations that include the aforementioned activities are addressed in the next section.

Conservation Recommendations

Based on the findings for this chapter on reef condition, the following recommendations are suggested.

- Set up marine managed areas (MMAs) immediately to include no-take areas or zones in consultation with all local stakeholders. Given the isolation of Nauru this is especially critical for re-seeding and maintaining the reefs and marine resources. Differences over time in key indicators (e.g. live coral cover, fish density and diversity) between marine managed areas and open use areas can be compared to illustrate the benefits of MMAs. Two ways to proceed are recommended. These include Nauru joining the Locally Managed Marine Area Network and conducting a marine spatial planning exercise with all stakeholders.
- Re-instate NCRMN or task another entity/organization to do reef check or set up monitoring stations for yearly monitoring of coral reef health. When a MMA is instituted, conduct monitoring inside and outside MMAs boundaries so comparisons can be made. Organize stakeholders by district to monitor their reefs and hold meetings to report their findings. Sites chosen for monitoring should be representative around the island and include the reef flat as well as to safe diving limits of the reef. The reef flats are extensive in Nauru, educating and training stakeholders on how to do an ecologically sound reef walk and collect data on invertebrates may be feasible.
- Public awareness campaign as well as in school curricula on importance of a healthy reef and the ecosystems services provided (e.g. protection from high wave energy and coastal erosion) is highly recommended. Special emphasis is advised on the critical need for balanced fish communities to maintain reef health and to ensure food security for themselves and future populations. Educate and provide visual aids to help all stakeholders to identify red-listed or special interest species, threats/disturbance to reefs (e.g. oil spills; bleaching; alga, coral and fish diseases and; corallivore outbreaks). Also instruct individuals on how, where and what to do when such incidences are observed. This campaign can be also used as way to re-invigorate or reinstate traditional environmental knowledge into the communities.
- Annual coastal cleanup events off each district as part of public awareness campaign. Debris is a major problem on the reefs and reef flats. A major initiative to have stakeholders dispose solid waste and other debris respectfully into marked receptacles is sorely needed as evidence by the high incidence of debris on the reefs. Perhaps the larger issue of waste disposal as a whole on the island of Nauru needs to be examined and improved. Nauru is not alone as waste is a major issue for all small island countries and all countries for that matter.
- IUCN redlist species including charismatic marine fauna need to be surveyed to confirm presence and or determine population status as was recommended by Armram and Deiye (2009).

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CHAPTER 10

A RAPID ASSESSMENT OF THE INTERTIDAL REEF FLATS WITH EMPHASIS ON THE MARINE FLORA OF NAURU

POSA A. SKELTON

Summary

- A rapid assessment of the intertidal flats of Nauru with a specific emphasis on the marine flora was completed as part of the Global Environment Facility – Pacific Alliance for Sustainability (Integrated Island Biodiversity) for Nauru. Surveys were undertaken for the entire coastline of the islands over a total of five field days (18-26 June 2013).
- The intertidal reef flat was fairly narrow with the widest margin at approximately (300 m) from the high-intertidal water mark to the reef crest. There is no deep lagoon but a number of channels and reef crevices are found scattered throughout the reef flat. Most of the reef flat is exposed during low-tides with a few shallow tidal pools. The short distance between the shoreline and the reef-crest ensures frequent daily flushing of the reef flats.
- Marine plants (mangroves and seagrasses) are absent from the coastal areas, with only a few plants of *Rhizophora* reported in land-locked ponds in the district of Anabar. Dominant organisms on the reef flats are algae comprising of the four major algal groups: Chlorophyta, Ochrophyta, Rhodophyta and Cyanophyta. In many parts of the reef flat clear zones can be seen with brown algae (Ochrophyta – mostly *Padina* sp.) dominating the high-intertidal area, green algae (Chlorophyta – comprising mostly of *Boergesenia forbesii, Microdictyon* sp., *Boodlea* sp.) dominated the mid-intertidal, and the red turf algae (Rhodophyta – *Ceramium* spp., *Polysiphonia* spp.) common in the low-intertidal to the reef crest area. The reef crest saw a mixture of red and green algae (*Dictyosphaeria cavernosa* and *D. versluysii*). The surveys yielded 20 new algal records for the island bringing the total number to 58 species.
- Fouling organisms, turf algae and hydroids, which are often associated with wharves, ports and pilings were found to be common throughout the reef flats. The marine flora was found to be typical of new habitats with many turf algae supporting the high number of grazers on the reef flat. A few species could be recent introductions including the fire-worms (*Hermodice carunculata*), found abundant near Gabab Channel, barnacles, hydroids and ascidians fouling many of the structures abandoned in the marine area.

Introduction

Nauru is interesting from a marine phyto-biogeographic perspective due to its isolation, origin and location in the vast Pacific Ocean. It is located in the path of the Southern Oscillation. Nauru's closest neighbor is Banaba or Ocean Islands (Kiribati) lying 300 km east. There is no major donor or source population for floristic or fauna biodiversity for the islands so much of its flora is naturally introduced by currents or on flotsam and jetsam. While knowledge on terrestrial flora is fairly well known due to botanists interest and collections in the early 1900s to 1980s (see Thaman *et al.* 2011 and Whistler 2014) very little is known of the marine flora. The first survey of the marine flora was made by G. Robin South and Stephen Yen in April and early May in 1990 based on collections made in the districts of Meneng and Anabare (South & Yen 1992). A total of 40 marine plants were found belonging to three phyla: Chlorophyta, Ochrophyta and Rhodophyta.

Methods

General surveys of intertidal reef health were conducted by visual observations, at approximately 2 hours per site. Marine flora surveys were carried out by snorkeling and wading during low tides. Specimens were collected whole (including holdfasts) for further identification. Those needing microscopic examinations were preserved in formalin/seawater (approximately 5%) solution. Specimens were labeled and photographed. Formalin/seawater solution was drained prior to shipment of specimens to SPREP for further analysis.

Sites

Five sites were surveyed, which covered most of the districts of the island. The sites are listed below.

SITE 1: AIWO BEACH (BEHIND ODN HOTEL) – S 00.536.78; E 166.910.74.

Aiwo District lies along the coast on the northern part of the air-strip. The survey took place from the old abandoned cantilevers running southward past the Gabab Channel in the district of Boe. The channel is man-made and is used daily for launching of local fishing vessels. There is a recent reclaimed area just south of ODN Hotel that is used by locals for fishing. The coastal area comprised mostly of flat intertidal area that is exposed during low tides extending from the shoreline to approximate 200 meters (100 meters near the cantilevers and 200 meters towards the Gabab Channel). Surveys were undertaken mainly by wading (reef flat) and snorkeling (reef crest and slope).

SITE 2: ANABAR TO DENIGOMODU: (S 00.51208; E 166.95700)

The survey started opposite the mangrove swamp and continued for 5 km towards Aiwo District. The Anabar reef flat is shallow with beach rock along the high-intertidal area. Limestone pinnacles, scattered in the mid-intertidal area, are exposed during low tide. The reef flat extends seaward to about 300 meters. Tide was high during the survey with a strong current flow. The survey was done by wading, snorkeling and collecting beach cast. That site had good vegetation near the high-tide mark, interspersed with pinnacles. The water visibility was fairly poor close to shore, becoming clear in the mid to reef crest area.

SITE 3: AIWO TO YAREN. NORTH OF GABAB CHANNEL (BOE): S00.53968; E 166.91066.

The site is located about 200 meters north of the Gabab Channel. This is a man-made channel that is about 5 meters wide and extends seaward to around 60 m, and is used for local fishing and recreational boats.

SITE 4: IJUW TO ANABARE (PART) (S0051509'; E166.95816')

The survey for site 4 started from Ijuw and headed south to Anabare. The reef flat was exposed, and extends approximately 100 m wide from the foreshore. The high intertidal area comprised of beach rock. Calcium rock with jagged pinnacle lined the mid to low intertidal areas.

SITE 5: MENENG TO ANABARE

The survey was undertaken during low tide starting from Meneng to Anabare. This site had a limited diversity of habitats, however, some micro-habitats found that were created by burrowing animals provided refuges for some species including delicate alga *Hypnea, Caulerpa, Avrainvillea, Gelidium* and some corals *Pocillopora, Montipora* and *Acropora.*

Results

The surveys of the five sites revealed that most of the marine flora comprised of turf algae, comprising the four major algal groups (Chlorophyta – green, Ochrophyta – brown, Rhodophyta – red, Cyanophyta – blue-green). The composition of the flora, in particular the species were typical of new habitats, where turf algae are the dominant organisms. Over time turf-algae will be replaced by coralline algae, corals or macro-algae, but this is determined by reef conditions.

For the Nauru reef flats there was a lack of macro-organisms with corals being highly fragmented and scattered throughout the crevices. There was also a lack of macro-algal beds that are common in many other islands of the Pacific, such as *Sargassum* or *Turbinaria* beds. No seagrass was found during the surveys. Some macro-invertebrates (*Actinopyga mauritania, Echinothrix cf. diadema*) were found common throughout the reef flats.

Table 1. Dominant species found in Site 1 Aiwo Beach (ODN Hotel)

**Boergesenia forbesii*
**Ceramium flaccidum*
**Hypnea pannosa*
**Microdictyon cf. japonicum*
Padina minor
Valonia aegagropila

Table 2. Dominant species found Site 2 (Anabar-Frigate Point)

Flora
**Boergesenia forbesii*
Bryopsis pennata
**Ceramium flaccidum*
**Cladophoropsis* sp.
**Codium arabicum*
Dictyosphaeria cavernosa
**Dictyota friabilis*
Gelidiopsis intricata
**Hypnea pannosa*
Jania adhaerens
Padina minor
Peyssonnelia sp.
**Turbinaria decurrens*
Valonia aegagropila
Valonia utricularis

Fauna
Actinopyga mauritania
Conus ebraeus
Gymnothorax pictus
Haminoea cymbalum
Leptograpsus variegata
Thais tuberosa

Table 3. Dominant species found Site 3 (Aiwo-Yaren)

Flora
**Boergesenia forbesii*
Caulerpa racemosa
**Cladophoropsis sp. 1*
**Cladophoropsis sp. 2*
**Codium arabicum*
Codium bartayresiana
Dictyosphaeria cavernosa
Dictyosphaeria versluysii
**Dictyota friabilis*
**Hypnea pannosa*
**Hypnea spinella*
Padina cf. minor
Peyssonnelia sp.
**Ralfsia* sp.
**Ventricaria ventricosa*

Fauna
Arothrom meleagris (yellow)
Ascidian (white)
Cypraea Mauritania

Table 4. Dominant species found Site 4 (Ijuw-Anabare)

Flora	
Avrainvillea sp.	*Dictyosphaeria cavernosa*
**Boergesenia forbesii*	*Dictyosphaeria versluysii*
Bryopsis pennata	**Dictyota friabilis*
Caulerpa peltata	*Hincksia sp.*
Caulerpa racemosa	*Jania adhaerens*
Ceramium sp.	**Microdictyon sp.*
**Cyanophyta (brown web)*	*Padina minor*
	**Valonia fragilis*

Table 5. Dominant species found Site 5 (Meneng- Anabare)

Flora	Fauna
**Boergesenia forbesii*	*Acropora sp.*
Ceramium sp.	*Actinopyga mauritania*
**Cladophora* sp.	*Arothrom meleagris*
**Cladophoropsis clathrata*	*Echinothrix cf. diadema*
**Cladophoropsis sp.*	*Holothuria atra*
**Codium arabicum*	*Montipora sp.*
Dictyosphaeria versluysii	*Saccostrea* sp.
Dictyosphaeria cavernosa	*Pocillopora damicornis*
**Dictyota friabilis*	*Pocillopora sp.*
**Halimeda incrassata*	*Porite sp.*
Halimeda sp.	*Sponge (black/grayish)*
Jania adhaerens	*Tripneustis gratilla*
**Microdictyon cf. japonicum*	*Turbo argyrostomus*
**Microdictyon sp.*	*Turbo setosus*
Padina minor	*Zoanthid*
**Turbinaria decurrens*	

* = denotes new records

Discussion

GENERAL HEALTH OF THE REEF FLATS

The reef flats of Nauru are generally uniform throughout, lacking diversity in habitats. Turf algae and low-growing algae are the dominant groups, with seagrass being absent from the island. The narrow reef flats allow for daily flushing of warm water trapped in tide pools by cooler oceanic water. The topography of the reef flat was typified by mixed coastal vegetations towards the high intertidal zone, replaced by a narrow strip of fine sand grading to coral ruble and hard carbonate rock. Limestone pinnacles scattered throughout the reef flats rising up to 3 meters high in some places. Carbonate rock was the main substratum that extended from the mid-intertidal to the reef crest.

The low intertidal areas were dominated by either turf algae (*Jania adhaerens* and other rhodophytes) or cyanophytes (blue-green algae). Generally cyanophyte clumps were common adjacent to nutrient rich sources, such as the Meneng Hotel and infrastructures with phosphate activities near the main port. In other parts of the islands the low-intertidal zone was dominated by *Padina minor* and *Valonia aegagropila.*

The mid intertidal zone was dominated by green algae *Boergesina forbesii* and *Microdictyon cf. japonicum*. The area towards the reef crest was dominated by a mix of *Dictyosphaeria versluysii, Bryopsis pennata* and other turf rhodophytes. Some natural crevices are formed between the low intertidal (back reef) area and the reef crest, trapping water during low-tides. Some crevices were fairly large 3-5 meter diameter but shallow (1 meter depth). These tide pools provide refuge for algae, corals and other marine life. Two main species of Holothuria were found common – *Holothuria atra and Actinopyga mauritania* with the former being common from low to high intertidal areas. *Actinopyga* was found from mid-intertidal to reef crest. There were three dominant echinoderm species found on the reef flats – *Echinometra mathaei, Tripneustis gratilla, Echinothrix cf diadema.* Although *E. mathaei* was only seen in a few sites (Aiwo in particular).

Due to the shallow reef flats and the lack of lagoonal waters, live coral cover was fairly low in Nauru. In most sites, there were only a few isolated colonies. On the reef slope and to subtidal areas live coral cover probably fared better than that on the reef flats.

What is clear from the survey was the demarcation of zones by dominant algal distribution. The brown algae dominated high-intertidal areas. The mid-intertidal zone was dominated by green algae and red algae dominated the low inter-tidal zone. The reef crest and the back-reef were dominated by a mixture of red and green algae.

The dominant algal turf communities resemble a newly established habitat, where cyanophytes and rhodophytes are usually the first inhabitants. Over a period of time other turf algae including chlorophytes and brown algae would establish and replace some of the original flora. For Nauru, the flora is unlikely to change over time given the topography of the reef flats: the narrow width, high desiccation and exposure to natural elements (heat, light, tidal movement, heavy grazing and fluctuating salinity level) conspiring to favour turf and low-growing macro-algae.

These turf algal communities play a critical role in the overall health of Nauru's marine ecosystem. They are the backbone of the fishery of the island, providing food to grazers and other herbivores. They in turn are preyed upon by the larger fishes (Lutjanidae, Lethrinidae, Serranidae and Carangidae), which are target species for fishers.

MARINE FLORA

Nauru's marine flora is of low diversity largely due to its isolation and equatorial location, and lacking a donor source for its flora. The major current that could possibly facilitate the introduction of marine flora is the South Equatorial current running from east to west. The flora east of Nauru (e.g. Banaba and Kiribati) is unknown at this stage. The survey confirms the observation of South & Yen (1992) reporting that the Nauru flora being impoverished due to its small size, isolation and lack of habitat diversity.

Subtidal surveys undertaken by the BIORAP marine team, found significant areas covered by *Halimeda* sp. Especially at the reef slope. The largest macro-algae would be extensive beds of *Valonia* found along the reef flats, with the occasional *Turbinaria decurrens* and *Sargassum* sp.

Twenty new algal records were found during the survey bringing the total marine flora of Nauru to 58. It is possible that with further analysis of micro-algae (including epiphytic) that the flora will rise to around 80 species. This is still an impoverished flora compared to neighbouring islands (Solomon Islands, Marshall Islands and Kiribati).

MARINE INVASIVES

Introduced marine species were observed in many of the sites surveyed. These were mostly fouling organisms found on pilings and other man-made structures abandoned on the reef flats and slope. Perhaps the most concerning of the introduced species were the bearded fire-worms (*Hermodice carunculata*) abundant at the mid-intertidal area near Gabab channel. At the time of the survey, many families, especially with young children were playing in the area. The bearded fire-worms were up to 30 cm long, with iridescent red and white bristles along the side. The bristles are filled with venom that can easily penetrate the flesh producing a burning sensation.

Barnacles, hydroids, ascidians and sponges were other fouling organisms seen on the reef flats off the districts of Aiwo, Meneng and Anabare. Further studies including quantitative surveys for marine invasive species will need to be carried out and is highly recommended for these three districts.

Conservation Recommendations

The marine flora of Nauru, despite its low diversity in comparison to other equatorial and small islands in the Pacific, remains an important component of the fisheries sector in Nauru. The high number of herbivores and other grazers seen during high tide provide food for economically important fishes such as the Lutjanidae, Lethrinidae, Serranidae and

Carangidae. Efforts should be made to ensure that parts of the coastal area is managed to reduce negative impacts from developments. Some of the sites that could be considered worthy of protection include Anabar District, especially near the mangrove swamps, and districts of Ijuw to Anabare, where large pinnacles are found. Note that Anabare is also the site where the endemic *Corallocoreus nauruensis* was collected from.

The large amount of debris along the reef flat should also be managed and that concerted efforts to remove some of these is recommended. Awareness campaigns to reduce waste from being disposed directly into the sea or into Bauda lagoon and remnant swamps should also be considered.

References

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APPENDICES

Appendix 1 ANNOTATED CHECKLIST OF THE FLORA OF NAURU

1. FERNS AND FERN ALLIES

ASPLENIACEAE (Bird's-Nest Fern Family)

Asplenium nidus **L.** **bird's-nest fern**

Indigenous, widespread in the Old World tropics. This terrestrial and epiphytic fern was reported by Burges as an epiphyte on *Calophyllum inophyllum* in 1935, but has been seen only as an ornamental since then.

NEPHROLEPIDACEAE (Sword Fern Family)

Nephrolepis hirsutula **(Forst. f.) Presl** **sword fern**

Synonym: *Nephrolepis biserrata* sensu auct. non (Sw.) Schott.

Nauruan Name: **dageang** (a general name for ferns)

Indigenous or possibly a modern or ancient introduction, widespread in the Indo-Pacific. This terrestrial and sometimes epiphytic fern is occasional in mined areas and sunny forests.

OPHIOGLOSSACEAE (Adder's Tongue Fern Family)

Ophioglossum petiolatum **Hook.** **Adder's tongue fern**

Indigenous, widespread in the tropics. It is found as scattered individuals in sandy, open or partly shaded areas, primarily in older strip-mined areas on floors of pits between pinnacles. Because of its small size, it is difficult to spot, and was last seen on Nauru in dried mud puddle in the Nauru Phosphate Company compound in 1996.

POLYPODIACEAE (Common Fern Family)

Microsorum grossum **(Langsd. & Fisch.) S.B. Andrews** **scented fern, lawai fern**

Synonym: *Phymatosorus grossus* (Langsd. & Fisch.) Brownlie

Nauruan Name: **dageang ini Makin?**

Indigenous, widespread in the Old World tropics. It is a terrestrial and epiphytic fern found in colonies and dense populations in pinnacle forest and scrub and on escarpments and cliffs below the plateau.

PSILOTACEAE (Psilotum Family)

Psilotum nudum **(L.) Beauv.** **whisk fern**

Nauruan Name: **ibiribir?**

Indigenous, widespread in the tropics and subtropics. It occurs as scattered individuals and small clusters in shady areas under unmined vegetation on the central plateau and is uncommon under trees and shrubs on the escarpment. A single individual was seen but not collected during the present survey.

PTERIDACEAE (Sword Brake Family)

Pteris tripartita **Swartz** **sword brake**

Nauruan Name: **dageang** (a general name for ferns)

Indigenous, widespread in the Old World tropics. It is occasional in isolated clusters at the base of limestone cliffs of escarpments, and in waste places near cliff base, and in shady forest and along trails.

Pteris vittata **L.**

Nauruan Name: **dageang** (a general name for ferns)

Indigenous or possibly introduced, ranging in the Old World tropics and subtropics from Africa to Micronesia. It is uncommon in sunny or shady disturbed places, seen only a few times during the present survey.

2. MONOCOTS

AGAVACEAE (Agave Family)

Agave sisalana **L.** **sisal**

Modern introduction, native to Mexico. It is occasional in village gardens and has become established as an adventive in dense populations along edges of old strip-mined areas, where it spreads by means of vegetative bulbils.

Sansevieria trifasciata **Prain** **bowstring hemp, mother-in-law's tongue**

Modern introduction, native to tropical West Africa. It is occasionally planted as an ornamental, but has become adventive along roadsides in a few places, where it forms dense clumps.

ARECACEAE (Palm Family)

Cocos nucifera **L.** **coconut palm**

Nauruan Name: **ini**

Aboriginal introduction or indigenous to Nauru, originating somewhere in South Asia or the Indian Ocean Islands. It is planted extensively in the coastal zone, around Buada Lagoon, and near roads in strip-mined areas.

CYPERACEAE (Sedge Family)

Cyperus compressus **L.**

Modern introduction, widespread in the tropics and warm subtropics. It is occasional as a weed of disturbed places.

Cyperus iria **L.**

Modern introduction, native to somewhere in the Old World tropics. It is uncommon as a weed of wet disturbed places, seen only once during the present survey.

Cyperus rotundus **L.** **nut sedge, nut grass**

Nauruan Name: **ibugibugi** (a general name for grasses and sedges)

Modern introduction, now cosmopolitan in distribution. It is common to locally abundant as a weed of disturbed places, particularly in food garden areas.

Fimbristylis cymosa **R. Br.**

Nauruan Name: **ibugibugi** (a general name for grasses and sedges)

Indigenous, pantropical in distribution. It is common in open disturbed places, particularly in sandy coastal areas.

Kyllinga nemoralis **(Forst.) Dandy ex Hutchinson & Dalziel** **white-flowered kyllinga**

Modern introduction, native to somewhere in the Old World tropics. It is uncommon as a weed of disturbed places, especially in lawns, and seen only once during the present survey.

Mariscus javanicus **(Houtt.) Merr.**

Nauruan Name: **reyenbangabangā**

Indigenous, native to the Old World tropics into the Pacific islands. It is common in coastal areas, especially in wet places, such as around Buada Lagoon, and occasional in disturbed places such as pinnacle forest and scrub.

PANDANACEAE (Pandanus Family)

Pandanus tectorius **Warb.** **pandanus, screw pine**

Nauruan Name: **epo, biterr** (wild, uncultivated trees)

Indigenous (the wild type), widespread in the tropical Pacific islands. It is common in coastal areas in houseyard gardens, and less so inland. Most of the individuals on the island are cultivars of ancient and modern introduction that are cultivated for their edible fruits.

POACEAE (Grass Family)

Arundo donax L. — giant reed

Modern introduction, native to somewhere in the Old World tropics or subtropics. It is occasionally planted around yards, and appears to escape in places, such as in open areas near the end of the road on the top of Meneng Terrace. It is only marginally an adventive.

Axonopus compressus (Sw.) Beauv. — carpet grass

Modern introduction, native to tropical America. It is uncommon in disturbed places. It was

reported in 2007 in a "grass along driveway in houseyard garden in Buada," and was seen only once during the present survey in the same general location. It is commonly a lawn grass.

Bothriochloa bladhii (Retz.) S.T. Blake — blue grass, Australian beardgrass

Modern introduction, ranging from tropical Africa through India to China and Australia. It is a common, conspicuous grass in open lots, roadsides, and other disturbed places. This is possibly the grass referred to by Fosberg as *Andropogon* or *Dichanthium* sp. in the 1980s with no species further identification provided.

Brachiaria subquadripara (Trin.) Hitchc.
Brachiaria cf. *paspaloides* sensu auct. non (Presl) C.E. Hubb.

Modern introduction, native to tropical Asia, but now a pantropical weed. It is occasional as a weed of disturbed places, appearing to become more common in recent times.

Cenchrus echinatus L. — burgrass, sand bur

Nauruan Name: **eakung**

Synonyms: *Cenchrus brownii* sensu auct.; non R. & S.?, *Cenchrus ciliaris* auct. non L.

Modern introduction, native to tropical America. It is a common weed of disturbed places, particularly in coastal areas. It is a noxious species because of the sharp spines on its burs, which enable it to stick to clothing.

Chloris barbata (L.) Sw. — woolly finger grass

Synonym: *Chloris inflata* Link

Nauruan Name: **ibugibugi**

Modern introduction, native to tropical America. It is occasional and conspicuous as a weed of disturbed places, especially roadsides.

Chrysopogon aciculatus (Retz.) Trin. — golden beard grass

Modern introduction, native to Southeast Asia and into the Pacific. It is uncommon in disturbed places, often found as a lawn plant, but not seen during the present survey.

Cynodon dactylon (L.) Pers. — Bermuda grass

Nauruan Name: **ibugibugi** (a general name for grasses and sedges)

Modern introduction, native to somewhere in the Old World tropics or subtropics. It is occasional to common in disturbed places, often forming mats or lawns, especially just inland from the beach.

Dactyloctenium aegyptium (L.) Beauv. — beach wire grass

Modern introduction, native to somewhere in the Old World tropics. It is occasional as a weed in open disturbed habitats in coastal areas.

Dichanthium annulatum (Forssk.) Stapf

Synonym: *Dichanthium* sp. of Thaman et al. (2007)

Modern introduction, native to somewhere in the Old World tropics. It is common to abundant in open disturbed places, such as roadsides, and especially along the margins of the airport.

Dichanthium sp.?

Modern introduction, origin unknown. This grass was found growing along a trailside next to a pinnacle scrub area, and is a new record for Nauru.

Digitaria ciliaris **(Retz.) Koel.** **crab grass**

Modern introduction, native to tropical Asia. It is occasional as a weed in gardens, roadsides, and other disturbed places.

Digitaria fuscescens **(Presl) Henrard**

Modern introduction, native to somewhere in tropical Asia. It was found only once during the present survey, growing on open soil in a newly mined area (which was formerly a road). A new record for Nauru.

Digitaria setigera **Roth ex R. & S.** **slender crab grass**

Nauruan Name: **ibugibugi** (a general name for grasses and sedges)

Probably a modern introduction, ranging from Southeast Asia to eastern Polynesia (as a native or perhaps aboriginally introduced species). It is uncommon as a weed of disturbed places, especially in coastal areas, but was not found during the present survey.

Digitaria violascens **Link.** **violet crab grass**

Modern introduction, native to tropical Asia. It is rare as a weed of disturbed places near Buada Lagoon. It was not found during the present survey, and may be a misidentification (but the specimen, apparently stored at the Smithsonian Institution, was not seen by the authors).

Echinochloa colona **(L.) Link.** **jungle rice**

Modern introduction, native to India. It is occasional as a weed of gardens, roadsides and other disturbed sites.

Eleusine indica **(L.) Gaertn.** **goosegrass**

Nauruan Name: **ibugibugi** (a general name for grasses and sedges)

Ancient or old introduction, native to India, but long naturalized in Old and New World tropics. It is common roadsides and dirt road centers, waste places, and lawns.

Eragrostis brownii **(Michx.) Nees**

Synonym: *Eragrostis pectinacea* sensu auct. Non (Michx.) Nees

Modern introduction, native to the India or southern Asia. It is occasional in open places, along roadsides, and in other disturbed places.

Eragrostis tenella **(L.) Beauv. ex Roem. & Schult.** **lovegrass**

Nauruan Name: **ibugibugi** (a general name for grasses and sedges)

Modern introduction, native to somewhere in the Old World tropics. It is common as a weed around buildings, along paths and roadsides, and other disturbed places.

Eustachys petrea **(Sw.) Desv.**

Modern introduction, native to tropical America. It is occasional to common in disturbed areas on Nauru, and has rapidly and recently spread in Micronesia.

Lepturus repens **(Forst. f.) R. Br.**

Nauruan Name: **ibugibugi** (a general name for grasses and sedges)

Indigenous, native throughout the tropical Pacific Islands. It is common in strand vegetation and in disturbed open sites in coastal areas, and is the most common native grass species on the island.

Melinus repens **(Willd.) Zizka** **Natal red top**

Modern introduction, native to southern Africa. It is occasional in waste places in the central plateau area, less so in coastal areas.

Oplismenus hirtellus **(L.) Beauv.** **basket grass**

Modern introduction, native to the Old World tropics, but now pantropical in distribution. It is rare in open areas in the central plateau, where it was reported only once (1987), and was not found during the present survey.

Paspalum conjugatum **Berg.** **T-grass**

Modern introduction, native to tropical America. It is rare on Nauru, where is has been reported only once—on disturbed roadside along the road to Buada above the calcinations plant in 2007.

Paspalum setaceum **Michx.**

Modern introduction, native to Mexico and the southeastern U.S. It is rare in disturbed places on Nauru, where it was previously reported only once—in one location in the main settlement in Aiwo in 2007. Found only once during the present survey—along a trail in the central plateau leading across the pinnacle area.

Pennisetum polystachyon **(L.) Schult.** **mission grass**

Modern introduction, native to Central America and now widely naturalized in the tropics. It was reported to be occasional in a remnant unmined area near a road junction near active mining area in Anibare and the rehabilitation site north of the Topside running track. It is on the U. S. list of noxious weeds and has been declared a noxious weed in the Northern Territory of Australia. It was seen only once during the present survey.

Sporobolus diander **(Retz.) Beauv.** **Indian dropseed**

Modern introduction, native to Southern Asia. It is occasional as a weed of roadsides, waste places, and other disturbed areas, especially near the coast.

Stenotaphrum micranthum **(Desv.) Hubb.**

Nauruan Name: **ibugibugi** (a general name for grasses and sedges)

Indigenous, ranging from the Mascarenes in the Indian Ocean through Malaysia to eastern Polynesia and the Marshall Islands in Micronesia. It is occasional in littoral or coastal areas, and is easily mistaken for *Lepturus repens*.

Stenotaphrum secundatum **(Walter) Kuntze** **buffalo grass**

Modern introduction, native to tropical America. It is rare as a lawn grass on Nauru, where it was seen only once—in a village garden on Command Ridge in 2007. Not found during the present survey.

Thuarea involuta **(Forst. f.) R. Br. ex R. & S.**

Indigenous, native from Madagascar to Eastern Polynesia and Micronesia. It is rare on Nauru, where it was once reported in 2007 in a small population in the littoral zone just north of the Meneng Hotel. It may be an occasional arrival via ocean dispersal but soon disappears ("ephemeral").

PONTEDERIACEAE (Pickerel Weed Family)

Eichhornia crassipes **(Mart. & Zucc.) Solms-Laub.** **water hyacinth**

Modern introduction, native to tropical and subtropical America. It was noted to be an aquatic weed in Buada Lagoon, where it covered extensive areas in 2007, and is sometimes cultivated in tubs of water. Thaman et al. (2007) noted it was to be the target of a planned S.P.C. biological control program in the future, and was not found during the present survey.

TACCACEAE (Polynesian Arrowroot Family)

Tacca leontopetaloides **(L.) O. Kuntze** **Polynesian arrowroot**

Nauruan Name: **damagmag**

An ancient introduction or perhaps indigenous, native to somewhere in the Old World tropics. It was noted it to be occasional in old gardens and in escarpment forest in the 1980s, but has not been recorded on the island since then, and may now be extirpated.

3. DICOTS

ACANTHACEAE (Acanthus Family)

Asystasia gangetica **(L.) Anders.** **asystasia, Chinese violet**

Modern introduction, native to somewhere in the Old World tropics. It is occasional as an ornamental, and was seen to be naturalized in a few disturbed places during the present survey.

Blechum pyramidatum **(Lam.) Urb.**

Modern introduction, native to Peru. It is occasional as a weed in lawns, gardens, moist shady roadsides and other disturbed sites, especially around Buada Lagoon.

Ruellia prostrata **Poiret**

Modern introduction, native to Java. It is common to abundant as a weed of disturbed places, especially in partly shady native forests and *Leucaena* thickets. It was first recorded on Nauru in 2007, but has spread rapidly since its introduction, as it has in other Pacific islands.

Ruellia tuberosa **L.**

Modern introduction, native to tropical America. It was probably originally introduced to Nauru as an ornamental, but has escaped to be a weed of disturbed places in the coastal zone. A new record for Nauru.

AMARANTHACEAE (Amaranth Family)

Achyranthes canescens **R. Br.**

Indigenous, widespread in the central Pacific islnads, but probably now extirpated from Nauru. It was reported by Schumann (1888) to have been collected by Finsch, and reported to be present by Burges in 1933; but it has not been seen since. It probably disappeared because of loss of habitat (undisturbed littoral strand and scrub).

Alternanthera sessilis **(L.) R. Br. ex R. & S.** **joyweed**

Modern introduction, pantropical in distribution. It was reported to be rare as a garden weed in 1980 and again in 2007 in a coastal garden near the abandoned cantilever in Aiwo. It was not found during the present survey.

Amaranthus dubius **Mart. ex Thell.** **spleen amaranth**

Modern introduction, native to tropical America. It is occasional to uncommon as a weed of disturbed places, especially around houses.

Amaranthus spinosus **L.** **spiny amaranth, thorny amaranth**

Modern introduction, native to tropical America. It was reported in the early 1980s to be a weed in waste places and gardens, and occasionally cultivated in Chinese contract workers' but was not found in 2007 or during the present survey.

Amaranthus viridis **L.** **slender amaranth**

Modern introduction, native to the Old World tropics, but now a pantropical weed. It is occasional as a weed of disturbed places.

ANNONACEAE (Custard Apple Family)

Annona muricata **L.** **soursop**

Nauruan Name: **dowaitsip**

Modern introduction, native to tropical America. It is occasional in cultivation for it edible fruit, and sometimes escapes into native and secondary and native forest.

APOCYNACEAE (Dog-bane Family)

Neisosperma oppositifolium **(Lam.) Fosb. & Sachet**

Indigenous, native from the Philippines to Southeastern Polynesia and Micronesia. It is rare on Nauru, where it is known from a small stand of trees discovered in a clearing about 10 m up the escarpment on the west end of Anibare Bay by R. Thaman in 1996. However, it was not found by Thaman in 2007 nor during the present survey.

Ochrosia elliptica **Labill.**

Nauruan Name: **eoerara**

Indigenous, native to Australia and the Pacific Islands. It is uncommon in forest remnants on rocky outcrops on the central plateau, in escarpment forests on southern half of the island, and occasionally in home gardens in the coastal zone.

ASCLEPIADACEAE (Milkweed Family)

Asclepias curassavica **L.** **milkweed**

Nauruan Name: **dupaimdupwaim**

Modern introduction, native to tropical America. It is rare on Nauru, where it was probably originally planted as an ornamental. It subsequently escaped, but seems now to have disappeared because it has not been collected on Nauru during the last two surveys.

ASTERACEAE (Aster Family)

Ageratum conyzoides **L.** **goat weed, ageratum**

Nauruan Name: **bwiyat tsige** ("goat excrement")

Modern introduction, native to tropical America. It is uncommon in disturbed places, and was found only once during the present survey.

Bidens pilosa **L.** **beggar's-tick**

Synonym: *Bidens alba* sensu auct. non (L.) DC.?

Nauruan Name: **kauwen oe**

Modern introduction, native to tropical America. It is uncommon as a weed of disturbed places. It was noted to be seen only in the FAO experimental garden in the 2007 survey, and was found only once during the present survey. This may be what was reported by Thaman et al. (2008a) to have been collected on Nauru in 1980 and 1982, since the species are so similar.

Conyza bonariensis **(L.) Cronq.** **hairy horseweed**

Modern introduction, native to the Old World tropics, but now a pantropical weed. It is a common weed of disturbed places, being reported to be rare on Nauru and in the 1980s, but common in 2007.

Cyanthillium cinereum **(L.) H. Rob.** **iron weed, little iron weed**

Synonym: *Vernonia cinerea* (L.) Less.

Modern introduction, native to tropical Asia. It is occasional as a weed of disturbed places.

Eclipta prostrata **(L.) L.** **false daisy**

Modern introduction, native to tropical Asia, but now a pantropical weed. It is rare as a weed of disturbed places, and during the present survey it was found only once—in a greenhouse near Buada.

Emilia sonchifolia **(L.) DC.** **Flora's paintbrush**

Modern introduction, native to somewhere in the Old World tropics. It is rare as a weed of disturbed places, and was not found in 2007 or during the present survey.

Mikania micrantha **Kunth** **mile-a-minute vine**

Modern introduction, native to tropical America. It is rare as a weed of disturbed places, reported in 2007 "in garden area on the lagoonside of the road in northeast Buada." It was not found during the present survey.

Sphagneticola trilobata **(L. C. Rich) Pruski.** **wedelia**

Synonym: *Wedelia trilobata* (L.) Hitchc.

Modern introduction, native to Central America, Caribbean and northern South America. It is common to locally abundant as a weed of disturbed places, having originally been brought in as an attractive ornamental ground cover. It is probably the most invasive weed on the island, and is quite common around Buada Lagoon, but does not spread readily to new places since it does not produce fertile seeds.

Synedrella nodiflora **(L.) Gaertn.** **synedrella, nodeweed**

Modern introduction, native to tropical America, but now pantropical in distribution. It is uncommon as a weed of disturbed places, especially roadsides.

Tridax procumbens **L.** **wild daisy, coat buttons**

Modern introduction, native to tropical America. It is common as a weed of disturbed places, especially roadsides.

BARRINGTONIACEAE (Barringtonia Family)

Barringtonia asiatica **(L.) Kurz.** **fish-poison tree, barringtonia**

Nauruan Name: **kwenababai**

Indigenous, widespread and often dominant on beaches in the Indo-Pacific. It is occasional in coastal areas, especially on the lower portion of the escarpment, where it was probably one of the original dominant trees in this habitat.

BIGNONIACEAE (Bignonia Family)

Tecoma stans **(L.) H.B.K.** **yellow bells**

Modern introduction, native to tropical America. This ornamental shrub is common in cultivation for it showy yellow flowers, but sometimes escapes and spreads by means of its windborne seeds.

BORAGINACEAE (Heliotrope Family)

Cordia subcordata **Lam.** **cordia, kou (Hawaii)**

Nauruan Name: **eongo**

Indigenous, ranging from the Indian Ocean Islands to Hawaii. It is uncommon on beaches, and a single tree was reported in 2007 "in secondary forest near the top of the escarpment above the calcination plant." Only a single tree was found, on the coast, during the present survey.

Heliotropium procumbens **Mill.** **heliotrope**

Modern introduction, native to tropical America. It is common as a weed of roadsides, waste areas, and other disturbed places, apparently increasing in frequency in the last 30 years.

Tournefortia argentea **L. f.** **beach heliotrope**

Nauruan Name: **irin**

Indigenous, ranging from the Indian Ocean to southeastern Polynesia. It is occasional in coastal areas, often in flats behind beaches in remnant coastal littoral forest and *Scaevola* scrub. Several planted trees are found on Topside in Ewa District.

CAPPARIDACEAE (Caper Family)

Capparis cordifolia **Lam.** **oceanic caper**

Nauruan Name: **ekabobwiya**

Indigenous, ranging from the Solomon Islands northward to the Mariana Islands and eastward to southeastern Polynesia. It is occasional on cliffs, pinnacles and rock outcroppings in coastal areas.

Capparis quiniflora **DC.**

Indigenous, ranging from eastern Indonesia to Tonga and northward to Nauru. It is uncommon on pinnacles and cliffs, mostly near the coast.

Cleome rutidosperma **DC.** **blue cleome**

Modern introduction, native to west tropical Africa. It is a common weed of disturbed places.

Cleome viscosa **L.** **yellow cleome**

Modern introduction, native to tropical Asia or elsewhere in the Old World tropics. It is common to locally abundant as a weed of disturbed places.

CARICACEAE (Papaya Family)

Carica papaya **L.** **papaya, pawpaw**

Nauruan Name: **dababaiya**

Modern introduction, native to tropical America. It is a common fruit tree grown in gardens, and sometimes escapes and becomes naturalized in disturbed areas.

CASUARINACEAE (Casuarina Family)

Casuarina equisetifolia **L.** **casuarina, she oak, ironwood**

Nauruan Name: **tanenbaum** (German for Christmas tree), **Christmas tree**

Modern introduction, native to the Indian Ocean and into Oceania, but its natural distribution is hard to determine since it has become naturalized in places where it has been introduced in ancient times. It is sometimes planted in gardens or as a street tree, and has become naturalized in the pinnacle forest and scrub near the Topside workshops.

CHENOPODIACEAE (Goosefoot Family)

Atriplex nummularia **Lindl.** **Australian saltbush**

Modern introduction, native to Australia. It was reported to be on Nauru by 1916, but has apparently not been found there since then. Probably no longer found on the island.

CLUSIACEAE (Mangosteen Family)

Calophyllum inophyllum **L.** **Alexandrian laurel**

Nauruan Name: **iyo**

Indigenous, ranging from tropical Africa to eastern Polynesia and Micronesia. It was probably the dominant forest tree in the original coastal, cliff, and inland forests on Nauru, and typically still dominates in native forest remnants. It can dominate pinnacle forest, particularly if there is a seed source nearby (its large seed does not readily disperse).

COMBRETACEAE (Terminalia Family)

Terminalia catappa **L.** **tropical almond**

Nauruan Name: **etetö**

Indigenous, ranging from tropical Asia and Australia to western Polynesia and Micronesia. It is common tree in remnants of native forest on the cliffs, beaches, and Topside, where it often shares dominance with *Calophyllum inophyllum*.

CONVOLVULACEAE (Morning-Glory Family)

Ipomoea hederifolia **L.**

Modern introduction, native to tropical America. It is uncommon in disturbed places in coastal areas and Topside.

Ipomoea littoralis **Bl.**

Indigenous, ranging from Malaysia eastward to eastern Polynesia. It was first reported on Nauru in 1988, and was possibly later seen again but unsuccessfully photographed in a roadside

Scaevola thicket just north of the Anetan ponds (Thaman et al. 2007). This may be a mistaken identification for *Ipomoea triloba*.

Ipomoea pes-caprae **(L.) Sweet** **beach morning-glory**

Nauruan Name: **erekogo**

Indigenous, pantropical in distribution. It is locally abundant on undisturbed sandy beaches, and weedy inland in the central plateau, where its seeds may have been accidentally transported in sand used for roads. Also found along the margins of Buada Lagoon.

Ipomoea triloba **L.** **little bell**

Modern introduction, native to the West Indies. It is occasional in disturbed places, where climbs over other weedy vegetation. It was first reported on Nauru in 2007, and as on other Pacific islands, has spread rapidly.

Ipomoea violacea **L.** **wild moon flower**

Synonym: *Ipomoea macrantha* R. & S.

Nauruan Name: **erekogo**

Indigenous, pantropical in distribution. It is occasional in littoral, cliff, and less commonly central plateau forests, where it typically climbs into the canopy.

Merremia quinquifolia **(L.) Hall. f.**

Modern introduction, native to the West Indies. It was reported as a weed in one place in a semi-open area on the escarpment in 2007, but was not found during the present survey.

CRASSULACEAE (Stonecrop Family)

Kalanchöe pinnata **(Lam.) Pers.** **life plant**

Modern introduction, native to Indian Ocean Islands. It was probably originally brought to Nauru as an ornamental, but was noted to be "spreading around the water tank near Topside Workshop food gardens" in 2007. During the present survey, it was seen only once—growing down a hillside below houses.

CUCURBITACEAE (Melon Family)

Luffa cylindrica **(L.) Roem. var.** *insularum* **(A. Gray) Cogn.** **wild loofah**

Modern introduction, native to tropical Asia. Although the variety *insularum* seems to be

indigenous to many Pacific islands, it may have been introduced to Nauru, where it is uncommon in disturbed places.

Momordica charantia **L.** **bitter melon, balsam pear**

Modern introduction, native to the Old World tropics. It may have originally been introduced as a food plant because of its succulent, squash-like fruits, but is naturalized as an occasional weed of disturbed places.

EUPHORBIACEAE (Spurge Family)

Acalypha indica **L.**

Modern introduction, native to tropical Asia. It is rare as weed of disturbed places. A new record for Nauru, seen only once in Buada.

Chamaesyce chamissonis **(Kl. & Garcke) Garcke) F.C. Ho** **beach spurge**

Synonym: *Chamaesyce atoto* sensu auct. non (Forst. f) Croizat

Nauruan Name: **e mai** (Burges)

Indigenous, widespread in the tropical Pacific. It is rare on Nauru in littoral areas, either on rocks or growing in the sand. It was not found during the present survey.

Chamaesyce hirta **(L.) Millsp.** **garden spurge**

Modern introduction, native to tropical America but now a pantropic weed. It is very common weed of disturbed places, especially on roadsides and in agricultural areas.

Chamaesyce hypericifolia **(L.) Millsp.** **graceful spurge**

Modern introduction, native to tropical America. It is occasional to common as a weed of disturbed places, especially on roadsides and in agricultural areas.

Chamaesyce prostrata **(Ait.) Small** **prostrate spurge**

Modern introduction, native to tropical America. It is a common weed in disturbed areas, especially in cracks in concrete and along paths. It often appears to be replaced by the following species when the two occur together.

Chamaesyce thymifolia **(L.) Millesp.** **thyme-leafed spurge**

Modern introduction, native to tropical America. It is a common weed around buildings and the same kind of places as the above weed.

Euphorbia cyathophora **Murr.** **Mexican poinsettia**

Nauruan Name: **deriba, deribeh**

Modern introduction, native to tropical America. It is occasional as a weed of disturbed places, especially on roadsides, and was probably originally introduced as an ornamental because of its showy red bracts.

Euphorbia heterophylla **L.** **wild spurge**

Modern introduction, native to the Texas, Mexico and West Indian areas. It is occasional as a weed of disturbed places, especially roadsides.

Phyllanthus amarus **Sch. & Th.**

Syn. *Phyllanthus niruri* L. sensu auct. non L.

Modern introduction, native to tropical America (despite an African type locality). It is common to abundant of gardens, roadsides, and other disturbed places.

Phyllanthus societatis **M.A.**

Nauruan Name: **eoemangemang**

Indigenous, native to Polynesia and Micronesia. It is occasional in coastal limestone areas and in sunny inland areas, such as pinnacle scrub and open forest.

Ricinus communis **L.** **castor bean**

Modern introduction, native to Africa. It is rare as a weed of disturbed places. A single population was seen near the roadside to Buada above the calcination plant, where it was also reported in 2007.

FABACEAE (Pea Family)

Acacia farnesiana **(L.) Willd.** **West Indian blackthorn**

Nauruan Name: **katin?, debena?** (Burges)

Modern introduction, native to tropical America. It is uncommon as a weed of disturbed places, and during the survey was seen only in the same place as the preceding species.

Adenanthera pavonina **L.** **red-bead tree**

Nauruan Name: **bin** ("bean")

Modern introduction, native to Malaysia. It is an abundant and often nearly monodominant forest tree in disturbed forests, where it out-competes all other species. This quality makes it the most invasive and harmful plant species on Nauru. It was reported in 2007 that "an extensive almost monospecific forest is found on the inner unmined margins of the limestone escarpment inland from the north end of Anibare Bay where the Japanese stayed during World War II."

Alysicarpus vaginalis **(L.) DC.** **alysicarpus**

Modern introduction, native to the Old World tropics. It is common as a weed of disturbed places, such as roadsides and lawns, especially in areas that are periodically cut (since it grows prostrate and is not much affected by mowing).

Caesalpinia bonduc **Roxb.** **grey nicker**

Nauruan Name: **dogienae**

Indigenous, pantropical in distribution. It is uncommon in coastal and inland areas, where it can form dense thickets. These thickets are impenetrable because of the thorny nature of all parts of the plant. This makes is a noxious species that should be eradicated from settled areas.

Calopogonium mucunoides **Desv.** **calopo**

Modern introduction, native to tropical America. It is uncommon as a weed of disturbed places, perhaps originally introduced as a green manure and nitrogen-fixing plant, but now naturalized. Seen only once during the present survey—in Buada.

Canavalia cathartica **Thou.** **Mauna Loa bean (Hawaii)**

Nauruan Name: **erekogo**

Indigenous, pantropical in distribution. It is occasional in coastal and inland forests, where it climbs into the forest canopy, particularly in disturbed or open forests.

Canavalia rosea **(Sw.) DC.** **sea bean**

Nauruan Name: **erekogo**

Indigenous, pantropical in distribution. It is rare on Nauru, where it was found in beach vegetation north of Gabab Channel in 1981. Not seen since.

Centrosema pubescens **Benth.**

Modern introduction, native to tropical South America. It is rare as a weed of disturbed places, and was reportedly introduced in 1935, but not seen in 1978 or thereafter until 2007, when a large population was seen growing in an open disturbed area on the lower escarpment in Boe District near the Aiwo border. This widely used pasture legume and nitrogenous cover or green manure crop species was not found during the present survey. Sometimes misspelled *Centrosoma*.

Chamaecrista nictitans **(L.) Moensch.** **partridge pea**

Modern introduction, native to tropical America. It is rare in disturbed places on Nauru, where it was found in 2007 long the road above and to the south of Buada forest. It was not found during the present survey.

Crotalaria goreensis **Guitl. & Pers.** **rattlepod**

Modern introduction, native to West Africa. It is common as a weed of disturbed places, especially of roadsides.

Crotalaria retusa **L.** **rattlepod**

Modern introduction, native to tropical Asia. It is rare as a weed of disturbed places, and was not found during the present survey, and perhaps not since 1980.

Derris trifoliata **Lour.** **beach derris**

Synonym: *Derris uliginosa* Benth.

Indigenous, ranging from tropical Africa to Polynesia. It is uncommon in coastal forest and on cliffs and steep slopes of the coastal escarpment. It was not seen in the 2007 survey, and was found only once during the present survey.

Desmodium incanum **DC.** **Spanish clover**

Modern introduction, native to the west Indies. It is common as a weed of disturbed places, especially on roadsides, where it readily spreads by means of its sticky fruits that adhere to clothing.

Desmodium scorpiurus **(Sw.) Desv.**

Synonym: "Desmodium sandwichensis???" of Thaman et al. (2007)

Modern introduction, native to tropical America. It is uncommon as a weed of disturbed places, but is sometimes locally common, especially around Buada Lagoon.

Desmodium tortuosum **(Sw.) DC.** **Florida beggarweed**

Modern introduction, native to the West Indies and Central America. It is common as a weed of disturbed places, especially in cultivated areas and villages.

Desmodium triflorum **(L.) DC.** **three-flowered beggarweed**

Modern introduction, native to somewhere in the Old World tropics. It is common in disturbed places, especially in lawns and along roadsides, where it forms prostrate mats.

Erythrina variegata **L.** **coral tree**

Nauruan Name: **eora**

Indigenous, widespread from Zanzibar to eastern Polynesia. It is uncommon in coastal areas, sometimes appearing to be part of the native littoral forest, but possibly sometimes planted as an ornamental because of it showy seasonal flowers.

Indigofera hirsuta **L.** **hirsute indigo**

Synonym: *Indigofera spicata* sensu auct. non Forssk.

Modern introduction, native to somewhere in the Old World tropics. It is uncommon in disturbed places in the central plateau, where it was seen only twice during the present survey.

Leucaena leucocephala **(Lam.) de Wit** **Caribbean tamarind**

Nauruan Name: **bin** ("bean")

Modern introduction, native to the Caribbean area. It is common in disturbed areas, especially on roadsides, where it often forms dense thickets.

Mimosa pudica **L.** **sensitive plant**

Modern introduction, native to tropical America. It is uncommon as a weed of disturbed places, especially in the Buada area. It was seen only once during the present survey.

Senna occidentalis **(L.) Link** **coffee senna**

Nauruan Name: **tan braua** ("sunflower")

Modern introduction, native to tropical America. It is common as a weed of disturbed places, especially roadsides and agricultural areas.

Sophora tomentosa **L.** **beach silverbush**

Indigenous, widely ranging from the Indian Ocean to eastern Polynesia and Micronesia. It is rare in littoral areas, and the 2007 survey noted that only a single individual was seen in the coastal strand vegetation about 10 m from the outpost zone about 100 m north of the Meneng Hotel, and two seedlings in the outpost zone among drift seedlings on the beach to the east of the east end of the runway. It appears to be an ephemeral species that periodically appears on Nauruan beaches, lives for awhile, then dies and disappears.

Vigna marina **(Burm.) Merr.** **beach pea**

Nauruan Name: **erekogo**

Indigenous, pantropical in distribution. It is common on sandy beaches, where it, along with the beach morning-glory *Ipomoea pes-capre*, typically comprise the dominant species in the creeping beach vegetation.

GOODENIACEAE (Naupaka Family)

Scaevola taccada **(Gaertn.) Roxb.** **scaevola**

Nauruan Name: **emet**

Indigenous, widely ranging from tropical Asia to Hawaii. It is very abundant on rocky and sandy beaches, often being the dominant species in strand vegetation, and is also one of the first colonizers on strip-mined areas.

HERNANDIACEAE (Hernandia Family)

Hernandia nymphaeifolia **(Presl.) Kubitzki Chinese lantern tree**

Nauruan Name: **etiu**

Indigenous, widely ranging from tropical Asia to the Pacific islands. It is rare in coastal areas, and perhaps was a dominant or at least a common tree in the original littoral forest. The 2007 survey reported it forming "a large stand of over ten trees behind a house in Ijuw District near the border of Anibare District and near the bottom of the escarpment behind Capelli's store," and this is the only place it was found during the present survey.

LAMIACEAE (Mint Family)

Hyptis rhomboidea **Mart. & Gal.** **rhomboid mintweed**

Modern introduction, native to tropical America. It was first recorded in the Pacific from Guam prior to 1970, but has recently spread to many other islands. It is rare on Nauru, and was reported in a "single population seen in a disturbed roadside site above the decalcination plant on the road to Buada lagoon." Not seen during the present survey,and perhaps extirpated from Nauru.

LAURACEAE (Laurel Family)

Cassytha filiformis **L.** **beach dodder** **Nauruan Name: denuwenini**

Indigenous, pantropical in distribution. It is common in coastal areas, where it is a parasite on other plants, found generally in sunny natural vegetation at all elevations in coastal areas, the central plateaux, and occasionally in mined areas.

MALVACEAE (Mallow Family)

Abutilon asiaticum (L.) Sweet — Asian mallow

Nauruan Name: **ekaura, inen ekaura**

It is probably a modern or ancient introduction, native from Southeast Asia to the Pacific islands. It is occasional as a weed of waste places in the coastal zone, and along trails and among pioneering weeds in topsoil in areas recently cleared for phosphate mining in the central plateau. Some authors consider this to be a native species, but it does not occur in undisturbed native habitats, indicating a more likely alien status.

Hibiscus tiliaceus L. — beach hibiscus

Nauruan Name: **wone**

Indigenous, pantropical in distribution. It is abundant in thickets and forests of the escarpment on the central plateau, on the inner and outer edges of coastal strip, and in areas surrounding mangrove swamps. It may be an ancient introduction, however, since seedlings are virtually unknown (meaning it would have to be carried to the island).

Malvastrum coromandelianum (L.) Garcke — false mallow

Modern introduction, native to Central America and the southern United States (despite its scientific name, which would indicate it is from India). It is occasional as a weed of disturbed places.

Sida acuta Burm. f. — broom weed

Synonym: *Sida spinosa* sensu auct. non L.?

Modern introduction, native to tropical America but now a pantropical weed. It is occasional as a weed of disturbed places. It is likely that references to *Sida spinosa* being on the island in 1980 are a mistaken identification for this similar looking species.

Sida fallax Walp. — golden mallow, ilima (Hawaii)

Nauruan Name: **ekaura, idibin ekaura**

Indigenous, native to the Indo-Pacific eastward to Hawaii. It was reported to be found in disturbed places in the coastal zone cleared recently for phosphate mining in the 1980s and 1990s, but it has not been seen since then and has probably been extirpated from Nauru.

Sida rhombifolia L. — Cuba jute

Nauruan Name: **coffee bush, itsi** ("tea")

Modern introduction, native to somewhere in tropical America, but now pantropic as a weed. It is a common weed of disturbed places, especially along roadsides.

Thespesia populnea (L.) Sol. ex Correa — Pacific rosewood

Nauruan Name: **itira**

Indigenous, widespread in the Old World tropics. It is occasional in coastal areas, especially along the along the coastal margins of mangroves in Anetan and in a number of coastal sites in Meneng and Aiwo.

MELIACEAE (Mahogany Family)

Melia azedarach L. — Persian lilac

Nauruan Name: **gadong**

Modern introduction, native to tropical Asia. It is occasionally planted as an ornamental, and sometimes escapes into pinnacle scrub and forest.

MORACEAE (Mulberry Family)

Ficus prolixa **Forst. f.** **Pacific banyan**

Nauruan Name: **eaeo**

Indigenous, ranging from New Caledonia and Micronesia to southeastern Polynesia. It is one of the most abundant trees in remnant forests, especially on escarpments as well as on the pinnacles, because it can grow out of limestone rock. In areas some areas of native forest it dominates the limestone surfaces, but tropical almond (*Terminalia catappa*) and Alexandrian laurel (*Calophyllum inophyllum*) dominate the areas of soil between the rocks.

MYRTACEAE (Myrtle Family)

Psidium guajava **L.** **guava**

Nauruan Name: **kowawa**

Modern introduction, native to Tropical America. It is occasionally planted as a fruit tree, and commonly becomes naturalized in disturbed areas.

NYCTAGINACEAE (Four-O'clock Family)

Boerhavia acutifolia **(Choisy) J.W. Moore**

Synonym: *Boerhavia repens* sensu auct. non L.

Possibly an ancient introduction to Nauru, or perhaps indigenous, widespread in the Pacific. It is most often found as a weed of rocky places in villages, especially around houses, which supports the notion that it has been introduced to to the island.

Boerhavia coccinea **Mill.**

A modern introduction, native to California and parts of the USA, but recently spreading in the Pacific islands. It is a common weed of roadsides and other disturbed areas. Although a new record for Nauru, it was probably lumped with the similar looking previous species in earlier surveys.

Pisonia grandis **R. Brown** **pisonia**

Nauruan Name: **yangis**

Indigenous, widespread throughout the Indo-Pacific. It is an uncommon tree usually found on the escarpments, especially along the crest of the escarpment above the northern portion of Anibare. It was probably more common in the original Nauruan forest, but has decreased in importance since then.

ONAGRACEAE (Evening Primrose Family)

Ludwigia octovalvis **(Jacq.) Raven** **willow primrose**

Synonym: *Ludwigia hyssopifolia* sensu Thaman et al. (2007); non (G. Don) Excell

Modern introduction, native to tropical or subtropical America including the Southern USA. It is occasional in wet places, such as in swampy areas bordering mangroves in Meneng, and reportedly around Buada Lagoon in 2007.

OXALIDACEAE (Wood Sorrel Family)

Oxalis corniculata **L.** **wood-sorrel**

Modern or perhaps an ancient introduction (as it is in Polynesia), first reported by Schumann and Lauterbach (1901) as collected by Finsch. It was noted in 1980 to be a weed at "MQ 40 Command Ridge," but has apparently not been collected on Nauru since then.

PASSIFLORACEAE (Passion Flower Family)

Passiflora foetida **L.** **love-in-a-mist**

Modern introduction, native to tropical America. It is uncommon to occasional as a weed of disturbed places, especially in thickets and along roadsides.

PIPERACEAE (Pepper Family)

Peperomia pellucida **(L.) H.B.K.** **peperomia**

Modern introduction, native to tropical America. It is rare of as a weed of potted plants and shady moist areas around homes, and was not seen during the present survey.

POLYGALACEAE (Polygala Family)

Polygala paniculata **L.** **bubblegum plant**

Modern introduction, native to tropical America. It is rare as a weed of disturbed places. It was not found during the 2007 survey, and only once during the present survey—along an inland trail leading from the Australian High Commission inland across the pinnacle areas.

POLYGONACEAE (Buckwheat Family)

Antigonon leptopus **Hook. and Arn.** **Mexican creeper**

Modern introduction, native to Mexico. It is occasional as a weed of disturbed places, but where it does occur, it tends to spread out to cover adjacent vegetation to form almost mono-dominant stands. It is sometimes considered to be a noxious weed, but it does not readily spread from place to place.

PORTULACACEAE (Purslane Family)

Portulaca oleracea **L.** **pig weed, purselane**

Nauruan Name: **doboiy**

Modern introduction, of uncertain origin but now cosmopolitan. It is occasional as a weed of disturbed places, especially in coastal areas and gardens.

RHAMNACEAE (Buckthorn Family)

Colubrina asiatica **(L.) Brongn.** **soapbush**

Nauruan Name: **ewongup**

Indigenous, native to somewhere in the Old World tropics. It is a common shrub in coastal and sometimes inland areas, sometimes forming thickets on the shore or along inland roadsides.

RHIZOPHORACEAE (Mangrove Family)

Bruguiera gymnorrhiza **(L.) Lam. f.** **Oriental mangrove**

Nauruan Name: **etõm**

Indigenous, native to the Indo-Pacific eastward to Samoa. It is known only from the edges of ankaline ponds at Meneng, Anabar, Ijuw and Anetan Districts (lake in Anabar known as Araro), although it was reported to be present around the main Buada Lagoon in the past.

Rhizophora stylosa **Griff.** **mangrove**

Nauruan Name: **dadongo**

Indigenous, native to the Indo-Pacific eastward to Tonga. It is reported to be localized in a small population in the inner part of a system of brackish lakes or lagoons near the base of escarpment in Ijuw, where it was first identified in 1996. It was not seen during the present survey, but a single tree was reported by informants to still grow in that area.

RUBIACEAE (Coffee Family)

Aidia racemosa **(Cav.) Trivengadum**

Nauruan Name: **enga**

Indigenous, ranging from tropical Asia to western Polynesia. It is rare on Nauru, where a small population of a few individuals was seen in a single location on a seaside escarpment terrace just below the main ridge above Anibare Bay in 2007. It was not found during the present survey.

Dentella repens **Forst.** **dentella**

Modern introduction, native to Melanesia, perhaps to New Caledonia, but now widespread as a weed. It is rare on Nauru, where it was reported in 2007 to be seen in a parking lot outside Rehabilitation Building, and was seen (but not collected) only once during the present survey.

Guettarda speciosa **L.** **guettarda**

Nauruan Name: **iut**

Indigenous, ranging from tropical Asia to the eastern Polynesia. It is occasional to common in native forest in coastal areas and in the interior.

Morinda citrifolia **L.** **Indian mulberry, noni (Hawai'i)**

Nauruan Name: **deneno**

Indigenous, widespread from tropical Asia to Polynesia. It is a common shrub or small tree of disturbed places and an understory tree in remnants of native forest, and is one of the first shrubs occupying pinnacle scrub.

Oldenlandia corymbosa **L.**

Synonym: *Hedyotis corymbosa* (L.) Lam.

Modern introduction, native from tropical and subtropical Asia eastward to India. This delicate weed has recently spread through the Pacific islands, and is occasional as a weed of disturbed places on Nauru.

Spermacoce assurgens **R. & P.** **buttonweed**

Modern introduction, native to southern Asia. It is a common weed of disturbed places, especially along roadsides.

Spermacoce bartlingiana **(DC.) Fosb.**

Modern introduction, native to southern Asia. It is uncommon to occasional as a weed of disturbed places.

SAPINDACEAE (Soapberry Family)

Dodonaea viscosa **(L.) Jacq.**

Nauruan Name: **eteweo**

Indigenous, pantropical in distribution. It is common in scrubby vegetation on the recently mined areas, but tends to disappear with time when a forest canopy shades it out.

SCROPHULARIACEAE (Snapdragon Family)

Bacopa procumbens **(Mill.) Greenm.**

Modern introduction, native to tropical America. It is rare as a weed in lawns and disturbed places, but is apparently known from a single collection in 1980. Possibly extirpated from Nauru.

Scoparia dulcis **L.**

Modern introduction, native to tropical America. It is occasional as a weed of disturbed places, especially around houses and on roadsides.

SOLANACEAE (Nightshade Family)

Physalis angulata **L.** **wild Cape-gooseberry**

Synonym: *Physalis lagascae* sensu auct. non R. & S.?

Nauruan Name: **watamo**

Modern introduction, native to tropical America. It is occasional as a weed of disturbed places. The name *Physalis lagascae* used in 2007 may refer to this species.

STERCULIACEAE (Cocoa Family)

Waltheria indica **L.** **waltheria**

Synonym: *Waltheria americana* L.

Modern introduction, probably native to tropical America, and interestingly, possibly Hawai'i, but now found as a weed throughout the tropics. It is occasional to common on Nauru as a weed of disturbed places, especially roadsides.

SURIANACEAE (Quassia Family)

Suriana maritima **L.**

Indigenous, pantropical in distribution. It is a rare as a littoral shrub, where it was seen as a small drift seedling in 1981, but has not been seen since. It probably no longer occurs on Nauru, being an "ephemeral" species.

TILIACEAE (Linden Family)

Muntingia calabura **L.** **Panama cherry**

Nauruan Name: **bin** ("bean")

Modern introduction, native to tropical America. It was probably originally introduced to Nauru as a minor fruit tree, but has escaped to be occasional weed in disturbed areas.

Triumfetta procumbens **Forst. f.** **beach burr**

Synonym: *Triumfetta semitriloba* sensu Burges (1935); non Jacq.?

Nauruan Name: **ikiao** (Burges, 1935)

Indigenous, widespread in the Old World tropics. It is rare on Nauru, where it was reported to be growing along coastal strip and in open areas in coastal thickets in the 1980s. It was reported in a seaside garden in 1996, but has not been seen since.

TURNERACEAE (Turnera Family)

Turnera ulmifolia **L.** **yellow alder**

Nauruan Name: **linkbelt**

Modern introduction, native to Mexico and the Caribbean to northern South America. It was originally introduced as an ornamental because of its showy yellow flowers, but has escaped and is now found in several places as a minor weed.

URTICACEAE (Nettle Family)

Laportea ruderalis **(Forst. f.) Chew**

Indigenous, ranging from Malaysia to the Pacific islands. It is uncommon on coastal limestone rocks and in shady areas near caves and in moist habitats at the base of the limestone escarpment.

Pilea microphylla **(L.) Liebm.** **artillery plant**

Modern introduction, native to tropical America. It is occasional as a weed of disturbed places, such as in cracks in pavement or sidewalks and in potted plants.

VERBENACEAE (Verbena Family)

Clerodendrum inerme **L.**

Nauruan Name: **eamwije**

Indigenous, native from Malaysia to the Pacific Islands. It is abundant in coastal areas as a shrub that often leans over other vegetation, and is occasionally a planted ornamental because of its showy flowers.

Lantana camara **L.** **lantana**

Nauruan Name: **magiroa**

Modern introduction, native to tropical America. It was probably introduced to Nauru as an ornamental, but has become naturalized as an escape in some disturbed places.

Phyla nodiflora (L.) E. Greene

Modern introduction, native to warm-temperate America. It is rare as a weed of disturbed areas in the coastal zone, where it was first reported in 2007. It was not found during the present survey.

Premna serratifolia L. premna

Nauruan Name: **idibiner**

Indigenous, widespread from the Indian Ocean to eastern Polynesia. . It is a common tree in the coastal zone, escarpment forest, scrubland, and in the understorey or old coconut plantations, but does not persist in shady forest.

Stachytarpheta cayennensis (Rich.) Vahl blue rat's-tail

Synonyms: *Stachytarpheta urticaefolia* sensu auct. non (Salisbury) Sims; *Stachytarpheta dichotoma* sensu auct. non (Ruiz & Pav.) Vahl (referring to a white flowered variety of this species)

Nauruan Name: **edidubai**

A modern introduction, native to tropical America. It is a common weed of disturbed places, especially along roadsides.

Stachytarpheta jamaicensis (L.) Vahl Jamaica vervain

Nauruan Name: **edidubai**

Modern introduction, native to tropical America. It was first reported to be present by Burges in 1935, but not seen again until 2007, when seen in a small population in an open field northeast of the hospital. It was seen several times during the present survey, and is sometimes confused with the previous species.

Vitex trifolia L. blue vitex

Nauruan Name: **dagaidu**

Indigenous, native from east Africa to the Pacific Islands. It is occasional in the coastal zone and in low-lying areas near base of escarpment and in some home gardens.

Appendix 2 CHECKLIST OF THE FLORA OF NAURU WITH VOUCHER SPECIMENS

Family	Species	Authors	Status1	Voucher	Nauruan Names
ASPLENIACEAE	*Asplenium nidus*	L.	I		
NEPHROLEPIDACEAE	*Nephrolepis hirsutula*	(Forst. f.) Presl	I?	13058	(dageang)
OPHIOGLOSSACEAE	*Ophioglossum petiolatum*	Hook.	I?		
POLYPODIACEAE	*Microsorum grossum*	(Langsd. & Fisch.) S.B. Andrews	I	13059	dageang ini Makin (?)
PSILOTACEAE	*Psilotum nudum*	(L.) Beauv.	I	(seen)	ibiribir?
PTERIDACEAE	*Pteris tripartita*	Swartz	I	13057	(dageang)
	Pteris vittata	L.	I?	13100	(dageang)
AGAVACEAE	*Agave sisalana*	L.	X	(seen)	
	Sansevieria trifasciata	Prain	X	(seen)	
ARECACEAE	*Cocos nucifera*	L.	I?	(seen)	ini
CYPERACEAE	*Cyperus compressus*	L.	X	13127	
	Cyperus iria	L.	X	13146	
	Cyperus rotundus	L.	X	13129	
	Fimbristylis cymosa	R. Br.	I	13156	
	Kyllinga nemoralis	(Forst.) Dandy ex Hutch. & Dalziel	X	13053	
	Mariscus javanicus	(Houtt.) Merr.	I	13106	reyenbangabangā
PANDANACEAE	*Pandanus tectorius*	Warb.	I	(seen)	epo, biterr
POACEAE	*Arundo donax*	L.	X	(seen)	
	Axonopus compressus	(Sw.) Beauv.	X	(seen)	
	Bothriochloa bladhii	(Retz.) S.T. Blake	X	13032	
	Brachiaria subquadripara	(Trin.) Hitchc.	X	13021	
	Cenchrus echinatus	L.	X	13120	eakung
	Chloris inflata	Link	X	13121	(ibugibugi)
	Chrysopogon aciculatus	(Retz.) Trin.	X		
	Cynodon dactylon	(L.) Pers.	X	13149	(ibugibugi)
	Dactyloctenium aegyptium	(L.) Beauv.	X	13119	
	Dichanthium annulatum	(Forssk.) Stapf	X	13123	
	Dichanthium **sp.?**		X	13143	
	Digitaria ciliaris	(Retz.) Koel.	X	13043	
	Digitaria fuscescens	(Presl) Henrard	X	13113	
	Digitaria setigera	Roth ex R. & S.	X		(ibugibugi)
	Digitaria violascens	Link	X		
	Echinochloa colona	(L.) Link	X	13147	
	Eleusine indica	(L.) Gaertn.	X	13128	(ibugibugi)
	Eragrostisbrownii	(Kunth) Nees in H. & A.	X	13062	
	Eragrostis tenella	(L.) Beauv. ex Roem. & Schult.	X	13118	(ibugibugi)
	Eustachys petrea	(Sw.) Desv.	X	13061	

Family	Species	Authors	Status1	Voucher	Nauruan Names
	Lepturus repens	(Forst. f.) R. Br.	I	13158	(ibugibugi)
	Melinus repens	(Willd.) Zizka	X	13116	
	Oplismenus hirtellus	(L.) Beauv.	X		
	Paspalum conjugatum	Berg.	X		
	Paspalum setaceum	Michx.	X	13094	
	Pennisetum polystachion	(L.) Schult.	X	13114	
	Sporobolus diander	(Retz.) Beauv.	X	13145	
	Stenotaphrum micranthum	(Desv.) Hubb.	I	13142	
	Stenotaphrum secundatum	(Walter) Kuntze	X		
	Thuarea involuta	(Forst. f.) R. Br. ex R. & S	I		
PONTEDERIACEAE	*Eichhornia crassipes*	(Mart. & Zucc.) Solms-Laub.	X		
TACCACEAE	*Tacca leontopetaloides*	(L.) O. Kuntze	X?		damagmag
ACANTHACEAE	*Asystasia gangetica*	(L.) Anders.	X	13088	
	Blechum pyramidatum	(Lam.) Urb.	X	13046	
	Ruellia prostrata	Poir.	X	13124	
	Ruellia tuberosa	L.	X	13035	
AMARANTHACEAE	*Achyranthes canescens*	R. Br.	I		
	Alternanthera sessilis	(L.) R. Br. ex R. & S.	X		
	Amaranthus dubius	Mart. ex Thell.	X	13026	
	Amaranthus spinosus	L.	X		
	Amaranthus viridis	L.	X	13039	
ANNONACEAE	*Annona muricata*	L.	X	(seen)	dowaitsip
APOCYNACEAE	*Neisosperma oppositifolium*	(Lam.) Fosb. & Sachet	I		
	Ochrosia elliptica	Labill.	I	13099	eoerara
ASCLEPIADACEAE	*Asclepias curassavica*	L.	X		dupaimdupwaim
ASTERACEAE	*Ageratum conyzoides*	L.	X	13107	bwiyat tsige
	Bidens pilosa	L.	X	13153	kauwen oe
	Conyza bonariensis	(L.) Cronq.	X	13063	
	Cyanthillium cinereum	(L.) H. Rob.	X	13037	
	Eclipta prostrata	(L.) L.	X	13110	
	Emilia sonchifolia	(L.) DC.	X		
	Mikania micrantha	Kunth	X		
	Sphagneticola trilobata	(L. C. Rich.) Pruski	X	13044	
	Synedrella nodiflora	(L.) Gaertn.	X	13122	
	Tridax procumbens	L.	X	13125	
BARRINGTONIACEAE	*Barringtonia asiatica*	(L.) Kurz	I	13098	kwenababai
BIGNONIACEAE	*Tecoma stans*	(L.) H.B.K.	X	13133	
BORAGINACEAE	*Cordia subcordata*	Lam.	I	13096	eongo

Family	Species	Authors	Status1	Voucher	Nauruan Names
	Heliotropium procumbens	Mill.	X	13072	
	Tournefortia argentea	L. f.	I	13075	irin
CAPPARIDACEAE	*Capparis cordifolia*	Lam.	I	13104	ekabobwiya
	Capparis quiniflora	DC.	I	13082	
	Cleome rutidosperma	DC.	X	13027	
	Cleome viscosa	L.	X	13030	
CARICACEAE	*Carica papaya*	L.	X	(seen)	dababaiya
CASUARINACEAE	*Casuarina equisetifolia*	L.	X	13151	tanenbaum
CHENOPODIACEAE	*Atriplex nummularia*	Lindl.	X		
CLUSIACEAE	*Calophyllum inophyllum*	L.	I	13112	iyo
COMBRETACEAE	*Terminalia catappa*	L.	I	13083	etetö
CONVOLVULACEAE	*Ipomoea hederifolia*	L.	X	13079	
	Ipomoea littoralis	Bl.	I		
	Ipomoea pes-caprae	(L.) R. Br.	I	13023	erekogo
	Ipomoea triloba	L.	X	13092	
	Ipomoea violacea	L.	I	13076	erekogo
	Merremia quinquifolia	(L.) Hall. f.	X		
CRASSULACEAE	*Kalanchoë pinnata*	(Lam.) Pers.	X	13157	
CUCURBITACEAE	*Luffa cylindrica*	(L.) Roem.	X?	13091	
	Momordica charantia	L.	X	13130	
EUPHORBIACEAE	*Acalypha indica*	L.	X	13028	
	Chamaesyce chamissonis	(Kl. & Garcke) F.C. Ho	I		e mae
	Chamaesyce hirta	(L.) Millsp.	X	13050	
	Chamaesyce hypericifolia	(L.) Millsp.	X	13036	
	Chamaesyce prostrata	(Ait.) Small	X	13071	
	Chamaesyce thymifolia	(L.) Millesp.	X	13148	
	Euphorbia cyathophora	Murr.	X	13031	
	Euphorbia heterophylla	L.	X	13077	
	Phyllanthus amarus	Sch. & Th.	X	13111	
	Phyllanthus societatis	Muell. Arg.	I	13034	eoemangemang
	Ricinus communis	L.	X	13117	
FABACEAE	*Acacia farnesiana*	(L.) Willd.	X	13131	katin?, debena?
	Adenanthera pavonina	L.	X	13155	bin
	Alysicarpus vaginalis	(L.) DC.	X	13144	
	Caesalpinia bonduc	Roxb.	I	13085	dogienae
	Calopogonium mucunoides	Desv.	X	13140	
	Canavalia cathartica	Thou.	I	13074	erekogo
	Canavalia rosea	(Sw.) DC.	I		erekogo
	Centrosema pubescens	Benth.	X		
	Chamaecrista nictitans	(L.) Moensch.	X		

Family	Species	Authors	Status1	Voucher	Nauruan Names
	Crotalaria goreensis	Guill. & Perr.	X	13055	
	Crotalaria retusa	L.	X		
	Derris trifoliata	Lour.	I	13103	
	Desmodium incanum	DC.	X	13134	
	Desmodium **cf.** *scorpiurus*	(Sw.) Desv.	X	13047	
FABACEAE (cont'd.)	*Desmodium triflorum*	(L.) DC.	X	13041	
	Erythrina variegata	L.	I	13095	eora
	Desmodium tortuosum	(Sw.) DC.	X	13048	
	Indigofera hirsuta	L.	X	13081	
	Leucaena leucocephala	(Lam.) de Wit	X	13090	bin
	Mimosa pudica	L.	X	13045	
	Senna occidentalis	(L.) Link	X	13049	tan braua
	Sophora tomentosa	L.	I		
	Vigna marina	(Burm.) Merr.	I	13024	erekogo
GOODENIACEAE	*Scaevola taccada*	(Gaertn.) Roxb.	I	13069	emet
HERNANDIACEAE	*Hernandia nymphaeifolia*	(Presl) Kubitzki	I	13154	etiu
LAMIACEAE	*Hyptis rhomboidea*	Mart. & Gal.	X		
LAURACEAE	*Cassytha filiformis*	L.	I	13066	denuwenini
MALVACEAE	*Abutilon asiaticum*	(L.) Sweet	X	13080	ekaura, inen ekaura
	Hibiscus tiliaceus	L.	X?	13089	wone
	Malvastrum coromandelianum	(L.) Garcke	X	13108	
	Sida acuta	Burm. f.	X	13040	
	Sida fallax	Walp.	I		ijibin ekaura, ekaura
	Sida rhombifolia	L.	X	13038	itsi
	Thespesia populnea	(L.) Sol. ex Correa	I	13097	itira
MELIACEAE	*Melia azedarach*	L.	X	13115	gadong
MORACEAE	*Ficus prolixa*	Forst. f.	I	13073	eaeo
MYRTACEAE	*Psidium guajava*	L.	X	13052	kowawa
NYCTAGINACEAE	*Boerhavia acutifolia*	(Choisy) J.W. Moore	X		
	Boerhavia coccinea	Mill.	X	13022	
	Pisonia grandis	R. Br.	I	13150	yangis
ONAGRACEAE	*Ludwigia octovalvis*	(Jacq.) Raven	X	13056	
OXALIDACEAE	*Oxalis corniculata*	L.	X		
PASSIFLORACEAE	*Passiflora foetida*	L.	X	13136	
PIPERACEAE	*Peperomia pellucida*	(L.) H.B.K.	X		
POLYGALACEAE	*Polygala paniculata*	L.	X	13093	
POLYGONACEAE	*Antigonon leptopus*	Hook. and Arn.	X	13086	
PORTULACACEAE	*Portulaca oleracea*	L.	X	13029	deboiy

Family	Species	Authors	Status1	Voucher	Nauruan Names
RHAMNACEAE	*Colubrina asiatica*	(L.) Brongn.	I	13033	ewongap
RHIZOPHORACEAE	*Bruguiera gymnorrhiza*	(L.) Lam.	I	13101	etõm
	Rhizophora stylosa	Griff.	I		eodongo
RUBIACEAE	*Aidia racemosa*	(Cav.) Trivengadum	I		enga?
	Dentella repens	Forst.	X	(seen)	
	Guettarda speciosa	L.	I	13068	iut
	Morinda citrifolia	L.	I	13132	deneno
	Oldenlandia corymbosa	L.	X	13070	
	Spermacoce assurgens	R. & P.	X	13126	
	Spermacoce bartlingiana	(DC.) Fosb.	X	13051	
SAPINDACEAE	*Dodonaea viscosa*	(L.) Jacq.	I	13067	eteweo
SCROPHULARIACEAE	*Bacopa procumbens*	(Mill.) Greenm.	X		
	Scoparia dulcis	L.	X	13109	
SOLANACEAE	*Physalis angulata*	L.	X	13020	watamo
STERCULIACEAE	*Waltheria indica*	L.	X	13064	
SURIANIACEAE	*Suriana maritima*	L.	I		
TILIACEAE	*Muntingia calabura*	L.	X	13078	bin
	Triumfetta procumbens	Forst. f.	I		ikiow
TURNERACEAE	*Turnera ulmifolia*	L.	X	13084	linkbelt
URTICACEAE	*Laportea ruderalis*	(Forst. f.) Chew	I	13137	
	Pilea microphylla	(L.) Liebm.	X	13042	
VERBENACEAE	*Clerodendrum inerme*	L.	I	13025	eamwije
	Lantana camara	L.	X	13087	magiroa
	Phyla nodiflora	(L.) E. Greene	X		
	Premna serratifolia	L.	I	13105	idibiner
	Stachytarpheta cayennensis	(Rich.) Vahl	X	13060	edidubai
	Stachytarpheta jamaicensis	(L.) Vahl	X	13065	edidubai
	Vitex trifolia	L.	I	13054	dagaidu

1. I = Indigenous; X= Alien.

Appendix 3 VEGETATION PLOT DATA

Plot 1. Uaboe Littoral Forest

(500 m² plot, midline line between S 00.51418, E 166.92667 to S 00.51396, E 166.92706)

Species	Nauru Name	No. of trees	No. Over 15cm	Total Basal Relative DBH Area (cm²)	Dominance
1. *Calophyllum inophyllum*	iyo	8	6	26,826	61%
2. *Terminalia catappa*	etetö	3	3	14,983	34%
3. *Adenanthera pavonina*	bin	6	2	1,186	3%
4. *Annona muricata*	dowaitsip	11	0	508	1%
5. *Morinda citrifolia*	deneno	3	0	153	+
6. *Cocos nucifera*	ini	1	0	133	+
7. *Guettarda speciosa*	iut	1	0	95	+
8. *Carica papaya*	dababaiya	2	0	40	+
9. *Premna serratifolia*	idibiner	1	0	20	+
Totals for 500 m²		36	11	43,944	100%
Totals extrapolated for 1000 m²		**72**	**22**	**97,888**	

Note: This was small patch of primary forest dominated the two native littoral and limestone forest trees.

Plot 2. Ijuw Escarpment Disturbed Limestone Forest

(Rugged area between S 00.52223, E 166.95563 to S 00.52770 (?), E 166.95595)

Species	Nauru Name	No. of trees	No. Over 15cm	Total Basal Relative DBH Area (cm²)	Dominance
1. *Terminalia catappa*	etetö	9	5	4,917	56%
2. *Adenanthera pavonina*	bin	10	5	2,734	31%
3. *Guettarda speciosa*	iut	2	1	475	5%
4. *Ficus prolixa*	eaeo	1	1	432	5%
5. *Calophyllum inophyllum*	iyo	6	0	265	3%
6. *Morinda citrifolia*	deneno	1	0	38	+
7. *Carica papaya*	dababaiya	3	0	20	+
Totals (no area parameter was used)		32	12	8,841	100%

Note: This was forest dominated by *Ficus prolixa*, which grew on the rocks and only occasionally rooted in the soil between the rocks, and a disturbed limestone forest, whose trees were rooted in the soil. It was virtually impossible to measure the multi-stemmed *Ficus* trees growing from the top of the tall, jagged rocks.

Plot 3. Buada disturbed Limestone Forest

(50 m line running from S 00.53339, E 166.92500 to S 00.53292, E 166.92490)

Species	Nauru Name	No. of trees	No. Over 15cm	Total Basal Relative DBH Area (cm²)	Dominance
1. *Calophyllum inophyllum* iyo	17	16	18,634	52%	
2. *Adenanthera pavonina* bin	16	3	7,888	22%	
3. *Terminalia catappae*tetö	2	2	7,356	21%	
4. *Cocos nucifera*	ini	2	2	1,321	4%
5. *Guettarda speciosa*	iut	1	1	201	1%
6. *Annona muricata*	dowaitsip	6	0	180	+
7. *Morinda citrifolia*	deneno	1	0	78	+
Totals for 500 m²		45	24	35,658	100%
Totals extrapolated for 1000 m²		**90**	**48**	**71,316**	

Note: The plot was not homogeneous, because *Adenanthera* was concentrated at one end.

Plot 4. Nibok Secondary Scrub

(150 m line between S 00.51740, E 166.92500 to S 00.51711, E 166.92545)

Species	Nauru Name	No. of trees	No. Over 15cm	Total Basal Relative DBH Area (cm²)	Dominance
1. *Calophyllum inophyllum*	iyo	6	2	1,312	32%
2. *Guettarda speciosa*	iut	14	1	969	24%
3. *Scaevola taccada* e	met	9	0	599	15%
4. *Terminalia catappa*e	tetö	4	2	593	14%
5. *Ficus prolixa*	eaeo	13	0	573	14%
6. *Premna serratifolia*	idibiner	2	0	58	1%
Totals (no area parameter was used)		47	5	4,104	100%

Note: This area of pinnacles mined decades ago was too rugged for the establishment of a plot, so only trees accessible from the adjacent road (where the 150 m line was put) were measured among the pinnacles.

Plot 5. Denig Secondary Scrub

(50 m line running from S 00.52478, E 166.91907 to S 00.52506, E 166.91875)

Species	Nauru Name	No. of trees	No. Over 15cm	Total Basal Relative DBH Area (cm^2)	Dominance
1. *Calophyllum inophyllum*	iyo	19	5	4,004	89%
2. *Guettarda speciosa*	iut	4	1	333	7%
3. *Premna serratifolia*	idibiner	4	1	98	2%
4. *Ficus prolixa*	eaeo	1	1	64	1%
5. *Scaevola taccada*	emet	1	0	38	+
Totals for 500 m^2		29	8	4,537	100%
Totals extrapolated for 1000 m^2		**58**	**16**	**9,074**	

Note: This plot was on rugged terrain in a line parallel to the raised trail leading across the central basin behind the Australian High Commission. It had probably been mined decades ago.

Plot 6. Aiwo Secondary Scrub

(50 m line running from S 00.53863, E 166.91704 to S 00.53893, E 166.91666)

Species	Nauru Name	No. of trees	No. Over 15cm	Total Basal Relative DBH Area (cm^2)	Dominance
1. *Guettarda speciosa*	iut	23	7	3,914	47%
2. *Adenanthera pavonina*	bin	24	2	2,524	30%
3. *Terminalia catappa*	etetö	5	3	1,026	12%
4. *Ficus prolixa*	eaeo	5	0	432	5%
5. *Calophyllum inophyllum*	iyo	1	1	314	4%
6. *Premna serratifolia*	idibiner	3	1	186	2%
Totals for 500 m^2		61	13	8,416	100%
Totals extrapolated for 1000 m^2		**122**	**26**	**15,192**	

Note: This plot was not homogeneous because the end closer to the road had a higher percentage of *Adenanthera*, probably because the tree was moving in from the roadside forest which was dominated by this invasive tree.

Plot 7. Buada Secondary Forest

(50 m line running from S 00.53052, E 166.92476 to S 00.53030 (?), E 166.92441)

Species	Nauru Name	No. of trees	No. Over 15cm	Total Basal Relative DBH Area (cm^2)	Dominance
1. *Adenanthera pavonina*	bin	20	6	9,086	59%
2. *Terminalia catappa*	etetö	3	3	6,286	41%
3. *Morinda citrifolia*	deneno	1	0	102	+
4. *Guettarda speciosa*	iut	1	0	20	+
5. *Calophyllum inophyllum*	iyo	1	0	20	+
Totals for 500 m^2		26	9	15,514	100%
Totals extrapolated for 1000 m^2		**52**	**18**	**31,028**	

Note: This plot was in a small patch of primary forest, but the plot was laid through a disturbed area dominated by *Adenanthera*. The area around the plot was probably dominated by *Terminalia* and *Calophyllum*.

Plot 8: Anbar Secondary Forest

(500 m^2 plot, midline line starting at S 00.52764, E 166.95094)

Species	Nauru Name	No. of trees	No. Over 15cm	Total Basal Relative DBH Area (cm^2)	Dominance
1. *Adenanthera pavonina*	bin	58	12	12,678	76%
2. *Ficus prolixa*	eaeo	1	1	4,109	24%
Totals for 500 m^2		59	13	16,787	100%
Totals extrapolated for 1000 m^2		**118**	**26**	**33,574**	

Note: Only one end point was recorded. The single *Ficus* was growing on a pinnacle in this generally flat plot in an area that had apparently been mined decades ago.

*For each plot, the number of trees present and the number of those above a dbh of 15 cm are indicated. That is followed by the total basal area and relative dominance of the species. The latter is calculated by dividing a species' total basal area by the total basal area of all the species. The totals for all the species are show on the next to the bottom line. The bottom line extrapolates the figures for the 500 m^2 plot to show how much it would be in a 1000 m^2 plot.

Appendix 4

ANNOTATED LIST OF MOTHS, ANTS, SNAILS AND OTHER INVERTEBRATES SURVEYED ON NAURU

by staff from Ministry for Commerce, Industry and Environment (CIE) and the SPREP international team (where "I" dentotes putative indigenous native and "X" indicates exotic while taxa of unknown origin are not assigned

Moths and butterflies				
Taxon	Locality	Date	I/X	Notes
Nepticulidae -Minute leafminer moths				
Stigmella species	Anibare Bay 3 m	18-Jun-2013	I	Two *Stigmella* species are described from Guam and information on Nepticulidae is summaried for Pacific islands (van Nieukerken and van den Berg 2003). This species is distinct from those. The known Pacific species have larvae mining the leaves of Urticaceae. *Laportea ruderalis* (Urticaceae) a Nauru native, is the likely host for the new *Stigmella* species present on Nauru. Invasive species are only known in Temporate Regions or the Mediteranian. Hibiscus and coconut forest at light trap
	Aiwo 35 m	20-Jun-2013		8x, Forest near Australian High Commission.
Tineidae -Clothes moths				
Erechthias penicillata (Swezey 1909)	Aiwo 35 m	20-Jun-2013		2x, Distributed French Polynesia and Hawaii. Zimmermann (1978) suggests this is most probably a tramp species but it may be a Pacific Island species. Larvae eat dead Pandanus. New record for Micronesia. Forest near Australian High Commission
Erechthias sp. nr. *coprosoma* (Gates Clarke 1971)	Buada Lagoon 10m	25-Jun-2013		E. coprosoma is only known from Rapa Island French Polynesia. Future dissection should show the relationship. Larval food is unknown but may include dead and decaying plant material. Related species (eg. E. simulans) have spread widely among Pacific Islands. Lagoon edge light trap
Erechthias species 1	Anibare Bay 3 m	18-Jun-2013		Hibiscus and coconut forest at light trap
	Menen 10 m	22-Jun-2013		coconut plantation, houses/garden
	Anitan 5 m	24-Jun-2013		coastal pinnacles, shrub, forest
	Buada Lagoon 10m	25-Jun-2013		Lagoon edge light trap
Erechthias species 2	Anitan 5 m	24-Jun-2013		coastal pinnacles, shrub, forest
Tineidae species 1	Menen 10 m	22-Jun-2013		coconut plantation, houses/garden
Tineidae species 2	Aiwo 35 m	20-Jun-2013		Pinnacles and Forest near Australian High Commission
Tineidae species 3	Anibare Bay 3 m	18-Jun-2013		Hibiscus and coconut forest at light trap
Tineidae/primative Lepidoptera family	Aiwo 5 m	22-Jun-2013		Hotel, urban and coastal shrubland

Gracillariidae -Leaf miner moths				
Gracillariidae sp.	Anibare Bay 3 m	18-Jun-2013		A leaf miner family. Hibiscus and coconut forest at light trap. This species is similar to Oboyski (2010) sp.6 from French Polynesia.
	Aiwo 35 m	20-Jun-2013		3x, Forest near Australian High Commission.
	Aiwo Power Stn 3m	21-Jun-2013		Open weedy damp grassland and limestone bluff forest
	Menen 10 m	22-Jun-2013		8x, coconut plantation, houses/garden
	Anitan 5 m	24-Jun-2013		coastal pinnacles, shrub, forest
	Buada Lagoon 10m	25-Jun-2013		2x, Lagoon edge light trap
Oecophoridae -Concealer moths				
Autosticha sp. nr. *merista* Gates Clarke 1971	Aiwo Power Stn 3m	21-Jun-2013	I	Gates Clarke (1971) states food plant —Unknown (probably dry vegetable matter). A. merista is apparently only known from Rapa Island but there are a number of related species in the genus for the Pacific. Recorded at light in open weedy damp grassland and limestone bluff forest.
Elachistidae -Grass or sedge miner moths				
Ethmia nigroapicella (Saalmüller 1880)	Anitan 5 m	24-Jun-2013	x	Kou Leafworm. Distributed pan Pacific, India and and elsewhere. Larvae eat *Ehretia* spp., *Cordia* spp. and most probably *Tournefortia argentea* Boraginaceae. Featured on a 1980 Kiribati stamp (Herbison-Evans and Crossley 2013). Zimmermann (1978) notes this species exotic to Hawai'i. Coastal pinnacles, shrub, forest
Stathmopodidae -Bristle legged micro-moths				
Stathmopodidae species	Anibare Bay 3 m	18-Jun-2013		Bristle legged micro-moths. Hibiscus and coconut forest at light trap
	Aiwo 35 m	20-Jun-2013		9x, Forest near Australian High Commission.
	Anitan 5 m	24-Jun-2013		coastal pinnacles, shrub, forest
	Buada Lagoon 10m	25-Jun-2013		Lagoon edge light trap
Batrachedridae -Leaf mining micro-moths				
Batrachedridae species	Anibare Bay 3 m	18-Jun-2013		In the tropics species in this family usually feed on Arecaceae (Palmae) such as Cocos. Hibiscus and coconut forest at light trap
Cosmopterigidae -Cosmet moths				
Asymphorodes montgomeryi J.F.G. Clarke 1986/*A. myronotus* Meyrick 1929	Anabar 5 m	18-Jun-2013	I	These two similar taxa are only known from the Marquesas Archipelago. Dissection of this Nauru series would likely show a species complex. Described by Gates Clarke (1986) for *A. myronotus* as probably a refuse feeder. Coastal pinnacles, shrub, forest.
	Anibare Bay 3 m	18-Jun-2013		Hibiscus and coconut forest at light trap
	Aiwo 35 m	20-Jun-2013		2x, Forest near Australian High Commission.
	Anitan 5 m	24-Jun-2013		3x, coastal pinnacles, shrub, forest

Asymphorodes sp. nr. *balanotis* (Meyrick 1934)	Aiwo 35 m	20-Jun-2013	I	*A. balanotis* is only known from the Marqueseas Archipelago and is part of a large radiated genus among Pacific islands. Larval host plant unknown but probably detris feeding. Adenanthera dominated forest near Australian High Commission.
Trissodoris honorariella (Walsingham 1907)	Aiwo Power Stn 3m	21-Jun-2013	X	Pandanus hole-cutter moth. Widely distributed in the Pacific. Larvae eat Pandanus species. Open weedy damp grassland and limestone bluff forest.
Gelechiidae -Twirler moths				
Gelechiidae species	Anabar 20 m	19-Jun-2013		Twirler moth family often with larvae boring in leaves and stems. Terminalia forest and shrubland
Pterophoridae -Plume moths				
Hepalastis pumilio (Zeller 1873)	Aiwo Power Stn 3m	21-Jun-2013	X	3X, Worldwide species. Larvae eat *Desmodium incanum* and Alysicarpus vaginalis Fabaceae and Oxalis species Oxalidaceae. Open weedy damp grassland and limestone bluff forest.
	Aiwo Harbour 3m	22-Jun-2013		Shipping container site
	Buada Lagoon 10m	25-Jun-2013		9x, Lagoon edge light trap
Megalorhipida leucodactyla (Fabricius 1794)	Anabar 35 m	18-Jun-2013	X	Pantropical distribution. Larvae polyphageous on plants in a range of families including Amaranthaceae, Cucurbitaceae, Goodinaceae and Leguminosae (Vargus 2007). Pinnacles habitat
	Anabar 20 m	19-Jun-2013		Terminalia forest and shrubland
	Aiwo 5 m	22-Jun-2013		3x, Hotel, urban and coastal shrubland
	Aiwo Harbour 3m	22-Jun-2013		2x, Shipping container site
	Anitan 5 m	24-Jun-2013		coastal pinnacles, shrub, forest
Sphenarches anisodactylus (Walker 1864)	Denigomodu 30 m	21-Jun-2013	X	2x, Geranium plume moth. Scattered distributed in the Americas, West Africa, India, Asia, Japan, Pacific and Australia. Larvae polyphageous including Cucurbitaceae, Fabaceae, Passiflora, Hibiscus and Lantana. Open old pinnacles forest
Carposinidae -Fruitworm moths				
Carposinidae species 1	Aiwo 35 m	20-Jun-2013		Many species in this family feed in shrubs. Forest near Australian High Commission
Carposinidae species 2	Aiwo 35 m	20-Jun-2013		7x, Forest near Australian High Commission.
	Menen 10 m	22-Jun-2013		coconut plantation, houses/garden
	Anitan 5 m	24-Jun-2013		4x, coastal pinnacles, shrub, forest
Carposinidae species 3	Buada Lagoon 10m	25-Jun-2013		Lagoon edge light trap
Carposinidae species 4	Aiwo 35 m	20-Jun-2013		4x, Pinnacles and Forest near Australian High Commission

Choreutidae -Metalmark moths				
Choreutis orthogona (Meyrick 1886)	Aiwo 35 m	20-Jun-2013	I	Forest near Australian High Commission. Banyan jumping moth with larvae on *Ficus* and *Streblus* Moraceae. J. Dugdale in McCormack (2007) describes this as a species of Brenthia, "a Small day-active moth, that walks jerkily and rockets when disturbed. Dance with head down and wings up is a feature of this genus. 7mm TL. LARVAE feed in groups, skeletonising banyan leaves".
	Denigomodu 30 m	21-Jun-2013		3x, Open old pinnacles forest
	Aiwo Power Stn 3m	21-Jun-2013		8x, Open weedy damp grassland and limestone bluff forest
	Aiwo Harbour 3m	22-Jun-2013		Shipping container site
	Menen 10 m	22-Jun-2013		8x, coconut plantation, houses/garden
Tortricidae -Leafroller moths				
Cryptophlebia ombrodelta (Lower 1898)	Buada Lagoon 10m	18-Jun-2013	x	Macadamia nut borer, Distributed Australia, Guam, India, Asia and Indonesia. Zimmerman (1978) notes its introduction to Hawaii. Larvae polyphageous boring into fruit or pod and feed on seed of shrubs and trees and eat for example Cocos Arecaceae (Palmae), Fabaceae, Sapandaceae, Proteaceae and Rutaceae. Swept from rank grasses and sedges
	Aiwo Power Stn 3m	21-Jun-2013		2x, Open weedy damp grassland and limestone bluff forest
Dudua species	Aiwo Power Stn 3m	21-Jun-2013		3x, A leafroller species. Many of these have larvae in a rolled leaf or flower of shrubs and trees. Open weedy damp grassland and limestone bluff forest.
Hesperidae -Skipper butterflies				
Badamia exclamationis (Fabricius, 1775)			I	Not recorded during this visit but recorded in Buden and Tennant (2008). Host trees *Terminalia catappa* are common and widespread. Native.
Lycaenidae -Blue butterflies				
Petrelaea tombugensis (Röber 1886)	Denigomodu 30 m	21-Jun-2013	I	2x, Open old pinnacles forest, Almond blue. Tropical Pacific species. Larvae eat flowers of native almond *Terminalia catappa* Combretaceae. Also recorded by Buden and Tennant (2008)
	Aiwo 5 m	21,22,24/06/2013		2x, Hotel, urban and coastal shrubland
Nymphalidae -Brushfooted butterflies				
Danaus plexippus (Linnaeus, 1758)	Anibare Bay 3 m	21-Jun-2013	X	Monarch. Recorded as caterpillars only. On Nauru larvae are restricted to feeding on *Calatropis gigantea* Apocynaceae. Elsewhere feeding on a range of milkweeds in this family. Radiated around the world following the spread of its caterpillar host plants and probably self introduced when caterpillar plants were established. Monarch Also noted by Buden and Tennant (2008)
Hypolimnas bolina (Linnaeus, 1758)	Aiwo 5 m	22-Jun-2013	I	Blue moon. Worldwide species. Larvae polyphageous. Hotel, urban and coastal shrubland. Shown on Nauru stamp issue and also recorded by Buden and Tennant (2008).

Pyralidae -Pyralid snout moths				
Etiella zinckenella (Treitschke 1832)	Anabar 20 m	19-Jun-2013	X	Been pod borer. Worldwide distribution. Larvae feed on many species in Leguminosae and known as a crop pest. Terminalia forest and shrubland
	Anitan 5 m	24-Jun-2013		coastal pinnacles, shrub, forest (Pyralidae phycitinae)
	Buada Lagoon 10m	25-Jun-2013		Lagoon edge light trap
Crambidae -Crambid snout moths				
Crambidae ?*Exeristis/ Metasia* species	Anabar 35 m	18-Jun-2013		2x, Pinnacles habitat
	Aiwo 35 m	20-Jun-2013		8x, Forest near Australian High Commission.
	Buada Lagoon 10m	25-Jun-2013		Lagoon edge light trap
Crambidae species 1	Aiwo 35 m	20-Jun-2013		4x, Pinnacles and Forest near Australian High Commission
Crambidae species 2	Aiwo 35 m	20-Jun-2013		4x, Pinnacles and Forest near Australian High Commission
	Aiwo 5 m	22-Jun-2013		Hotel, urban and coastal shrubland
Diaphania indica (Sanders 1851)	Aiwo Power Stn 3m	21-Jun-2013	X	7X, Spilomelinae. Cucumber moth larvae eat Cucurbitaceae (all species of this plant are considered a recent introduction (Thaman et al. 1994). Open weedy damp grassland and limestone bluff forest.
Glyphodes multilinealis Kenrick 1907	Aiwo Power Stn 3m	21-Jun-2013	I	Fig tiger moth. Distributed Fiji, Nuie, Cook Islands and Society Islands as well as Australia, Papua New Guinea and Japan. Larvae eat *Ficus prolixa* Moraceae. Open weedy damp grassland and limestone bluff forest.
Parotis suralis (Lederer 1863)	Aiwo 35 m	20-Jun-2013	I	Distributed Western Pacific including northern Australia, Solomon Is., Indonesia, China and many Pacific islands. Sister species are polyphageous. Pinnacles and Forest near Australian High Commission
Spoladela recurvalis (Fabricius 1775)	Buada Lagoon 10m	25-Jun-2013	X	Beet webworm. A worldwide species -mainly in the tropics. Larvae eat a range of fleshy leaved annuals mostly in the plant family Amaranthaceae. Lagoon edge light trap
Sphingidae -Spinx moths				
Gnathothlibus erotus (Cramer, 1777)	Aiwo 5 m	24-Jun-2013	I	White brow hawkmoth. In Nauru a lava was found on *Morinda citrifolia* Rubiaceae (widespread and common native on the island. *G. erotus* also feeds on Convulvulaceae and Vitaceae. Distributed From India to Indonesia, New Guinea, Australia and many Pacific islands.
Geometridae -Loopers or Geometrid moths				
Chloroclystis species	Anibare Bay 3 m	18-Jun-2013	I	Larvae usually eat flowers. While species is undetermined, likely to be native. Hibiscus and coconut forest at light trap
	Aiwo 35 m	20-Jun-2013		Forest near Australian High Commission
	Anitan 5 m	24-Jun-2013		coastal pinnacles, shrub, forest

Erebidae -a macro-moth family				
Eublemma anachoresis (Wallgren 1863)	Aiwo Power Stn 3m	21-Jun-2013	X	6X, Larvae known to feed on *Waltheria indica* Malvaceae, sleepy morning. This sub-shrub is not recorded by Tharman et al. (1994) although a number of related shrubs are. Open weedy damp grassland
Nolidae -Tuft moths				
Westermannia superba (Huber 1823/*W. gloriosa* (Hampson 1912)	Aiwo 35 m	20-Jun-2013	x	2x, The two are possibly synonyms. *W. superba* is distributed India, Indonesia, New Guinea and Australia. Not known among Pacific Islands. Possibly introduced from Australia. Larvae eat *Terminalia* and other species in Combretaceae and species in Lythraceae. Pinnacles and Forest near Australian High Commission
Noctuidae -Owlets and others				
Achaea janata (Linnaeus, 1758)	Aiwo 5 m	24-Jun-2013	x	Castor Semi-Looper. Distributed Southeast Asia to Australia and among Pacific Islands south to New Zealand and east to Easter Island. Larvae common on nonu Morinda citrifolia Rubiaceae and polyphageous on many tree species. Hotel, urban and coastal shrubland
Anticarsia irrorata (Fabricius 1781)	Aiwo 5 m	22-Jun-2013	x	Owl moth. Larvae eat eat legumes and grasses. Hotel, urban and coastal shrubland
Chrysodeixis eriosoma (Doubleday 1843)	Aiwo Power Stn 3m	21-Jun-2013	x	Silver Y moth or green looper. Caterpillars eat a wide variety of plants. Distributed Asia to Australia and Pacific islands to New Zealand. Open weedy damp grassland and limestone bluff forest
Mocis frugalis (Fabricius 1775)				Not seen during the survey -an uncertain record noted in North (1903) as *Remigia translata* Walker, 1865. Sugar cane looper. Distributed Orient to Australia and Pacific islands. Larvae eat Zingiberaceae. May possibly have been the similar sister species *Mocis trifasciata* we recorded.
Mocis trifasciata (Stephens 1829)	Buada Lagoon 10m	18-Jun-2013	x	Distributed west Pacific region, including Samoa, Fiji, Hawaii, New Zealand, the Society Islands and Queensland. Adults flushed from rank grasses and herbs. Larvae feed on fabaceae and poaceae.
	Aiwo 35 m	20-Jun-2013		Pinnacles and Forest near Australian High Commission
Rivula sp.	Aiwo 35 m	20-Jun-2013	I	2x, Forest near Australian High Commission. Species in this genus often have larvae on grasses. Some species are native to Pacific islands or widely distributed indo-Pacific region.
	Menen 10 m	22-Jun-2013		5x, coconut plantation, houses/garden
	Anitan 5 m	24-Jun-2013		coastal pinnacles, shrub, forest
	Buada Lagoon 10m	25-Jun-2013		Lagoon edge light trap
Spodoptera mauritia (Boisduval 1833)	Aiwo Power Stn 3m	21-Jun-2013	x	4X, Lawn Armyworm. Almost pan tropical -distributed North Africa to Asia and Pacific to Australia and many islands from Solomons to Hawaii. An international agricultural pest on grasses and crops with larvae on grasses. Open weedy damp grassland and limestone bluff forest.

	Aiwo 5 m	22-Jun-2013		Hotel, urban and coastal shrubland
	Anitan 5 m	24-Jun-2013		2X, coastal pinnacles, shrub, forest
Stictoptera cuculliоides Guenée 1852	Aiwo Power Stn 3m	21-Jun-2013	X	Distributed from Sri Lanka to Hawaii and Northern Australia. Introduced around the Pacific. Pest larvae on mangosteen leaves and also feeds on *Callophylum* and other species in Clusiaceae. Open weedy damp grassland and limestone bluff forest.
Ants and wasps (Hymenoptera: determinations by Darren Ward)				
Formicidae -Ants				
Anochetus graeffei Mayr 1870	Anabar 20 m	19/06/2013	X	A small exotic ant distributed many Pacific Islands, Australia, Indonesia, China, India and africa. Terminalia forest shrubland
	Anabare Bay 3 m	21/06/2013		Coconut, hibiscus, pandanus among houses
	Anitan 3 m	24/06/2013		Village mixed shrubland coconut pinnacles
	Menen 2 m	24/06/2013		7x. Scaviola shrubland
Anoplolepis gracilipes (Smith 1857)	Aiwo 3 m	22/06/2013	X	20x. Yellow crazy ant. Distributed in many parts of the Pacific, Americas, South Africa and native to Asia. Of concern for Nauru, this species does not appear to have spread beyond the port facilities yet. Elsewhere in the Pacific the Global Invasives Species Database (GISD) notes yellow crazy ants invading and causing environmental damage to many islands including Hawai'i and Christmas Island where 'super-colonies' threaten seabird nests. These ants apparently interfere with invertebrates, lizards, birds and mammals in many places around the Pacific (GISD Oct 2013). Shipping container site
Monomorium destructor (Jerdon 1851)	Aiwo 3 m	22/06/2013	X	Singapore Ant. A global tramp species and significant threat to native biological diversity and human health (Sarnat 2008). Shipping container site
	Aiwo 5 m	18/06/2013		Urban and shrub habitats
	Anitan 3 m	24/06/2013		2x. Village mixed shrubland coconut pinnacles
	Buada Lagoon 10m	18/06/2013		Sheltered urban forest
Monomorium floricola (Jerdon 1851)	Anabare 30 m	18,25/06/2013	X	39x. Flower ant. Global tramp ant species. Climbs trees and predator of insect eggs and insects. Adenanthera forest-edge pinnacles
	Buada Lagoon 10m	26/06/2013		4x. Lagoon edge light trap
	Buada Lagoon 10m	18,21/06/2013		2x. Sheltered urban forest
Monomorium pharaonis (Linnaeus 1758)	Menen 10 m	22/06/2013	X	4x. Pharaohs ant. Pan tropical in distribution and also in heated buildings of cooler areas. Considered an indoor pest. Coconut plantation, village
Nylanderia sp (small brown)	Aiwo 3 m	22/06/2013	X	Parrot ants. Includes invasive species. Shipping container site. New record since Clouse (2007) for the Micronesia region.
	Anabare 30 m	25/06/2013		5x. Adenanthera forest-edge pinnacles
	Anabare Bay 3 m	21/06/2013		Coconut, hibiscus, pandanus among houses
	Buada Lagoon 10m	25/06/2013		Lagoon edge light trap

	Buada Lagoon 10m	21,25/06/2013		7x. Sheltered urban forest
	Menen 10 m	22/06/2013		12x. Coconut plantation, village
	Menen 2 m	24/06/2013		Scaviola shrubland
	Yaren 2 m	24/06/2013		Village, Scaviola shrubland
Odontomachus simillimus Smith 1858	Menen 10 m	22/06/2013	X	Trap-jaw ants. Widespread among Pacific Islands and also Australia, Indonesia and parts of Africa. Solitary hunter in disturbed habitats. Although invasive not considered a significant pest. Coconut plantation, village
Paratrechina longicornis (Latreille, 1802)	Aiwo 3 m	22/06/2013	x	10x. Crazy ant or Black crazy ant or Longhorn crazy ant. Distributed worldwide and common around the Pacific as a household pest and commonly a pest in forests. Shipping container site
	Aiwo 35 m	21/06/2013		Near Aust. High Comm. -Mined pinnacles sparse shrubland
	Aiwo 5 m	18/06/2013		2x. Urban and shrub habitats
	Anabar 5 m	18, 25/06/2013		25x. Coastal pinnacles disturbed forest
	Anabare 30 m	21/06/2013		Adenanthera forest-edge pinnacles
	Anabare Bay 3 m	21/06/2013		2x. Coconut, hibiscus, pandanus among houses
	Anitan 3 m	24/06/2013		2x. Village mixed shrubland coconut pinnacles
	Buada Lagoon 10m	26/06/2013		11x. Lagoon edge light trap
	Buada Lagoon 10m	18,21,25/06/2013		26x. Sheltered urban forest
	Menen 2 m	24/06/2013		Scaviola shrubland
Pheidole fervens Forel 1902	Aiwo 5 m	21/06/2013	X	Distributed tropical Asia, America and widespread in the Pacific. Can be a household nuisance and thrives in disturbed dry forest. Hospital bluffs
	Anabar 20 m	19/06/2013		Terminalia forest shrubland
	Anabar 5 m	25/06/2013		5x. Coastal pinnacles disturbed forest
	Anabar 5 m	25/06/2013		3x. Coastal pinnacles disturbed forest
	Anabare 30 m	18/06/2013		2x. Forest-edge pinnacles
	Buada Lagoon 10m	26/06/2013		Lagoon edge light trap
	Buada Lagoon 10m	18,21,25/06/2013		8x. Sheltered urban forest
	Yaren 2 m	24/06/2013		2x, Village, Scaviola shrubland
	Yaren airport 15m	24/06/2013		3x. Rubble in slope forest
Pyramica membranifera (Emery 1869)	Anabar 5 m	25/06/2013	X	An invasive ant in the Pacific being a pan tropical tramp species. Inhabits disturbed open areas. Coastal pinnacles disturbed forest
	Menen 2 m	24/06/2013		2x. Scaviola shrubland
Solenopsis geminata (Fabricius 1804)	Aiwo 35 m	21/06/2013	X	5x. Tropical fire ant. Significant pest in America, Australia, Phillipines and China. Known to cause damage to ecological and agricultural systems (Sarnat 2008). Near Aust. High Comm. -Mined pinnacles sparse shrubland
	Aiwo 5 m	18/06/2013		3x. Urban and shrub habitats
	Anabar 20 m	19/06/2013		8x. Terminalia forest shrubland

	Anabare Bay 3 m	21/06/2013		16x. Coconut, hibiscus, pandanus among houses
	Anitan 3 m	24/06/2013		3x. Village mixed shrubland coconut pinnacles
	Menen 10 m	22/06/2013		8x. Coconut plantation, village
Tapinoma melanocephalum (Fabricius, 1793)	Aiwo Power Stn 3m	21/06/2013	X	Ghost ant. Widespread in the tropical Pacific and other tropical areas. A common household pest. Urban land bluffs
	Anabare Bay	25/06/2013		Beach
	Anitan 3 m	24/06/2013		Village mixed shrubland coconut pinnacles
	Buada Lagoon 10m	18, 21/06/2013		28x. Sheltered urban forest
	Menen 10 m	22/06/2013		Coconut plantation, village
	Menen 2 m	24/06/2013		Scaviola shrubland
Tapinoma sp.	Aiwo 35 m	21/06/2013	?	7x. Wetterer (2002) lists an ant Tapinoma minutum as a wide-ranging Pacific native but these amost likely adults of above species. Near Aust. High Comm. -Mined pinnacles sparse shrubland
	Aiwo Power Stn 3m	21/06/2013		Urban land bluffs
	Anabar 20 m	19/06/2013		Terminalia forest shrubland
	Anabar 5 m	25/06/2013		Coastal pinnacles disturbed forest
	Anabare 30 m	18/06/2013		5x. Adenanthera forest-edge pinnacles
	Menen 10 m	22/06/2013		7x. Coconut plantation, village
Technomyrmex sp.	Buada Lagoon 10m	18/06/2013	?	Wetterer (2002) lists an ant Technomyrmex albipes as a wide-ranging Pacific native. Sheltered urban forest
Tetramorium bicarinatum (Nylander 1846)	Aiwo 35 m	21/06/2013	X	2x. Pennant ants or tramp ants. Global tropical and subtropical distribution and many Pacific Islands. Described as likely to affect indigenous biodiversity (Sarnat 2008). Near Aust. High Comm. -Mined pinnacles sparse shrubland
	Aiwo 5 m	21/06/2013		3x. Hospital bluffs
	Anabar 5 m	25/06/2013		47x. Coastal pinnacles disturbed forest
	Anabare 30 m	25/06/2013		5x. Adenanthera forest-edge pinnacles
	Anitan 3 m	24/06/2013		Village mixed shrubland coconut pinnacles
	Buada Lagoon 10m	26/06/2013		5x. Lagoon edge light trap
	Buada Lagoon 10m	18,21,25/06/2013		12x. Sheltered urban forest
	Menen 10 m	22/06/2013		Coconut plantation, village
	Yaren airport 15m	24/06/2013		Rubble in slope forest
Tetramorium caldarium (Roger, 1857) ?	Menen 10 m	22/06/2013	X	Tentative determination and there are local Tetramorium species on neighbouring islands. However, T. calderium is almost global in the tropics and many subtropical areas including many Pacific Islands. Coconut plantation, village
Tetramorium lanuginosum Mayr 1870	Aiwo 3 m	22/06/2013	X	A small reddish ant widely distributed across the Pacific and other tropical regions. Range of habitats but mainly forest litter and considered a lesser pest species (Sarnat 2008). Shipping container site
	Anabar 35 m	18/06/2013		Mined pinnacles habitat Terminalia

	Anabar 5 m	25/06/2013		5x. Coastal pinnacles disturbed forest
	Buada Lagoon 10m	26/06/2013		Lagoon edge light trap
	Buada Lagoon 10m	18,21,25/06/2013		8x. Sheltered urban forest
	Denigomodu 30 m	21/06/2013		Mined pinnacles forest
unidentified ants	Aiwo Power Stn 3m	21/06/2013		Females and males. urban land bluffs. Also note Froggatt (1906) mentions a single taxon.
unidentified ants	Anabare Bay 3 m	21/06/2013		Females and males. Coconut, hibiscus, pandanus among houses
Wasps (Determinations by Darren Ward)				
Bethylidae -Cuckoo wasps and allies				
Goniozus? sp.	Anabare 30 m	25/06/2013		A genus of small parasitic wasps. Adenanthera forest-edge pinnacles
Braconidae -braconid wasps				
Braconidae species	Anabare 30 m	25/06/2013		A family of parasitic wasps. Adenanthera forest-edge pinnacles
Microgastrinae species	Anabare 30 m	18/06/2013		A subfamily of parasitic wasps. Forest-edge pinnacles
Microgastrinae species	Anabare 30 m	25/06/2013		Adenanthera forest-edge pinnacles
Chalcidoidea -Chalcid wasps				
Chalcids (various spp)	Aiwo Power Stn 3m	21/06/2013		A superfamily of small parasitic wasps. Urban land bluffs
	Anabar 5 m	25/06/2013		Coastal pinnacles disturbed forest
	Anabare 30 m	25/06/2013		Adenanthera forest-edge pinnacles
	Anabare Bay 3 m	21/06/2013		Coconut, hibiscus, pandanus among houses
Eupelmidae -a family of Chalcid wasps				
Anastatus? sp.	Buada Lagoon 10m	25/06/2013		Tiny wasps parasitising eggs of true bugs -Hemiptera. Sheltered urban forest
Euplemidae sp 2	Buada Lagoon 10m	18/06/2013		A family of small parasitic wasps. Sheltered urban forest
Evaniidae -Ensign wasps				
Evaniidae species	Menen 10 m	26/06/2013	I	Ensign wasps. Parasitic in cockroach egg cases. Three species are known in Micronesia (Townes 1958). Coconut plantation, village
Figitidae -a tiny parasitic wasp family				
Figitidae species	Anabare 30 m	25/06/2013		A family of small parasitic wasps. Forest-edge pinnacles
Figitidae species	Buada Lagoon 10m	18/06/2013		Sheltered urban forest
Megachilidae -Leafcutter bees				
Megachile? sp.	Aiwo 5 m	22/06/2013		Leaf cutter bee. Urban and shrub habitats
Platygastridae -tiny egg parasite wasps				
Platygastridae1	Buada Lagoon 10m	26/06/2013		A family of small parasitic wasps. Lagoon edge light trap
Platygastridae2	Buada Lagoon 10m	26/06/2013		Lagoon edge light trap
Sphecidae -Thread waisted wasps				
Sceliphron sp.	Aiwo 5 m	22/06/2013		Mud dauber wasp. Female hunts spiders for their nest. Urban and shrub habitats

Vespidae - Yellowjackets and Hornets, Paper Wasps; Potter, Mason Wasps				
Pachodynerus nasidens (Latreille 1817)	Aiwo 5 m	22/06/2013	X	Keyhole Wasp. Distributed from United states to Argentina and adventive in Hawai'i and Micronesia. This wasp was common during our visit to Nauru. Urban and shrub habitats
	Aiwo Power Stn 3m	21/06/2013		urban land bluffs
	Anabar 20 m	18/06/2013		Terminalia forest shrubland
	Anabare Bay 3 m	21/06/2013		Coconut, hibiscus, pandanus among houses
	Anitan 3 m	24/06/2013		Village mixed shrubland coconut pinnacles
	Buada Lagoon 10m	18/06/2013		Sheltered urban forest
	Buada Lagoon 10m	25/06/2013		2x. Lagoon edge light trap
Land snails (determinations by Fred Brook)				
	Anabare 30 m	18,21,25/06/2013		

Dragonflies and Damselfly (Determinations by Milen Marinov)		
Additional invertebrates recorded and available for expert interpretation		
Class Oligochaeta	Earthworms. A few specimens	
Order Scorpiones	One individual scorpion	
Order Pseudoscorpiones	One individual false scorpion	
Order Acarina	Mites. A few specimens	
Order Isopoda	Slater. Possibly only one species but very abundant at many sites with skeletal soils and probably a key role in organic matter breakdown.	
Order Amphipoda	Amphipod hoppers. Two species from two coastal plain sites	
Class Chilopoda	Centipedes. At least two species common and widespread on Nauru	
Class Diplopoda	Millipedes. A red species is widespread on Nauru	

Appendix 5

A TENTATIVE IUCN RED LIST ASSESSMENT (IUCN 2012) OF THREE LAND SNAILS ENDEMIC TO NAURU.

Two endemic insects are noted but not assessed (IUCN 2012)

Land snails: *Trochomorpha insolata* **and** *T. contigua var. nauruana. Tentative rank: for both land snails = Critically Endangered = CR B2 a. b. (ii) & (iii)*	
Category and Criteria	Assessment Against Criteria
CRITICALLY ENDANGERED (CR) A taxon is Critically Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing an extremely high risk of extinction in the wild:	
B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:	Geographic range can be inferred with reasonable confidence based on the following points: 1) Systematics of Pacific island land snails and their patterns of occurrence and speciation is well reported and there is high confidence in the two *Trocomorpha* as endemic species. Being invertebrates the appropriate measure of population health is based on distribution rather than abundance and raw sampling data is derived from presence or absence at 14 widely spaced localities providing insight on area of occupancy.
B2. Area of occupancy estimated to be less than 10 km^2, and estimate indicating at least two of a-c:	Area of occupancy is inferred with high confidence to be less than 10 km^2 since the entire area of Nauru Island is 21 km^2 and surface mining has stripped soils over more than half of the area. More supporting evidence comes from point sampling results.
a. Severely fragmented or known to exist at only a single location.	Nauru habitats are small in extent and known to be severely fragmented.
b. Continuing decline, observed, inferred or projected, in any of the following:	
(i) extent of occurrence	
(ii) area of occupancy	(ii) is appropriate since surface mining is ongoing and only one out of 14 sampling localities recorded *T. insolata* (as a dead shell) and *T contigua var nauruana* is not recorded since 1905. [THIS INFORMATION SHOULD BE INTERPRETED AS EITHER CONSIDERABLE DECLINE AND – CRITICALLY ENDANGERED OR, EXTINCT FOR BOTH SPECIES]
(iii) area, extent and/or quality of habitat	(iii) is also appropriate given past landuse and future plans. Addition of invasive plants and invertebrates (eg. ants and predatory snails) has been ongoing over recent decades among Micronesian islands including Nauru.
(iv) number of locations or subpopulations	
(v) number of mature individuals	

Land snail: *Sturanya subsuturalis. Tentative rank: = Vulnerable (VU) =VU B2 a. b. (iii)*	
Category and Criteria	Assessment Against Criteria
VULNERABLE (VU) A taxon is Vulnerable when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing a high risk of extinction in the wild:	IUCN definition for location (applied to Criteria B and D) The term 'location' defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. Where a taxon is affected by more than one threatening event, location should be defined by considering the most serious plausible threat.
2. Area of occupancy estimated to be less than 2,000 km^2, and estimates indicating at least two of a-c:	Nauru total size is 21 km^2
a. Severely fragmented or known to exist at no more than 10 locations.	While this endemic snail shows resilience to habitat modification, it occupies one location in terms of its vulnerability to a new invading predator.
b. Continuing decline, observed, inferred or projected, in any of the following: (i) extent of occurrence (ii) area of occupancy (iii) area, extent and/or quality of habitat (iv) number of locations or subpopulations (v) number of mature individuals.	(iii) applies to the inter-decadal timescale and the likelihood of snail predators known elsewhere in Micronesia establishing on Nauru, while, biosecurity measures are presently under resourced.
Tidal reef bug *Corallocoris nauruensis*	Nauru endemic: Not evaluated but note its very small habitat area among intertidal pinnacles and eventual vulnerability to climate change processes or vulnerability to oil spill.
Tiny leafminer moth *Stigmella* **species**	Nauru endemic: Not evaluated but note its vulnerability will be associated with the threat status of its host plant most likely to be *Laportea ruderalis* a herb in shaded sites.

Appendix 6

CAPACITY BUILDING WITH NAURUAN CIE AND USGS COMBINING LABORATORY AND FIELD TECHNIQUES

Appendix 7

REPTILE TAXA FOUND AT SAMPLING STATIONS IN NAURU, JUNE 18–26, 2013

Station #	Latitude	Longitude	District	EMCY	EMSP	GEIN	GEOC	HEFR	LELU	Total Lizards
1-1	-0.512828	166.953081	Anabar	0	0	0	0	0	0	0
1-2	-0.512921	166.953357	Anabar	0	0	0	0	0	0	0
1-3	-0.512978	166.953728	Anabar	3	1	0	0	0	0	4
1-4	-0.513109	166.953958	Anabar	1	0	0	1	0	0	2
1-5	-0.513069	166.954229	Anabar	0	2	0	0	0	0	2
1-6	-0.512887	166.954445	Anabar	4	1	0	0	1	0	6
1-7	-0.512605	166.954495	Anabar	4	1	1	0	2	1	9
1-8	-0.512285	166.954316	Anabar	12	0	0	0	0	0	12
1-9	-0.511970	166.954353	Anabar	4	0	1	0	0	0	5
1-10	-0.511670	166.954446	Anabar	14	0	0	0	0	0	14
1-11	-0.511346	166.954520	Anabar	6	0	0	1	0	0	7
1-12	-0.511019	166.954426	Anabar	0	0	0	0	0	0	0
1-13	-0.510752	166.954322	Anabar	13	0	1	2	0	0	16
1-14	-0.510457	166.954382	Anabar	13	0	0	1	0	1	15
1-15	-0.510537	166.954629	Anabar	14	0	1	1	1	5	22
1-16	-0.510282	166.955400	Anabar	3	0	0	0	1	0	4
1-17	-0.510565	166.955597	Anabar	1	0	0	0	0	1	2
2-1	-0.520692	166.919359	Nibok	1	0	0	0	1	1	3
2-2	-0.520511	166.919578	Nibok	4	0	0	0	0	0	4
2-3	-0.520354	166.919830	Nibok	3	0	0	0	0	0	3
2-4	-0.520473	166.920118	Nibok	0	0	0	0	0	0	0
2-5	-0.520751	166.920136	Nibok	0	0	0	0	0	0	0
2-6	-0.521028	166.920109	Nibok	0	0	0	0	0	0	0
2-7	-0.521334	166.920078	Nibok	0	0	0	0	0	0	0
2-8	-0.521620	166.920060	Nibok	0	0	1	0	0	0	1
2-9	-0.521902	166.920071	Denigomodu	0	0	0	0	0	0	0
2-10	-0.522208	166.920023	Denigomodu	0	0	0	0	0	0	0
2-11	-0.522496	166.920019	Denigomodu	0	0	0	0	0	2	2
2-12	-0.522765	166.919948	Denigomodu	2	0	0	0	0	0	2
2-13	-0.523023	166.919886	Denigomodu	0	0	0	0	0	0	0
2-14	-0.523255	166.919760	Denigomodu	0	0	0	0	0	0	0
2-15	-0.523482	166.919641	Denigomodu	0	0	0	1	0	0	1
3-1	-0.525993	166.949809	Anibare	0	0	0	0	0	0	0
3-2	-0.526300	166.949825	Anibare	2	0	0	0	0	0	2
3-3	-0.526541	166.950003	Anibare	1	0	0	0	0	0	1
3-4	-0.526625	166.950317	Anibare	2	0	0	0	0	0	2
3-5	-0.526867	166.950541	Anibare	2	0	0	0	0	0	2

Station #	Latitude	Longitude	District	EMCY	EMSP	GEIN	GEOC	HEFR	LELU	Total Lizards
3-6	-0.527037	166.950792	Anibare	0	0	1	0	1	0	2
3-7	-0.526889	166.951036	Anibare	0	0	0	0	1	0	1
3-8	-0.526672	166.951149	Anibare	2	0	0	0	0	0	2
3-9	-0.526642	166.951451	Anibare	0	0	0	0	0	0	0
3-10	-0.526767	166.951715	Anibare	3	0	0	0	0	0	3
3-11	-0.526776	166.951968	Anibare	1	0	0	0	0	0	1
3-12	-0.527153	166.950528	Anibare	3	0	0	0	0	0	3
3-13	-0.527244	166.950266	Anibare	1	0	0	0	0	0	1
3-14	-0.527509	166.950163	Anibare	3	0	0	0	0	0	3
3-15	-0.527744	166.949998	Anibare	0	0	0	0	0	0	0
3-16	-0.527985	166.949836	Anibare	8	0	0	0	0	0	8
3-17	-0.528087	166.949570	Anibare	1	0	0	0	1	0	2
3-18	-0.527908	166.949357	Anibare	6	0	0	0	0	0	6
3-19	-0.527885	166.949054	Anibare	1	0	0	1	0	0	2
3-20	-0.527718	166.948806	Anibare	0	0	0	0	0	0	0
3-21	-0.527622	166.948553	Anibare	1	0	0	0	0	0	1
3-22	-0.527695	166.948305	Anibare	0	1	0	0	0	0	1
3-23	-0.527941	166.948161	Anibare	0	1	0	0	0	0	1
4-1	-0.508388	166.938949	Ewa	0	0	0	0	0	1	1
4-2	-0.508135	166.939015	Ewa	0	0	0	0	2	0	2
4-3	-0.507857	166.939063	Ewa	0	0	0	0	0	1	1
4-4	-0.507631	166.939124	Ewa	1	0	1	0	0	0	2
4-5	-0.507359	166.939104	Ewa	0	0	3	0	1	2	6
4-6	-0.507098	166.939087	Ewa	0	0	0	0	0	0	0
4-7	-0.506789	166.939000	Ewa	0	0	0	0	0	0	0
4-8	-0.506515	166.938913	Ewa	0	0	0	0	0	0	0
4-9	-0.506324	166.938718	Ewa	0	1	0	0	0	0	1
4-10	-0.506173	166.938493	Ewa	0	0	0	0	1	1	2
4-11	-0.506097	166.938232	Ewa	0	1	0	0	0	1	2
4-12	-0.505947	166.937989	Ewa	0	0	0	0	0	0	0
4-13	-0.505838	166.937732	Ewa	0	1	0	0	0	0	1
4-14	-0.505725	166.937475	Ewa	0	1	0	0	0	0	1
4-15	-0.505615	166.937227	Ewa	0	1	0	0	0	1	2
4-16	-0.505524	166.936953	Ewa	0	0	0	0	0	0	0
4-17	-0.505536	166.936674	Ewa	0	1	0	0	0	0	1
4-18	-0.505570	166.936397	Ewa	1	0	0	0	0	0	1
4-19	-0.505590	166.936132	Ewa	1	0	0	0	0	2	3
4-20	-0.505640	166.935848	Ewa	2	0	0	0	0	0	2
4-21	-0.505802	166.935732	Ewa	0	0	0	0	0	1	1
5-1	-0.536630	166.921622	Buada	0	0	0	0	1	0	1
5-2	-0.536727	166.921890	Buada	3	0	0	0	1	0	4
5-3	-0.536882	166.922149	Buada	7	0	0	0	1	0	8
5-4	-0.537006	166.922424	Buada	0	0	0	0	1	0	1
5-5	-0.536969	166.922707	Buada	0	0	0	0	0	0	0

Station #	Latitude	Longitude	District	EMCY	EMSP	GEIN	GEOC	HEFR	LELU	Total Lizards
5-6	-0.536870	166.922966	Buada	5	0	0	1	2	0	8
5-7	-0.536688	166.923127	Buada	2	0	0	0	0	0	2
5-8	-0.536419	166.923219	Buada	1	0	0	0	0	0	1
5-9	-0.536135	166.923216	Buada	2	0	0	0	0	0	2
5-10	-0.535870	166.923254	Buada	2	0	0	3	1	0	6
5-11	-0.535596	166.923295	Buada	1	0	0	0	0	0	1
5-12	-0.535318	166.923330	Buada	4	0	0	1	0	0	5
5-13	-0.535037	166.923256	Buada	2	0	0	0	0	0	2
5-14	-0.534755	166.923242	Buada	2	0	0	0	0	0	2
5-15	-0.534558	166.923396	Buada	0	0	0	0	1	0	1
5-16	-0.533653	166.923450	Buada	0	0	0	0	1	0	1
5-17	-0.533382	166.923294	Buada	0	0	0	0	0	0	0
5-18	-0.533102	166.923316	Buada	2	0	0	0	0	1	3
5-19	-0.532827	166.923315	Buada	7	0	0	0	0	0	7
5-20	-0.532715	166.923067	Buada	3	0	0	0	0	0	3
5-21	-0.532587	166.922820	Buada	3	0	0	0	0	0	3
6-1	-0.535503	166.943927	Anibare	0	0	0	0	0	0	0
6-2	-0.535713	166.944067	Anibare	0	0	0	0	0	0	0
6-3	-0.535923	166.944244	Anibare	0	0	0	0	0	0	0
6-4	-0.536193	166.944358	Anibare	0	0	0	0	1	0	1
6-5	-0.536441	166.944498	Anibare	0	0	0	0	0	0	0
6-6	-0.536614	166.944734	Anibare	0	0	0	0	0	0	0
6-7	-0.536876	166.944735	Anibare	0	0	0	0	0	0	0
6-8	-0.537163	166.944763	Anibare	0	0	0	0	0	0	0
6-9	-0.537431	166.944877	Anibare	0	0	0	0	0	0	0
6-10	-0.537690	166.944958	Anibare	0	0	0	0	0	0	0
6-11	-0.537860	166.945187	Anibare	0	0	0	0	0	0	0
6-12	-0.538035	166.945383	Anibare	0	0	0	0	0	0	0
6-13	-0.538200	166.945629	Anibare	0	0	0	0	0	0	0
6-14	-0.538403	166.945819	Anibare	0	0	0	0	0	1	1
6-15	-0.538579	166.946036	Anibare	0	0	0	0	0	0	0
6-16	-0.538661	166.946300	Anibare	0	0	0	0	0	0	0
6-17	-0.538714	166.946540	Anibare	0	0	0	0	0	0	0
6-18	-0.538817	166.946787	Anibare	0	0	0	0	1	0	1
6-19	-0.538916	166.947045	Anibare	0	0	0	0	1	0	1
6-20	-0.539148	166.946916	Anibare	0	0	0	0	0	0	0
6-21	-0.539426	166.946964	Anibare	0	0	0	0	0	0	0
6-22	-0.539678	166.946844	Anibare	0	0	0	0	0	0	0
6-23	-0.539956	166.946939	Anibare	0	0	0	0	1	0	1
6-24	-0.540244	166.947024	Anibare	2	0	0	0	0	0	2
6-25	-0.540507	166.947122	Anibare	0	0	0	0	0	0	0
Total:				192	13	10	13	26	23	277

Key: EMCY - Emoia cyanura; EMSP - Emoia spp.; GEIN - Gehyra insulensis;

GEOC - Gehyra oceanica; LELU - Lepidodactylus lugubris; HEFR - Hemidactylus frenatus

Appendix 8

Table 1. Average Warbler and Micronesian pigeon numbers obtained from point counts divided into three land cover categories.

Site	Latitude	Longitude	Habitat type	Average warbler numbers	Average pigeon numbers
1	-0.52687	166.95054	forest + scrub areas	6.5	0
2	-0.52680	166.95104	forest + scrub areas	2.5	0
3	-0.52669	166.95131	forest + scrub areas	3.5	0
4	-0.52678	166.95197	forest + scrub areas	1.5	0
5	-0.52724	166.95027	forest + scrub areas	0	0
6	-0.52774	166.95000	forest + scrub areas	0.5	0
7	-0.52809	166.94957	forest + scrub areas	0.5	0
8	-0.52789	166.94905	forest + scrub areas	1	0
9	-0.52762	166.94855	forest + scrub areas	0	0
10	-0.52794	166.94816	forest + scrub areas	1	0
11	-0.53673	166.92189	forest + scrub areas	5.5	0
12	-0.53701	166.92242	forest + scrub areas	5	0
13	-0.53687	166.92297	forest + scrub areas	3	0
14	-0.53642	166.92322	forest + scrub areas	5.5	0
15	-0.53587	166.92325	forest + scrub areas	4.5	0
16	-0.53532	166.92333	forest + scrub areas	5.5	0
17	-0.53476	166.92324	forest + scrub areas	4	0
18	-0.53365	166.92345	forest + scrub areas	4	0
19	-0.53310	166.92332	forest + scrub areas	2	0
20	-0.53272	166.92307	forest + scrub areas	5.5	0
21	-0.51261	166.95450	forest + scrub areas	4.5	0
22	-0.51197	166.95435	forest + scrub areas	5	0
23	-0.51135	166.95452	forest + scrub areas	2	0
24	-0.51075	166.95432	forest + scrub areas	2	0
25	-0.51054	166.95463	forest + scrub areas	3	0
26	-0.51057	166.95560	forest + scrub areas	3	0
27	-0.52746	166.92313	forest + scrub areas	4	0
			AVERAGE	3.148148148	0
			SD	1.925610866	0
			% sites with birds occurring	92.59259259	0

Site	Latitude	Longitude	Habitat type	Average warbler numbers	Average pigeon numbers
1	-0.52599	166.94981	newer mined pinnacle area	0	0
2	-0.52644	166.95001	newer mined pinnacle area	1	0
3	-0.53550	166.94393	newer mined pinnacle area	0	0
4	-0.53592	166.94424	newer mined pinnacle area	0	0
5	-0.53644	166.94450	newer mined pinnacle area	0	0
6	-0.53688	166.94474	newer mined pinnacle area	0	0
7	-0.53743	166.94488	newer mined pinnacle area	0	0
8	-0.53786	166.94519	newer mined pinnacle area	0	0
9	-0.53820	166.94563	newer mined pinnacle area	0	0
10	-0.53858	166.94604	newer mined pinnacle area	0	0
11	-0.53871	166.94654	newer mined pinnacle area	0	0
12	-0.53892	166.94705	newer mined pinnacle area	0.5	0
13	-0.53943	166.94696	newer mined pinnacle area	0	0
14	-0.53996	166.94694	newer mined pinnacle area	0.5	0
15	-0.54051	166.94712	newer mined pinnacle area	0	0
			AVERAGE	0.133333333	0
			SD	0.29680842	0
			% sites with birds occurring	20	0

Site	Latitude	Longitude	Habitat type	Average warbler numbers	Average pigeon numbers
1	-0.52301	166.93835	old mined pinnacle area	0	4
2	-0.52129	166.93497	old mined pinnacle area	0.5	2
3	-0.51886	166.93324	old mined pinnacle area	0	1
4	-0.51830	166.93143	old mined pinnacle area	1.5	0
5	0.51745	166.92970	old mined pinnacle area	1	2.5
6	-0.52069	166.91936	old mined pinnacle area	1	1
7	-0.52035	166.91983	old mined pinnacle area	1.5	0
8	-0.52075	166.92014	old mined pinnacle area	3	1
9	-0.52133	166.92008	old mined pinnacle area	2	0
10	-0.52190	166.92007	old mined pinnacle area	1	0.5
11	-0.52250	166.92002	old mined pinnacle area	1	0
12	-0.52302	166.91989	old mined pinnacle area	0	0
13	-0.52348	166.91964	old mined pinnacle area	1	0
14	-0.51283	166.95308	old mined pinnacle area	0	0
15	-0.51298	166.95373	old mined pinnacle area	0.5	0
16	-0.51307	166.95423	old mined pinnacle area	0	0
			AVERAGE	0.875	0.75
			SD	0.842332363	0.812110713
			% sites with birds occurring	68.75	43.75

Appendix 9

MARINE SURVEY SITES WITH DATE OF SAMPLE, SITE NUMBER, COORDINATES AND DISTRICT/HABITAT SAMPLED

In cases where more than one site was sampled off a district, a brief description is included in parentheses. Three reef flats also surveyed on foot and by snorkelling are included, and labelled with rf before site number (e.g. rf1).

Date	Site	Latitude	Longitude	District/Habitat
18 June 2013	1	0°32′31.07″S	166°54′35.84″E	Aiwo /fringe
18 June 2013	2	0°32′13.49″S	166°54′29.57″E	Aiwo/fringe (off old cantilever)
18 June 2013	3	0°32′54.54″S	166°54′52.05″E	Yaren/fringe (off airport strip near offices)
19 June 2013	4	0°32′42.73″S	166°57′9.31″E	Meneng /fringe (off Menen hotel)
19 June 2013	5	0°32′28.39″S	166°57′7.92″E	Anibare/fringe (south of fisheries boat launch)
19 June 2013	6	0°31′10.99″S	166°57′39.24″E	Ijuw/fringe
20 June 2013	7	0°30′33.12″S	166°57′29.52″E	Anabar/fringe south
20 June 2013	8	0°30′9.72″S	166°57′2.52″E	Anabar/fringe north
20 June 2013	9	0°29′57.49″S	166°56′3.80″E	Ewa/fringe
21 June 2013	10	0°31′42.11″S	166°57′19.52″E	Anibare/fringe (north)
21 June 2013	11	0°33′20.19″S	166°56′7.17″E	Meneng/fringe (south of and off wireless station)
21 June 2013	12	0°33′9.75″S	166°56′32.25″E	Meneng/fringe
23 June 2013	rf1	0°32′10.00″S	166°54′35.73″E	Anibare/reef flat
23 June 2013	rf2	0°32′1.81″S	166°57′2.66″E	Aiwo/reef flat
23 June 2013	rf3	0°30′28.14″S	166°57′11.31″E	Anabar/Reef flat
24 June 2013	13	0°30′1.31″S	166°56′38.51″E	Anetan/fringe
24 June 2013	14	0°30′26.38″S	166°55′32.09″E	Baiti/fringe
24 June 2013	15	0°30′35.16″S	166°55′25.33″E	Uaboe/fringe
25 June 2013	16	0°30′51.97″S	166°55′10.25″E	Nibok/fringe
25 June 2013	17	0°31′18.40″S	166°54′41.88″E	Denigomodu/fringe
25 June 2013	18	0°33′18.52″S	166°55′35.98″E	Yaren/fringe (south airport strip)
26 June 2013	19	0°32′10.87″S	166°57′6.35″E	Anibare/ fringe (north of fisheries boat launch)
26 June 2013	20	0°31′52.71″S	166°54′30.35″E	Aiwo/fringe (off working cantilever)

Appendix 10

CORAL SPECIES OF NAURU RECORDED BY SITES WITH RELATIVE ABUNDANCES INDICATED ON THE DAFOR SCALE, WITH R = RARE, U = UNCOMMON, C = COMMON, A = ABUNDANT, AND D = DOMINANT.

Species		Sites and abundance
Family Pocilloporidae		
1.	*Pocillopora eydouxi*	1D, 2C, 3C, 4C, 5C, 6C, 7C, 8C, 9C, 10C, 11C, 12C, 13C, 14C, 15C, 16U, 17U, 18U, 19C, 20C
2.	*Pocillopora fungiformis*	4U, 5U, 13U, 15U, 20U
3.	*Pocillopora meandrina*	1U, 2U, 5R, 6R, 7U, 8U, 9U, 10U, 13R, 16R, 17R, 19U, 20U
4.	*Pocillopora setichelli*	4C, 5U, 6U, 7U, 8U, 9U, 10U, 11U, 12C, 19U
5.	*Pocillopora verrucosa*	2R, 3R, 4U, 5U, 8R, 9U, 10U, 11U, 12U, 13U, 14U, 15U, 16U, 17U, 18U, 19U, 20U
6.	*Pocillopora cf. zelli*	5R
Family Acroporidae		
7.	*Montipora caliculata*	5R
8.	*Montipora* cf. *danae*	19R
9.	*Montipora foveolata*	6R, 7R, 10R, 13R
10.	*Montipora grisea*	1C, 2U, 3U, 4A, 5A, 6A, 7A, 8A, 9U, 10U, 11U, 12U, 13U, 14U, 15U, 16R, 17R, 18R, 19C, 20R
11.	*Montipora* cf. *nodosa*	6R, 7U, 8A, 12R, 19R
12.	*Montipora tuberculosa*	4U, 5U, 6R, 7U, 8R, 12R, 19R
13.	*Montipora* cf. *venosa*	13U, 16R, 17R, 18R
14.	*Acropora hyacinthus*	1R, 4R, 5R, 6R, 9R, 19U
15.	*Acropora* cf. *valida*	18U, 20R
16.	*Acropora* sp. 1	7R
17.	*Acropora* sp. 2	6U, 11R, 12R, 19R
18.	*Acropora* sp. 3	12R
19.	*Acropora* sp. 4	Reef flat: cantilevers R
Family Siderastreidae		
20.	*Psammocora nierstraszi*	4R, 8R, 11R, 12R, 13R, 20R
21.	*Psammocora haimeana*	6R, 10R, 11R, 20R
Family Agariciidae		
22.	*Pavona chriquensis*	2R, 4R, 5R, 6R, 9R, 10R, 11U, 18R, 19U, 20U
23.	*Pavona duerdeni*	1R, 2R, 3R, 4U, 5U, 6U, 7U, 8R, 9R, 10R, 11R, 12R, 13R, 16R, 19U, 20U
24.	*Pavona explanulata*	1R, 8R, 17R
25.	*Pavona frondifera*	20R
26.	*Pavona gigantea*	1R, 2U, 5U, 7R, 11R, 12R, 13R, 17R, 18R, 19R, 20R
27.	*Pavona maldivensis*	4R, 5R, 11R, 12R, 17R, 19R
28.	*Pavona varians*	1U, 2R, 4U, 5R, 6R, 8U, 9U, 10R, 11U, 12R, 13R, 15R, 17C, 18R, 19R, 20U
29.	*Pavona venosa*	18R, 20R
30.	*Leptoseris explanata*	18R
31.	*Leptoseris mycetoseroides*	3R
32.	*Gardineroseris planulata*	13R, 18R, 20R

Species		Sites and abundance
Family Fungiidae		
33.	*Cycloseris vaughani*	20R
34.	*Fungia concina*	3R, 10R, 12R, 20U
35.	*Fungia scutaria*	9R, 12R, 13R, 19R
36.	*Halomitra pileus*	2R, 18R, 20R
37.	*Sandalolitha robusta*	8R, 10R, 18R
Family Dendrophyllidae		
38.	*Tubastraea* sp.	1R
Family Faviidae		
39.	*Favia stelligera*	4R, 6R, 8R, 10R, 11R
40.	*Leptastrea pruinosa*	20R
41.	*Leptastrea transversa*	1R, 2R, 4R, 6R, 7R, 11R, 18R, 19R, 20R
Family Poritidae		
42.	*Porites* cf. *annae*	6U, 7U, 8R, 12R, 13R
43.	*Porites arnaudi*	4R, 5U, 6U, 7U, 8U, 9U, 10U, 13R, 19U
44.	*Porites lutea/evermanni*	2R, 3U, 4R, 7U, 10R, 12R, 17R, 18R, 19R
45.	*Porites massive*	1C, 2U, 3U, 4C, 5C, 7C, 8C, 9U, 10U, 11U, 13U, 18R, 19U
46.	*Porites monticulosa*	2R, 7R, 8R, 11R, 12R, 20R
47.	*Porites rus*	1U, 2D, 3D, 4C, 5D, 6A, 7A, 8A, 9A, 10D, 11D, 12D, 13D, 14D, 15D, 16D, 17D, 18D, 19, 20C
Subclass Octocorallia, Order Alcyonacea		
48.	*Heliopora coerulea*	1A, 2C, 3C, 4U, 5U, 6C, 7U, 8U, 9U, 10U, 11U, 12U, 13U, 14U, 15C, 16C, 17C, 18C, 19C, 20U
Class Hydrozoa, Family Stylasteridae		
49.	*Distichopora violacea*	1D, 2C, 3U, 4C, 5C, 6U, 7C, 8C, 9C, 10C, 11C, 12C, 13C, 14C, 15C, 16C, 17C, 18C, 19U, 20U
50.	*Stylaster* sp.	12R, 14R, 15U, 16R
Family Milleporidae		
51.	*Millepora* cf. *platyphylla*	12U, 19U

Appendix 11

ADDITIONAL INFORMATION FOR SPECIES WHICH REPRESENT RANGE EXTENSIONS IN NAURU

Pavona gigantea is a species previously known only from the eastern Pacific. The author has found it in American Samoa and New Caledonia. This species in Nauru is an extension of its known range, by a significant distance.

Pavona chiriquensis was described from the eastern Pacific (Glynn et al. 2001), after the publication of Corals of the World (Veron 2000) the only source of range information for all genera other than *Acropora*. The author has also recorded it from Fiji, New Caledonia, and the Commonwealth of the Marianas Islands, and it is reported from Hawaii (B. Vargas-Angel, personal comm.). So it appears to be a widespread species, but has not been reported near Nauru previously.

Pavona frondifera in Nauru is outside the known range of the species indicated in Veron (2000). It is in a gap in the known distribution, and thus helps to fill that gap to make a single continuous distribution.

Pocillopora setichelli is recognized by Randall and Myers (1983) from Guam, but not by Veron (2000). In American Samoa, it forms distinct colonies which are not rare, and the author has also reported it from Fiji and New Caledonia. The range of this species is not well known, but appears to be widespread. Nauru is between the known locations and thus helps fill in a wide gap in the known distribution.

Porites arnaudi , found in Nauru, is also an extension for this species. The author has found it in American Samoa, which is an area in which Veron (2000) indicates it is, but is slightly different from the eastern Pacific area where it was discovered. The author can find no differences between skeletal samples of the colonies in American Samoa and the type description.

Porites monticulosa in Nauru is outside its reported range, however, this species has significant taxonomic problems that complicate the picture.

Porites evermanni is in Hawaii (the type location) and in a somewhat different form in Southeast Asia and the northern Indian Ocean Veron (2000). The author has found colonies in American Samoa that are the same as in Hawaii, and the Nauru colonies are also the same as Hawaii, and outside both known areas indicated in Veron (2000) and so a range extension. Thus, range extensions were found for a total of seven species.

Appendix 12

TOTAL MARINE INVERTEBRATE SPECIES RECORDED WITH NUMBER OF SITES SPECIES OBSERVED.

Species are in descending order from most widespread to least.

Species	Number of sites present
Echinothrix diadema	19
Drupella cornus	16
Trapezia rufopunctata	16
Coralliophila neritoidea	15
Actinopyga mauritiana	13
Diadema setosum	13
Spirobranchus giganteus	11
Echinostrephus sp.	9
Trapezia bidentata	9
Alpheus sp. 1	8
Paguritta corallicola	7
Tripneustes gratilla	7
Echinometra mathaei	6
Linckia laevigata	6
Bohadschia graeffei	5
Orange sponge sp.	5
Actinopyga palauensis	4
Calcinus minutus	4
Holothuria atra	4
Turbo argyrostomus	4
Calcinus haigae	3
Cymo quadrilobatus	3
Daira perlata	3
Mitra stictica	3
Serpulid tube worms	3
Ciliopagurus strigatus	2
Coralliophila monodonta	2

Species	Number of sites present
Culcita novaeguineae	2
Cypraea caputserpentis	2
Cypraea moneta	2
Drupa grossularia	2
Drupa morum	2
Heteractis magnifica	2
Heteractis sp.	2
Lambis truncata	2
Periglypta reticulata	2
Phyllidia elegans	2
Spondylus sp	2
Thelenota ananas	2
Tridacna maxima	2
Vasum ceramicum	2
Acanthaster planci	1
Acrosterigma elongata	1
Astralium stellare	1
Birgus latro	1
Bonellia viridis	1
Calcinus gaimardii	1
Calcinus laevimanus	1
Calcinus morgani	1
Carpilius convexus	1
Carpilius maculatus	1
Conus distans	1
Conus miles	1
Conus miliaris	1

Species	Number of sites present
Cypraea carneola	1
Dardanus guttatus	1
Domecia hispida	1
Etisus splendidus	1
Grapsus albolineatus	1
Heteractis crispa	1
Heterocentrotus mammillatus	1
Lambis lambis	1
Octopus sp.	1
Panulirus sp.1	1
Panulirus sp.2	1
Periclimenes soror	1
Peristernia gemmata	1
Philarius gerlachei	1
Phyllacanthus imperialis	1
Phyllidia carlsonhoffi	1
Pilumnus vespertilio	1
Saron neglectus	1
Stenopus hispidus	1
Synalpheus carinatus	1
Terebra dimidiata	1
Thais armigera	1
Thais virgatus	1
Trapezia cymodoce	1
Trapezia flavopunctata	1
Trapezia sp. 1	1

Appendix 13

FULL LIST OF MACRO INVERTEBRATE SPECIES KNOWN TO OCCUR IN NAURU, INCLUDING EXTERNAL SOURCES.

BIORAP indicates species recorded in present study. PROCFish indicates species recorded in 2005 study. Other references are from the data bases of the respective museums listed. Highlighted cells indicate new species records that were found in the present BIORAP study.

Nauru macro invertebrate species record	Reference
Acanthaster planci	BIORAP
Acanthaster planci	PROCFish surveys
Acrosterigma elongata	BIORAP
Actinodendron sp.	PROCFish surveys
Actinopyga mauritiana	BIORAP
Actinopyga mauritiana	Australia museum collection
Actinopyga mauritiana	PROCFish surveys
Actinopyga palauensis	BIORAP
Alpheus sp. 1	BIORAP
Aniculus aniculus	Florida Museum
Astralium stellare	BIORAP
Astrosclera willeyana	Florida Museum
Birgus latro	BIORAP
Bivalve Chama sp.	PROCFish surveys
Bohadschia graeffei	BIORAP
Bohadschia graeffei	PROCFish surveys
Bonellia viridis	BIORAP
Bulla sp.	PROCFish surveys
Bursa bufonia	Australia museum collection
Bursa granularis	Florida Museum
Bursa tuberosissima	Australia museum collection
Calappa sp.	PROCFish surveys
Calcinus elegans	Florida Museum
Calcinus gaimardii	BIORAP
Calcinus guamensis	Florida Museum
Calcinus haigae	BIORAP
Calcinus haigae	Florida Museum
Calcinus isabellae	Florida Museum
Calcinus laevimanus	BIORAP
Calcinus laevimanus	Florida Museum
Calcinus minutus	BIORAP
Calcinus minutus	Florida Museum
Calcinus morgani	BIORAP
Calcinus morgani	Florida Museum

Nauru macro invertebrate species record	Reference
Calcinus sp.	PROCFish surveys
Cantharus frageria	Florida Museum
Cardisoma sp.	PROCFish surveys
Carpilius convexus	BIORAP
Carpilius maculatus	BIORAP
Carpilius maculatus	Florida Museum
Carpilius maculatus	PROCFish surveys
Cerithium columna	Australia museum collection
Cerithium echinatum	Australia museum collection
Cerithium echinatum	Florida Museum
Cerithium nodulosum	Australia museum collection
Cerithium punctatum	Florida Museum
Chama cerion	Australia museum collection
Chama pacifica	Australia museum collection
Cheilopogon suttoni	Australia museum collection
Ciliopagurus strigatus	BIORAP
Clibanarius corallinus	Florida Museum
Clypeomorus nympha	Australia museum collection
Coenobita rugosus	Florida Museum
Coenobita sp.	PROCFish surveys
Colubraria sp. 1	Florida Museum
Colubraria tortuosa	Florida Museum
Conus catus	Australia museum collection
Conus catus	Florida Museum
Conus chaldeus	Australia museum collection
Conus coffeae	Florida Museum
Conus distans	BIORAP
Conus distans	Florida Museum
Conus ebraeus	Australia museum collection
Conus flavidus	Australia museum collection
Conus flavidus	PROCFish surveys
Conus lividus	Australia museum collection
Conus miles	BIORAP
Conus miles	Australia museum collection

Nauru macro invertebrate species record	Reference
Conus miles	Florida Museum
Conus miles	PROCFish surveys
Conus miliaris	BIORAP
Conus miliaris	Australia museum collection
Conus nussatella	Florida Museum
Conus obscurus	Florida Museum
Conus pulicarius	Australia museum collection
Conus sanguinolentus	Australia museum collection
Conus sp.	PROCFish surveys
Conus sponsalis	Australia museum collection
Conus textile	Florida Museum
Conus tulipa	Australia museum collection
Coralliophila (Quoyula)	Australia museum collection
Coralliophila monodonta	BIORAP
Coralliophila violacea	BIORAP
Coralliophila violacea	Florida Museum
Ctena bella	Australia museum collection
Culcita novaeguineae	BIORAP
Culcita novaeguineae	PROCFish surveys
Cymatium aquatile	Florida Museum
Cymatium sp.	PROCFish surveys
Cymo quadrilobatus	BIORAP
Cypraea arabica	Australia museum collection
Cypraea caputserpenits	PROCFish surveys
Cypraea caputserpentis	Australia museum collection
Cypraea caputserpentis	Florida Museum
Cypraea caputserpentis	BIORAP
Cypraea carneola	Australia museum collection
Cypraea carneola	Florida Museum
Cypraea carneola	Florida Museum
Cypraea carneola	BIORAP
Cypraea childreni	Australia museum collection
Cypraea cicercula	Australia museum collection
Cypraea depressa	Australia museum collection
Cypraea depressa	Florida Museum
Cypraea eglantina	Australia museum collection
Cypraea erosa	Australia museum collection
Cypraea helvola	Australia museum collection
Cypraea isabella	Australia museum collection
Cypraea lynx	Australia museum collection

Nauru macro invertebrate species record	Reference
Cypraea maculifera	Australia museum collection
Cypraea mappa	Australia museum collection
Cypraea mariae	Florida Museum
Cypraea mauritiana	Australia museum collection
Cypraea moneta	BIORAP
Cypraea moneta	Australia museum collection
Cypraea moneta	Florida Museum
Cypraea moneta	PROCFish surveys
Cypraea nucleus	Australia museum collection
Cypraea poraria	Australia museum collection
Cypraea scurra	Australia museum collection
Cypraea stolida	Australia museum collection
Cypraea talpa	Australia museum collection
Cypraea talpa	PROCFish surveys
Cypraea teres	Australia museum collection
Cypraea testudinaria	Australia museum collection
Cypraea testudinaria	Florida Museum
Cypraea tigris	Australia museum collection
Cypraea tigris	PROCFish surveys
Cypraea ventriculus	Australia museum collection
Cypraea vitelllus	Florida Museum
Cypraea vitellus	Australia museum collection
Daira perlata	BIORAP
Dardanus guttatus	BIORAP
Dardanus guttatus	Florida Museum
Dardanus lagopodes	Florida Museum
Dardanus longior	Florida Museum
Dendropoma gregaria	Florida Museum
Dendropoma gregaria	Florida Museum
Dendropoma maximum	Florida Museum
Diadema setosum	BIORAP
Diadema sp.	PROCFish surveys
Domecia hispida	BIORAP
Drupa grossularia	Australia museum collection
Drupa grossularia	Florida Museum
Drupa grossularia	BIORAP
Drupa morum	BIORAP
Drupa morum	Australia museum collection
Drupa morum	Florida Museum
Drupa morum	PROCFish surveys

Nauru macro invertebrate species record	Reference
Drupa ricinus	Florida Museum
Drupa rubusidaea	Florida Museum
Drupa rubusidaeus	Australia museum collection
Drupa rubusidaeus	Florida Museum
Drupa sp.	PROCFish surveys
Drupella cornus	BIORAP
Drupella cornus	Florida Museum
Drupella sp.	PROCFish surveys
Echinometra mathaei	BIORAP
Echinometra mathaei	PROCFish surveys
Echinostrephus sp.	BIORAP
Echinothrix calamaris	PROCFish surveys
Echinothrix diadema	BIORAP
Echinothrix diadema	PROCFish surveys
Echinothrix sp.	PROCFish surveys
Engina bonasia	Australia museum collection
Engina mendicaria	Australia museum collection
Eriphia scabricula	Florida Museum
Eriphia sebana	Florida Museum
Eriphia sebana	PROCFish surveys
Etisus splendidus	BIORAP
Etisus splendidus	PROCFish surveys
Exotica obliquaria	Australia museum collection
Fromia sp.	PROCFish surveys
Fulvia subquadrata	MNHM
Geograpsus crinipes	Florida Museum
Grapsus albolineatus	BIORAP
Grapsus albolineatus	PROCFish surveys
Grapsus albolineatus	PROCFish surveys
Grapsus grapsus	PROCFish surveys
Haliotis jacnensis	Australia museum collection
Harpa amouretta	Australia museum collection
Hebra crenoliratus	MNHM
Heteractis crispa	BIORAP
Heteractis magnifica	BIORAP
Heteractis sp.	BIORAP
Heterocentrotus mammillatus	BIORAP
Heteropoda venatoria	Australia museum collection
Hippopus hippopus	Australia museum collection
Holothuria atra	BIORAP
Holothuria atra	PROCFish surveys
Holothuria difficilis	Florida Museum
Holothuria nobilis	PROCFish surveys
Hydatina amplustre	Australia museum collection
Isognomon isognomon	Australia museum collection
Isognomon pernum	Florida Museum
Lambis lambis	BIORAP
Lambis lambis	PROCFish surveys
Lambis truncata	BIORAP
Lambis truncata	PROCFish surveys
Latirolagena smaragdula	PROCFish surveys
Lepidozygus tapeinosoma	Australia museum collection
Linckia laevigata	BIORAP
Linckia laevigata	PROCFish surveys
Liralucina craticula	MNHM
Liralucina craticula	MNHM
Littoraria coccinea	Australia museum collection
Littoraria coccinea	Florida Museum
Lysiosquillina sp.	PROCFish surveys
Mammilla melanostoma	Australia museum collection
Melampus flavus	Florida Museum
Melampus luteus	Australia museum collection
Mitra (Nebularia)	Australia museum collection
Mitra acuminata	Australia museum collection
Mitra cardinalis	Australia museum collection
Mitra litterata	Florida Museum
Mitra paupercula	Florida Museum
Mitra stictica	BIORAP
Mitra stictica	Australia museum collection
Modiolus auriculatus	Florida Museum
Morula granulata	Australia museum collection
Morula margariticola	Australia museum collection
Morula sp.	PROCFish surveys
Morula spinosa	MNHM
Morula uva	Australia museum collection
Morula uva	Florida Museum
Murexsul cuspidatus	MNHM
Nassa serta	Australia museum collection
Nassarius (Alectrion)	Australia museum collection

Nauru macro invertebrate species record	Reference
Nassarius castus	MNHM
Nassarius concinnus	MNHM
Nassarius conoidalis	MNHM
Nassarius crematus	MNHM
Nassarius elegans	MNHM
Nassarius fraudulentus	MNHM
Nassarius glans	MNHM
Nassarius luridus	MNHM
Nassarius nodicostatus	MNHM
Nassarius splendidulus	MNHM
Nerita albicilla	Australia museum collection
Nerita plicata	Australia museum collection
Nerita plicata	Florida Museum
Nerita plicata	PROCFish surveys
Nerita polita	Australia museum collection
Nerita polita	PROCFish surveys
Nerita sp.	PROCFish surveys
Notocochlis cernica	Australia museum collection
Octopus sp.	BIORAP
Octopus sp.	PROCFish surveys
Oliva sp.	PROCFish surveys
Ophiocoma erinaceus	Florida Museum
Ophiocoma scolopendrina	Florida Museum
Orange sponge sp.	BIORAP
Ovula ovum	PROCFish surveys
Paguritta corallicola	BIORAP
Panulirus sp.	PROCFish surveys
Panulirus sp.1	BIORAP
Panulirus sp.2	BIORAP
Parahyotissa numisma	Australia museum collection
Parahyotissa numisma	Florida Museum
Parribacus antarcticus	Florida Museum
Pascahinnites coruscans	Florida Museum
Periclimenes soror	BIORAP
Periglypta reticulata	BIORAP
Periglypta reticulata	Florida Museum
Peristernia gemmata	BIORAP
Peristernia ustulata	Florida Museum
Philarius gerlachei	BIORAP

Nauru macro invertebrate species record	Reference
Phyllacanthus imperialis	BIORAP
Phyllidia carlsonhoffi	BIORAP
Phyllidia elegans	BIORAP
Pilumnus sp.	PROCFish surveys
Pilumnus vespertilio	BIORAP
Pinctada maculata	Australia museum collection
Quoyula madreporarum	Florida Museum
Sabia conica	Australia museum collection
Saron neglectus	BIORAP
Semele australis	Australia museum collection
Serpulid tube worms	BIORAP
Spirobranchus giganteus	BIORAP
Spondylus sp	BIORAP
Staphylaea staphylaea	Australia museum collection
Stenopus hispidus	BIORAP
Stichodactyla sp.	PROCFish surveys
Strombus mutabilis	Australia museum collection
Synalpheus carinatus	BIORAP
Tellina (Scutarcopagia)	Australia museum collection
Terebra crenulata	Australia museum collection
Terebra dimidiata	BIORAP
Terebra succincta	MNHM
Thais aculeata	Australia museum collection
Thais armigera	BIORAP
Thais armigera	Australia museum collection
Thais armigera	Florida Museum
Thais armigera	PROCFish surveys
Thais sp.	PROCFish surveys
Thais squamosa	Australia museum collection
Thais tuberosa	Australia museum collection
Thais virgatus	BIORAP
Thelenota ananas	BIORAP
Thelenota ananas	PROCFish surveys
Trapezia bidentata	BIORAP
Trapezia cymodoce	BIORAP
Trapezia flavopunctata	BIORAP
Trapezia rufopunctata	BIORAP
Trapezia sp. 1	BIORAP
Trapezium oblongum	Australia museum collection

Nauru macro invertebrate species record	Reference
Trapezium oblongum	Florida Museum
Tridacna maxima	BIORAP
Tridacna maxima	Australia museum collection
Tripneustes gratilla	BIORAP
Trochus histrio	Florida Museum
Trochus sp.	PROCFish surveys
Turbo argyrostomus	Australia museum collection
Turbo argyrostomus	Florida Museum
Turbo argyrostomus	PROCFish surveys
Turbo argyrostomus	BIORAP
Turbo setosus	Australia museum collection
Turbo setosus	Florida Museum
Turbo setosus	PROCFish surveys
Vasum ceramicum	BIORAP
Vasum ceramicum	Australia museum collection
Vasum ceramicum	PROCFish surveys
Vasum sp.	PROCFish surveys
Zosimus aeneus	Florida Museum

Appendix 14 FAMILY GROUPS REPRESENTED PER SITE

Family Grouping	Number of sites
Diadematidae	22
Muricidae	20
Holothuriidae	18
Trapeziidae	18
Serpulidae	13
Echinometridae	12
Alpheidae	9
Paguridae	7
Toxopneustidae	7
Ophidiasteridae	6
Cypraeidae	5
Diogenidae	5
Paguroidea	5
Sponge	5
Turbinidae	5
Stichodactylidae	4
Dairidae	3
Mitridae	3
Phyllidiidae	3
Xanthidae	3
Conidae	2
Oreasteridae	2
Spondylidae	2
Stichopodidae	2
Strombidae	2
Tridacnidae	2
Turbinellidae	2
Veneridae	2
Bonelliidae	1
Cardiidae	1
Carpiliidae	1
Domeciidae	1
Fasciolariidae	1
Hippolytidae	1
Palaemonidae	1
Pilumnidae	1
Stenopodidae	1
Terebridae	1

Appendix 15 FULL LIST OF REEF FISH SPECIES KNOWN TO OCCUR IN NAURU

All Nauruan names sourced from Cain J, Jimwereiy A, Debao A, Deiye C, Pitcher A, Roxen Agadio P, Tebano T (1997) Nauru Plant, Fish And Bird Names: A Preliminary Listing. Editor T. Tebano. Atoll Research Programme, University Of The South Pacific. Allen et al. 2003 refers to Nauruan fishers identifying fishes within the reef fish identification book "Allen, G., R. Steene, P. Humann, and N. Deloch. 2003. Reef Fish Identification Tropical Pacific. New World Publications Inc., Jacksonville, FL, pp 431"; CoFish,2005 refers to "CoFish. 2005. Nauru Country Report: Profile and Results From In-Country Survey Work. Noumea, Pacific Regional Coastal Fisheries Development Programme (CoFish), Secretariat of the Pacific Community"; SPREP, 2013 refers to a species list of reef fish species collated during a survey of aquarium fishes by Franck Magron and Collette Wabnitz during June 2013; BIORAP, 2013 refers to the survey results of the present work.

Nauruan/local	Family	Species	References
	Acanthuridae	*Acanthurus achilles*	Allen et al. 2003; SPREP, 2013
	Acanthuridae	*Acanthurus albipectoralis*	Allen et al. 2003
	Acanthuridae	*Acanthurus blochii*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
yab	Acanthuridae	*Acanthurus guttatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Acanthuridae	*Acanthurus leucocheilus*	Allen et al. 2003; CoFish, 2009
iwiji	Acanthuridae	*Acanthurus lineatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Acanthuridae	*Acanthurus nigricans*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Acanthuridae	*Acanthurus nigricauda*	CoFish, 2009
	Acanthuridae	*Acanthurus nigricaudus*	Allen et al. 2003
	Acanthuridae	*Acanthurus nigrofuscus*	Allen et al. 2003
	Acanthuridae	*Acanthurus olivaceus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Acanthuridae	*Acanthurus pyroferus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
dereba	Acanthuridae	*Acanthurus sp.*	CoFish, 2009; BIORAP, 2013
	Acanthuridae	*Acanthurus thompsoni*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
eweo	Acanthuridae	*Acanthurus triostegus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
deiboe	Acanthuridae	*Acanthurus xanthopterus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Acanthuridae	*Ctenochaetus binotatus*	Allen et al. 2003; CoFish, 2009
	Acanthuridae	*Ctenochaetus cyanocheilus/flavicauda*	BIORAP, 2013
	Acanthuridae	*Ctenochaetus marginatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Acanthuridae	*Ctenochaetus sp.*	CoFish, 2009
iubwiya	Acanthuridae	*Ctenochaetus striatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Acanthuridae	*Ctenochaetus strigosus*	SPREP, 2013
	Acanthuridae	*Naso annulatus*	CoFish, 2009; BIORAP, 2013
	Acanthuridae	*Naso brevirostris*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Acanthuridae	*Naso caesius*	Allen et al. 2003; CoFish, 2009

Nauruan/local	Family	Species	References
	Acanthuridae	*Naso hexacanthus*	Allen et al. 2003; BIORAP, 2013
irer	Acanthuridae	*Naso litturatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Acanthuridae	*Naso thynnoides*	Allen et al. 2003; CoFish, 2009
	Acanthuridae	*Naso unicornis*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Acanthuridae	*Naso vlamingii*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Acanthuridae	*Paracanthurus hepatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Acanthuridae	*Zebrasoma scopas*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Acanthuridae	*Zebrasoma veliferum*	Allen et al. 2003; CoFish, 2009; SPREP, 2013
	Apogonidae	*Pristiapogon kallopterus*	BIORAP, 2013
	Aulostomidae	*Aulostomus chinensis*	Allen et al. 2003; BIORAP, 2013
	Balistidae	*Abalistes stellatus*	Allen et al. 2003
	Balistidae	*Balistapus undulatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Balistidae	*Balistoides conspicillum*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Balistidae	*Balistoides viridescens*	Allen et al. 2003; BIORAP, 2013
	Balistidae	*Melichthys niger*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Balistidae	*Melichthys vidua*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Balistidae	*Odonus niger*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
kumum	Balistidae	*Pseudobalistes flavimarginatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Balistidae	*Rhinecanthus aculeatus*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Balistidae	*Rhinecanthus lunula*	BIORAP, 2013
	Balistidae	*Rhinecanthus rectangulus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Balistidae	*Sufflamen bursa*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Balistidae	*Sufflamen chrysopterum*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Belonidae	*Platybelone argalus*	Allen et al. 2003
	Belonidae	*Strongylura incisa*	Allen et al. 2003
iuiuj	Belonidae	*Tylosorus crocodilus crocodilus*	Allen et al. 2003; BIORAP, 2013
	Blenniidae	*Cirripectes spp1*	BIORAP, 2013
	Blenniidae	*Cirripectes spp2*	BIORAP, 2013
	Blenniidae	*Cirripectes spp3*	BIORAP, 2013
	Blenniidae	*Cirripectes spp4*	BIORAP, 2013
	Blenniidae	*Cirripectes spp5*	BIORAP, 2013

Nauruan/local	Family	Species	References
	Blenniidae	*Cirripectes spp6*	BIORAP, 2013
	Blenniidae	*Cirripectes spp7*	BIORAP, 2013
	Blenniidae	*Cirripectes springeri*	BIORAP, 2013
	Blenniidae	*Plagiotremus rhinorhunchos*	BIORAP, 2013
	Bothidae	*Bothus mancus*	BIORAP, 2013
	Caesionidae	*Caesio caerulaurea*	Allen et al. 2003
	Caesionidae	*Caesio teres*	Allen et al. 2003; BIORAP, 2013
	Caesionidae	*Pterocaesio tile*	Allen et al. 2003; BIORAP, 2013
	Caracanthidae	*Caracanthus maculatus*	BIORAP, 2013
	Carangidae	*Alectis ciliaris*	Allen et al. 2003
	Carangidae	*Carangoides ferdau*	Allen et al. 2003
	Carangidae	*Carangoides fulvoguttatus*	Allen et al. 2003
eaeo	Carangidae	*Carangoides orthogrammus*	Allen et al. 2003
	Carangidae	*Carangoides sp.*	CoFish, 2009
doruwa	Carangidae	*Caranx ignobilis*	Allen et al. 2003; BIORAP, 2013
apwe	Carangidae	*Caranx lugubris*	Allen et al. 2003
kwidada	Carangidae	*Caranx melampygus*	CoFish, 2009
	Carangidae	*Caranx nobilis*	BIORAP, 2013
	Carangidae	*Caranx papuensis*	Allen et al. 2003
apwe	Carangidae	*Caranx sexfasciatus*	Allen et al. 2003; BIORAP, 2013
	Carangidae	*Echidna polyzona*	Allen et al. 2003
eokwoy	Carangidae	*Elagatis bipinnulata*	Allen et al. 2003; BIORAP, 2013
	Carangidae	*Naucrates ductor*	Allen et al. 2003
	Carangidae	*Seriola dumerili*	Allen et al. 2003
	Carangidae	*Seriola lalandi*	Allen et al. 2003
	Carangidae	*Trachinotus baillonii*	Allen et al. 2003
	Carcharhinidae	*Carcharinus melapterus*	Allen et al. 2003
	Carcharhinidae	*Galocerdo cuvier*	Allen et al. 2003
	Carcharhinidae	*Triaenodon obesus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Chaetodontidae	*Chaetodon auriga*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Chaetodontidae	*Chaetodon bennetti*	SPREP, 2013
	Chaetodontidae	*Chaetodon citrinellus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Chaetodontidae	*Chaetodon decussatus*	BIORAP, 2013
	Chaetodontidae	*Chaetodon ephippium*	Allen et al. 2003; CoFish, 2009; SPREP, 2013

Nauruan/local	Family	Species	References
	Chaetodontidae	*Chaetodon kleinii*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Chaetodontidae	*Chaetodon lineolatus*	SPREP, 2013
	Chaetodontidae	*Chaetodon lunula*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Chaetodontidae	*Chaetodon melannotus*	SPREP, 2013
	Chaetodontidae	*Chaetodon mertensii*	Allen et al. 2003; CoFish, 2009; SPREP, 2013
	Chaetodontidae	*Chaetodon meyeri*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Chaetodontidae	*Chaetodon ornatissimus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Chaetodontidae	*Chaetodon pelewensis*	Allen et al. 2003; CoFish, 2009
	Chaetodontidae	*Chaetodon quadrimaculatus*	BIORAP, 2013
	Chaetodontidae	*Chaetodon reticulatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Chaetodontidae	*Chaetodon semeion*	BIORAP, 2013
	Chaetodontidae	*Chaetodon spp.*	BIORAP, 2013
	Chaetodontidae	*Chaetodon ulietensis*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Chaetodontidae	*Chaetodon unimaculatus*	Allen et al. 2003; CoFish, 2009; SPREP, 2013
	Chaetodontidae	*Chaetodon vagabundus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Chaetodontidae	*Forcipiger flavissimus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Chaetodontidae	*Forcipiger longirostris*	Allen et al. 2003; CoFish, 2009; SPREP, 2013
	Chaetodontidae	*Hemitaurichthys polylepis*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Chaetodontidae	*Hemitaurichthys thompsoni*	Allen et al. 2003; BIORAP, 2013
	Chaetodontidae	*Heniochus acuminatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Chaetodontidae	*Heniochus chrysostomus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Chaetodontidae	*Heniochus monoceros*	SPREP, 2013
	Chaetodontidae	*Heniochus singularius*	SPREP, 2013
	Chaetodontidae	*Heniochus varius*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
ibiya	Chanidae	*Chanos chanos*	Allen et al. 2003
	Cirrhitidae	*Amblycirrhitus biamacula*	BIORAP, 2013
	Cirrhitidae	*Cirrhitichthys oxycephalus*	BIORAP, 2013; SPREP, 2013
	Cirrhitidae	*Cirrhitichtys arcatus*	Allen et al. 2003
	Cirrhitidae	*Cirrhitichtys forsteri*	Allen et al. 2003
	Cirrhitidae	*Cirrhitichtys hemistictus*	Allen et al. 2003

Nauruan/local	Family	Species	References
	Cirrhitidae	*Cirrhitichtys oxycephalus*	Allen et al. 2003
	Cirrhitidae	*Cirrhitichtys pinnulatus*	Allen et al. 2003
	Cirrhitidae	*Neocirrhites armatus*	SPREP, 2013
	Cirrhitidae	*Paracirrhites arcatus*	BIORAP, 2013; SPREP, 2013
	Cirrhitidae	*Paracirrhites forsteri*	BIORAP, 2013; SPREP, 2013
	Cirrhitidae	*Paracirrhites hemistictus*	BIORAP, 2013
eaywiwi	Coryphaenidae	*Coryphaena hippurus*	Allen et al. 2003
	Diodontidae	*Diodon hystrix*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Diodontidae	*Diodon sp.*	CoFish, 2009
	Ephippidae	*Platax orbicularis*	Allen et al. 2003; BIORAP, 2013
	Ephippidae	*Platax teira*	Allen et al. 2003
	Fistulariidae	*Fistularia commersonii*	BIORAP, 2013
	Gobiidae	*Blenny spp1*	BIORAP, 2013
	Gobiidae	*Goby spp.*	BIORAP, 2013
	Gobiidae	*Ptereleotris zebra*	BIORAP, 2013; SPREP, 2013
	Gobiidae	*Valenciennea strigata*	BIORAP, 2013; SPREP, 2013
	Hemiramphidae	*Hyporhamphus dussumieri*	Allen et al. 2003
	Holocentridae	*Myripristis adusta*	Allen et al. 2003; BIORAP, 2013
	Holocentridae	*Myripristis amaena*	BIORAP, 2013
emwan	Holocentridae	*Myripristis berndti*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Holocentridae	*Myripristis botche*	Allen et al. 2003; CoFish, 2009
	Holocentridae	*Myripristis chryseres*	Allen et al. 2003
	Holocentridae	*Myripristis kuntee*	Allen et al. 2003; CoFish, 2009
	Holocentridae	*Myripristis murdjan*	Allen et al. 2003; CoFish, 2009
iebo	Holocentridae	*Myripristis pralinia*	CoFish, 2009
	Holocentridae	*Myripristis sp.*	CoFish, 2009
	Holocentridae	*Myripristis vittata*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Holocentridae	*Neoniphon opercularis*	Allen et al. 2003; BIORAP, 2013
	Holocentridae	*Neoniphon sammara*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Holocentridae	*Neoniphon sp.*	CoFish, 2009
	Holocentridae	*Sargocentron caudimaculatum*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Holocentridae	*Sargocentron cornutum*	Allen et al. 2003; CoFish, 2009
	Holocentridae	*Sargocentron diadema*	CoFish, 2009
	Holocentridae	*Sargocentron sp.*	CoFish, 2009

Nauruan/local	Family	Species	References
eabangingab	Holocentridae	*Sargocentron spiniferum*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
ebo	Holocentridae	*Sargocentron tiere*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Kuhlidae	*Kuhlia mugil*	Allen et al. 2003
	Kyphosidae	*Kyphosus bigibbus*	Allen et al. 2003; BIORAP, 2013
ebawo/ iyibawo	Kyphosidae	*Kyphosus cinerascens*	Allen et al. 2003
	Kyphosidae	*Kyphosus vaigiensis*	Allen et al. 2003
	Labridae	*Anampses geographicus*	SPREP, 2013
	Labridae	*Anampses meleagrides*	SPREP, 2013
	Labridae	*Anampses twistii*	SPREP, 2013
	Labridae	*Bodianus axillaris*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Labridae	*Bodianus diana*	SPREP, 2013
	Labridae	*Bodianus dictynna*	Allen et al. 2003; BIORAP, 2013
	Labridae	*Bodianus loxozonus*	SPREP, 2013
	Labridae	*Bodianus mesothorax*	Allen et al. 2003; SPREP, 2013
	Labridae	*Bolbometopon muricatum*	Allen et al. 2003
	Labridae	*Cheilinus undulatus*	Allen et al. 2003; BIORAP, 2013
	Labridae	*Cirrhilabrus exquistes*	BIORAP, 2013; SPREP, 2013
	Labridae	*Cirrhilabrus spp1*	BIORAP, 2013
	Labridae	*Cirrhilabrus spp2*	BIORAP, 2013
	Labridae	*Coris aygula*	Allen et al. 2003; CoFish, 2009; SPREP, 2013
	Labridae	*Coris gaimard*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Labridae	*Gomphosus varius*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Labridae	*Halichoeres binotopsis*	Allen et al. 2003; BIORAP, 2013
	Labridae	*Halichoeres biocellatus*	SPREP, 2013
	Labridae	*Halichoeres chrysus*	SPREP, 2013
	Labridae	*Halichoeres hortulanus*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Labridae	*Halichoeres margaritaceus*	SPREP, 2013
	Labridae	*Halichoeres marginatus*	SPREP, 2013
	Labridae	*Halichoeres melanurus*	BIORAP, 2013; SPREP, 2013
	Labridae	*Halichoeres ornatissimus*	SPREP, 2013
	Labridae	*Halichoeres scapularis*	SPREP, 2013
	Labridae	*Halichoeres spp1*	BIORAP, 2013
	Labridae	*Halichoeres spp2*	BIORAP, 2013

Nauruan/local	Family	Species	References
	Labridae	*Halichoeres trimaculatus*	SPREP, 2013
	Labridae	*Hemigymnus fasciatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Labridae	*Labrichthys unilineatus*	BIORAP, 2013
	Labridae	*Labroides bicolor*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Labridae	*Labroides dimidiatus*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Labridae	*Labroides pectoralis*	Allen et al. 2003; SPREP, 2013
	Labridae	*Labroides rubiolabiatus*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Labridae	*Labropsis xanthonota*	BIORAP, 2013
	Labridae	*Macropharyngodon meleagris*	BIORAP, 2013; SPREP, 2013
	Labridae	*Novaculichthys taeniourus*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Labridae	*Oxycheilinus digrammus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Labridae	*Pseudocheilinus evanidus*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Labridae	*Pseudocheilinus hexataenia*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Labridae	*Pseudocheilinus octotaenia*	Allen et al. 2003; BIORAP, 2013
	Labridae	*Pseudocheilinus tetrataenia*	Allen et al. 2003
	Labridae	*Pseudocoris yamashiroi*	SPREP, 2013
	Labridae	*Pseudodax mollucanus*	BIORAP, 2013; SPREP, 2013
	Labridae	*Stethojulis bandanensis*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Labridae	*Stethojulis strigiventer*	Allen et al. 2003; BIORAP, 2013
	Labridae	*Stethojulis trilineata*	Allen et al. 2003; BIORAP, 2013
	Labridae	*Thalassoma amblycephylum*	BIORAP, 2013; SPREP, 2013
	Labridae	*Thalassoma hardwicke*	BIORAP, 2013
	Labridae	*Thalassoma jansenii*	BIORAP, 2013; SPREP, 2013
	Labridae	*Thalassoma lunare*	SPREP, 2013
	Labridae	*Thalassoma lutescens*	SPREP, 2013
	Labridae	*Thalassoma purpureum*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Labridae	*Thalassoma quenquevittatum*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Labridae	*Thalassoma trilobatum*	SPREP, 2013
	Lethrinidae	*Gnathodentex aureolineatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Lethrinidae	*Gnathodentex speciosus*	Allen et al. 2003
	Lethrinidae	*Lethrinus olivaceus*	Allen et al. 2003; CoFish, 2009
eaouna	Lethrinidae	*Lethrinus xanthochilus*	Allen et al. 2003; CoFish, 2009
	Lethrinidae	*Monotaxis grandoculis*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013

Nauruan/local	Family	Species	References
	Lutjanidae	*Aphareus furca*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Lutjanidae	*Aprion virescens*	Allen et al. 2003
eanurum,	Lutjanidae	*Lutjanus bohar*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
iniame	Lutjanidae	*Lutjanus fulvus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
agen	Lutjanidae	*Lutjanus gibbus*	Allen et al. 2003
earata	Lutjanidae	*Lutjanus kasmira*	Allen et al. 2003; BIORAP, 2013
ituwabu	Lutjanidae	*Lutjanus monostigma*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Lutjanidae	*Lutjanus russellii*	Allen et al. 2003
	Lutjanidae	*Lutjanus semicinctus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Lutjanidae	*Lutjanus spp1*	BIORAP, 2013
	Lutjanidae	*Macolor macularis*	Allen et al. 2003; BIORAP, 2013
	Lutjanidae	*Macolor niger*	Allen et al. 2003; CoFish, 2009
	Molidae	*Mola mola*	Allen et al. 2003
earata	Monacanthidae	*Aluterus scriptus*	Allen et al. 2003; BIORAP, 2013
	Monacanthidae	*Amanses spp1*	BIORAP, 2013
ipwo	Monacanthidae	*Cantherhines dumerili*	Allen et al. 2003; BIORAP, 2013
	Monacanthidae	*Cantherhines pardalis*	Allen et al. 2003
	Mugilidae	*Crenimugil crenilabris*	Allen et al. 2003
ekiakuo	Mugilidae	*Liza vaigiensis*	Allen et al. 2003
	Mugilidae	*Neomyxus leuciscus*	Allen et al. 2003
	Mullidae	*Mullid spp1*	BIORAP, 2013
	Mullidae	*Mulloidichthys barberinus*	Allen et al. 2003
	Mullidae	*Mulloidichthys cyclostomus*	Allen et al. 2003
dorangarang	Mullidae	*Mulloidichthys flavolineatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Mullidae	*Mulloidichthys insularis*	Allen et al. 2003
	Mullidae	*Mulloidichthys mimicus*	Allen et al. 2003
	Mullidae	*Mulloidichthys multifasciatus*	Allen et al. 2003
	Mullidae	*Mulloidichthys pleurostigma*	Allen et al. 2003
	Mullidae	*Mulloidichthys vanicolensis*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Mullidae	*Parupeneus multifasciatus*	BIORAP, 2013
	Mullidae	*Parupeneus bifasciatus*	CoFish, 2009
	Mullidae	*Parupeneus cyclostomus*	CoFish, 2009
	Mullidae	*Parupeneus multifasciatus*	CoFish, 2009
	Mullidae	*Parupeneus pleurostigma*	CoFish, 2009
	Mullidae	*Upeneus molluccensis*	Allen et al. 2003

Nauruan/local	Family	Species	References
	Mullidae	*Upeneus vittata*	BIORAP, 2013
	Muraenidae	*Decapterus macarellus*	Allen et al. 2003
	Muraenidae	*Echidna nebulosa*	Allen et al. 2003; BIORAP, 2013
	Muraenidae	*Enchelynassa canina*	Allen et al. 2003
	Muraenidae	*Gymnomuraena zebra*	Allen et al. 2003
	Muraenidae	*Gymnothorax breedeni*	Allen et al. 2003; BIORAP, 2013
	Muraenidae	*Gymnothorax fimbriatus*	Allen et al. 2003
	Muraenidae	*Gymnothorax flavimarginatus*	Allen et al. 2003; BIORAP, 2013
	Muraenidae	*Gymnothorax javanicus*	Allen et al. 2003; BIORAP, 2013
	Muraenidae	*Gymnothorax meleagris*	Allen et al. 2003
	Muraenidae	*Gymnothorax pictus*	Allen et al. 2003; BIORAP, 2013
	Myliobatidae	*Aetobatus narinari*	Allen et al. 2003
	Myliobatidae	*Manta birostris*	Allen et al. 2003
	Myliobatidae	*Mobula tarapacana*	Allen et al. 2003
degomat	Ostraciidae	*Ostracion cubicus*	Allen et al. 2003; BIORAP, 2013
	Ostraciidae	*Ostracion meleagris*	Allen et al. 2003; SPREP, 2013
	Ostraciidae	*Ostracion whitleyi*	BIORAP, 2013
	Pempheridae	*Pempherus oualensis*	BIORAP, 2013
	Plotosidae	*Plotosus lineatus*	Allen et al. 2003
	Pomacanthidae	*Apolemichthys griffisi*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Pomacanthidae	*Apolemichthys trimaculatus*	Allen et al. 2003; CoFish, 2009; SPREP, 2013
	Pomacanthidae	*Apolemichthys xanthopunctatus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Pomacanthidae	*Centropyge bicolor*	Allen et al. 2003; CoFish, 2009; SPREP, 2013
	Pomacanthidae	*Centropyge bispinosa*	SPREP, 2013
	Pomacanthidae	*Centropyge flavissimus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Pomacanthidae	*Centropyge heraldi*	SPREP, 2013
	Pomacanthidae	*Centropyge loriculus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Pomacanthidae	*Centropyge sp.*	CoFish, 2009
	Pomacanthidae	*Centropyge vrolikii*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Pomacanthidae	*Paracentropyge multifasciata*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Pomacanthidae	*Pomacanthus imperator*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
kimago	Pomacanthidae	*Pygoplites diacanthus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013

Nauruan/local	Family	Species	References
	Pomacentridae	*Abudefduf septemfasciatus*	Allen et al. 2003; BIORAP, 2013
	Pomacentridae	*Abudefduf vaigiensis*	BIORAP, 2013
	Pomacentridae	*Amphiprion chrysopterus*	BIORAP, 2013; SPREP, 2013
	Pomacentridae	*Amphiprion clarkii*	SPREP, 2013
	Pomacentridae	*Amphiprion melanopus*	SPREP, 2013
	Pomacentridae	*Amphiprion perideraion*	BIORAP, 2013; SPREP, 2013
	Pomacentridae	*Chromis acares*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Pomacentridae	*Chromis amboinensis*	Allen et al. 2003; BIORAP, 2013
	Pomacentridae	*Chromis analis*	Allen et al. 2003; BIORAP, 2013
	Pomacentridae	*Chromis atripectoralis*	SPREP, 2013
	Pomacentridae	*Chromis margaritifer*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Pomacentridae	*Chromis opercularis*	Allen et al. 2003; BIORAP, 2013
	Pomacentridae	*Chromis spp1*	BIORAP, 2013
	Pomacentridae	*Chromis spp2*	BIORAP, 2013
	Pomacentridae	*Chromis spp3*	BIORAP, 2013
	Pomacentridae	*Chromis vanderbilti*	Allen et al. 2003; BIORAP, 2013
	Pomacentridae	*Chromis weberi*	Allen et al. 2003; BIORAP, 2013
	Pomacentridae	*Chromis xanthura*	BIORAP, 2013
	Pomacentridae	*Chrysiptera brownriggi/unimaculata*	BIORAP, 2013
	Pomacentridae	*Chrysiptera hemicyanea*	Allen et al. 2003; BIORAP, 2013
	Pomacentridae	*Chrysiptera rollandi*	BIORAP, 2013
	Pomacentridae	*Dascyllus auripinnis*	BIORAP, 2013
	Pomacentridae	*Dascyllus reticulatus*	BIORAP, 2013; SPREP, 2013
	Pomacentridae	*Dascyllus sp.*	SPREP, 2013
	Pomacentridae	*Dascyllus trimaculatus*	Allen et al. 2003; SPREP, 2013
	Pomacentridae	*Plectroglyphidodon dickii*	BIORAP, 2013; SPREP, 2013
	Pomacentridae	*Plectroglyphidodon imparipennis*	BIORAP, 2013
	Pomacentridae	*Plectroglyphidodon johnstonianus*	BIORAP, 2013; SPREP, 2013
	Pomacentridae	*Plectroglyphidodon lacrymatus*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Pomacentridae	*Plectroglyphidodon leucozomus*	Allen et al. 2003; BIORAP, 2013
	Pomacentridae	*Plectroglyphidodon phoenixensis*	Allen et al. 2003; BIORAP, 2013
	Pomacentridae	*Pomacentrus analis*	BIORAP, 2013
	Pomacentridae	*Pomacentrus coelestis*	BIORAP, 2013; SPREP, 2013

Nauruan/local	Family	Species	References
	Pomacentridae	*Pomacentrus moluccensis*	SPREP, 2013
	Pomacentridae	*Pomacentrus vaiuli*	BIORAP, 2013; SPREP, 2013
	Pomacentridae	*Stegastes albifasciatus*	BIORAP, 2013
	Pomacentridae	*Stegastes fasciolatus*	BIORAP, 2013
	Priacanthidae	*Priacanthus blochii*	Allen et al. 2003
	Priacanthidae	*Priacanthus hamrur*	Allen et al. 2003; BIORAP, 2013
	Rhincodontidae	*Rhincodon typus*	Allen et al. 2003
	Scaridae	*Cetoscarus bicolor*	CoFish, 2009
	Scaridae	*Cetoscarus ocellatus*	Allen et al. 2003
	Scaridae	*Chlorurus japanensis*	Allen et al. 2003; CoFish, 2009
	Scaridae	*Chlorurus microrhinos*	CoFish, 2009; BIORAP, 2013
	Scaridae	*Chlorurus sordidus*	BIORAP, 2013
	Scaridae	*Hipposcarus longiceps*	Allen et al. 2003
	Scaridae	*Scarus flavipectoralis*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Scaridae	*Scarus forsteni*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Scaridae	*Scarus frenatus*	CoFish, 2009
	Scaridae	*Scarus ghobban*	Allen et al. 2003
	Scaridae	*Scarus juv*	BIORAP, 2013
	Scaridae	*Scarus microrhinos*	BIORAP, 2013
	Scaridae	*Scarus niger*	CoFish, 2009; BIORAP, 2013
	Scaridae	*Scarus oviceps*	Allen et al. 2003; BIORAP, 2013
	Scaridae	*Scarus psittacus*	Allen et al. 2003; CoFish, 2009
	Scaridae	*Scarus rubroviolaceus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Scaridae	*Scarus sp.*	CoFish, 2009
	Scaridae	*Scarus spinus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Scaridae	*Scarus tricolor*	Allen et al. 2003; CoFish, 2009
egow	Scombridae	*Acanthocybium solandri*	Allen et al. 2003
	Scombridae	*Grammatorcynus bilineatus*	Allen et al. 2003
itsibab	Scombridae	*Gymnosarda unicolor*	Allen et al. 2003
	Scombridae	*Sarda orientalis*	Allen et al. 2003
	Scombridae	*Scomberoides commersonnianus*	Allen et al. 2003
	Scombridae	*Scomberomorus commerson*	Allen et al. 2003
itsibab	Scombridae	*Thunnus albacares*	Allen et al. 2003
	Scorpaenidae	*Parascorpaena spp*	BIORAP, 2013

Nauruan/local	Family	Species	References
	Scorpaenidae	*Pterois radiata*	Allen et al. 2003
	Scorpaenidae	*Pterois volitans*	Allen et al. 2003; BIORAP, 2013
	Scorpaenidae	*Scorpaenopsis diabolus*	BIORAP, 2013
	Scorpaenidae	*Sebastapistes cyanostigma*	BIORAP, 2013
	Serranidae	*Aethaloperca rogaa*	Allen et al. 2003; CoFish, 2009
iwuro	Serranidae	*Anyperodon leucogrammicus*	Allen et al. 2003; CoFish, 2009
etom	Serranidae	*Cephalopholis argus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Serranidae	*Cephalopholis leopardus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
ianit	Serranidae	*Cephalopholis miniata*	Allen et al. 2003; BIORAP, 2013
	Serranidae	*Cephalopholis sexmaculata*	Allen et al. 2003; CoFish, 2009
	Serranidae	*Cephalopholis sonnerati*	Allen et al. 2003
ianit	Serranidae	*Cephalopholis sp.*	CoFish, 2009
	Serranidae	*Cephalopholis spiloparaea*	Allen et al. 2003
	Serranidae	*Cephalopholis urodeta*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013
	Serranidae	*Epinephelus areolatus*	BIORAP, 2013
	Serranidae	*Epinephelus hexagonatus*	BIORAP, 2013
	Serranidae	*Epinephelus caeruleopunctatus*	Allen et al. 2003
earo/ ianen	Serranidae	*Epinephelus fasciatus*	Allen et al. 2003
	Serranidae	*Epinephelus fuscoguttatus*	Allen et al. 2003
iwuro	Serranidae	*Epinephelus hexagonatus*	Allen et al. 2003
	Serranidae	*Epinephelus howlandi*	CoFish, 2009
	Serranidae	*Epinephelus longispinis*	Allen et al. 2003
iwuro	Serranidae	*Epinephelus melanostigma*	CoFish, 2009
iwuro	Serranidae	*Epinephelus merra*	Allen et al. 2003; CoFish, 2009
	Serranidae	*Epinephelus polyphekadion*	Allen et al. 2003
	Serranidae	*Epinephelus sexfasciatus*	CoFish, 2009
	Serranidae	*Epinephelus spilotoceps*	CoFish, 2009
	Serranidae	*Epinephelus tukula*	Allen et al. 2003
	Serranidae	*Gracila albomarginata*	Allen et al. 2003; BIORAP, 2013
	Serranidae	*Pogonoperca punctata*	Allen et al. 2003
	Serranidae	*Pseudanthias bartlettorum*	BIORAP, 2013; SPREP, 2013
	Serranidae	*Pseudanthias dispar*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Serranidae	*Pseudanthias olivaceus*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Serranidae	*Pseudanthias pascalus*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013

Nauruan/local	Family	Species	References
erenai	Serranidae	*Variola louti*	Allen et al. 2003
	Siganidae	*Siganus argenteus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013
	Siganidae	*Siganus punctatus*	Allen et al. 2003; CoFish, 2009
degabouwa	Sphyraenidae	*Sphyraena barracuda*	Allen et al. 2003
	Sphyraenidae	*Sphyraena forsteri*	Allen et al. 2003
etaro	Sphyraenidae	*Sphyraena jello/qenie*	BIORAP, 2013
	Sphyraenidae	*Sphyraena obtusata*	Allen et al. 2003
	Sphyrnidae	*Sphyrna mokarran*	Allen et al. 2003
	Tetraodontidae	*Arothron hispidus*	Allen et al. 2003; BIORAP, 2013
	Tetraodontidae	*Arothron meleagris*	Allen et al. 2003; BIORAP, 2013; SPREP, 2013
	Tetraodontidae	*Arothron nigropunctatus*	Allen et al. 2003; SPREP, 2013
	Tetraodontidae	*Arothron sp.*	CoFish, 2009
	Tetraodontidae	*Arothron stellatus*	Allen et al. 2003; BIORAP, 2013
	Tetraodontidae	*Canthigaster spp1*	BIORAP, 2013
	Tripterygiidae	*Triplefin spp1*	BIORAP, 2013
	Tripterygiidae	*Triplefin spp2*	BIORAP, 2013
	Tripterygiidae	*Triplefin spp3*	BIORAP, 2013
	Tripterygiidae	*Triplefin spp4*	BIORAP, 2013
	Zanclidae	*Zanclus cornutus*	Allen et al. 2003; CoFish, 2009; BIORAP, 2013; SPREP, 2013

Appendix 16

NUMBER OF INDIVIDUALS, MEAN DENSITIES AND MEAN BIOMASS OF ALL FINFISH SPECIES RECORDED IN THE 2013 NAURU BIORAP

Famillies / Species	No. of individuals	Total Mean Densities	Total Mean Biomass
Acanthuridae	**3009**	**0.3009**	**35.53**
Acanthurus albipectoralis	50	0.005	0.24
Acanthurus guttatus	6	0.0006	0.11
Acanthurus lineatus	220	0.022	3.76
Acanthurus nigricans	613	0.06	5.54
Acanthurus nigrofuscus	2	0.0002	0.0098
Acanthurus olivaceus	2	0.0002	0.0212
Acanthurus pyroferus	10	0.001	0.0073
Acanthurus triostegus	264	0.02	1.31
Ctenochaetus binotatus	Out of Transect		
Ctenochaetus marginatus	252	0.02	2.96
Ctenochaetus striatus	825	0.08	9.52
Naso brevirostris	10	0.001	0.76
Naso hexacanthus	23	0.002	3.69
Naso lituratus	171	0.017	4.07
Naso unicornis	3	0.0003	0.16
Naso vlamingii	15	0.0015	2.12
Paracanthurus hepatus	2	0.0002	0.063
Zebrasoma scopas	496	0.049	1.071
Zebrasoma veliferum	32	0.0032	0.042
Aulostomidae	**1**	**0.0001**	**0.009**
Aulostomus chinensis	1	0.0001	0.009
Balistidae	**1710**	**0.171**	**19.62**
Balistapus undulatus	169	0.016	2.17
Balistoides conspicillum	5	0.0005	0.16
Balistoides viridescens	3	0.0003	1.06
Melichthys niger	378	0.037	6.53
Melichthys vidua	560	0.056	7.87
Odonus niger	520	0.052	1.35
Pseudobalistes flavimarginatus	Out of Transect		
Rhinecanthus rectangulus	4	0.0004	0.019
Sufflamen bursa	49	0.0049	0.28
Sufflamen chrysopterum	22	0.0022	0.14
Belonidae	**0**	**0**	**0**
Tylosurus crocodiluscrocodilus	0	0	0
Caesionidae	**200**	**0.02**	**5.63**

Famillies / Species	No. of individuals	Total Mean Densities	Total Mean Biomass
Caesio caerulaurea	15	0.0015	0.14
Caesio teres	185	0.018	5.49
Pterocaesio tile	Out of Transect		
Carangidae	**33**	**0.0033**	**1.96**
Carangoides ferdau	9	0.0009	0.7
Carangoides orthogrammus	2	0.0002	0.15
Caranx lugubris	18	0.0018	0.35
Caranx melampygus	4	0.0004	0.74
Caranx papuensis	Out of Transect		
Caranx sexfasciatus	Out of Transect		
Elagatis bipinnulata	Out of Transect		
Trachinotus baillonii	Out of Transect		
Carcharhinidae	**18**	**0.0018**	**25.84**
Triaenodon obesus	18	0.0018	25.84
Chaetodontidae	**710**	**0.071**	**3.64**
Chaetodon auriga	44	0.0044	0.32
Chaetodon citrinellus	2	0.0002	0.0048
Chaetodon ephippium	4	0.0004	0.029
Chaetodon kleinii	45	0.0045	0.12
Chaetodon lunula	217	0.021	1.67
Chaetodon meyeri	197	0.019	0.8
Chaetodon ornatissimus	22	0.0022	0.12
Chaetodon reticulatus	3	0.0003	0.013
Chaetodon ulietensis	Out of Transect		
Chaetodon vagabundus	33	0.0033	0.19
Forcipiger flavissimus	96	0.0096	0.12
Forcipiger longirostris	Out of Transect		
Hemitaurichthys polylepis	Out of Transect		
Hemitaurichthys thompsoni	40	0.004	0.15
Heniochus acuminatus	Out of Transect		
Heniochus chrysostomus	4	0.0004	0.052
Heniochus varius	*3*	*0.0003*	*0.0053*
Diodontidae	**9**	**0.0009**	**4.031**
Diodon hystrix	*9*	*0.0009*	*4.031*
Ephippidae	**0**	**0**	**0**
Platax orbicularis	Out of Transect		
Fistulariidae	**1**	**0.0001**	**0.0036**
Fistularia commersonii	1	0.0001	0.0036
Holocentridae	**181**	**0.018**	**1.4**
Myripristis amaena	Out of Transect		

Famillies / Species	No. of individuals	Total Mean Densities	Total Mean Biomass
Myripristis berndti	70	0.007	0.57
Myripristis vittata	1	0.0001	0.0072
Neoniphon Sammara	2	0.0002	0.027
Sargocentron caudimaculatum	92	0.0092	0.73
Sargocentron spiniferum	Out of Transect		
Sargocentron tiere	16	0.0016	0.06
Kyphosidae	**10**	**0.001**	**0.72**
Kyphosus cinerascens	Out of Transect		
Kyphosus vaigiensis	10	0.001	0.72
Labridae	**1**	**0.0001**	**0.03**
Cheilinus undulatus	Out of Transect		
Coris aygula	Out of Transect		
Hemigymnus fasciatus	1	0.0001	0.03
Hemigymnus melapterus	Out of Transect		
Oxycheilinus unifasciatus	Out of Transect		
Lethrinidae	**295**	**0.029**	**7.51**
Gnathodentex aureolineatus	265	0.026	5.37
Lethrinus xanthochilus	Out of Transect		
Monotaxis grandoculis	30	0.003	2.13
Lutjanidae	**76**	**0.0076**	**2.02**
Aphareus furca	41	0.0041	1.07
Aprion virescens	Out of Transect		
Lutjanus bohar	1	0.0001	0.0004
Lutjanus fulvus	28	0.0028	0.71
Lutjanus gibbus	Out of Transect		
Lutjanus kasmira	Out of Transect		
Lutjanus monostigma	5	0.0005	0.10
Lutjanus semicinctus	1	0.0001	0.12
Macolor macularis	Out of Transect		
Monacanthidae	**18**	**0.0018**	**0.18**
Aluterus scriptus	7	0.0007	0.07
Cantherhines dumerilii	7	0.0007	0.095
Cantherhines pardalis	4	0.0004	0.02
Mugilidae	**0**	**0**	**0**
Crenimugil crenilabis	Out of Transect		
Mullidae	**260**	**0.026**	**6.72**
Mulloidichthys mimicus	252	0.0252	6.5
Mulloidichthys vanicolensis	Out of Transect		
Parupeneus barberinus	Out of Transect		
Parupeneus crassilabris	1	0.0001	0.094

Famillies / Species	No. of individuals	Total Mean Densities	Total Mean Biomass
Parupeneus cyclostomus	4	0.0004	0.07
Muraenidae	**0**	**0**	**0**
Echidna nebulosa	Out of Transect		
Gymnothorax breedeni	Out of Transect		
Gymnothorax flavimarginatus	Out of Transect		
Gymnothorax javanicus	Out of Transect		
Pempheridae	**78**	**0.0078**	**0.89**
Pempheris adusta	78	0.0078	0.89
Priacanthidae	**0**	**0**	**0**
Priacanthus Hamrur	Out of Transect		
Scaridae	**143**	**0.0143**	**12.15**
Chlorurus microrhinos	11	0.0011	1.25
Hipposcarus longiceps	Out of Transect		
Scarus forsteni	1	0.0001	0.03
Scarus frenatus	19	0.0019	1.37
Scarus niger	8	0.0008	0.34
Scarus oviceps	4	0.0004	0.17
Scarus rubroviolaceus	86	0.0086	8.27
Scarus tricolor	10	0.001	0.53
Serranidae	**223**	**0.0223**	**1.56**
Aethaloperca rogaa	1	0.0001	0.007
Anyperodon leucogrammicus	Out of Transect		
Cephalopholis argus	13	0.0013	0.38
Cephalopholis leopardus	27	0.0027	0.11
Cephalopholis miniata	Out of Transect		
Cephalopholis spiloparaea	Out of Transect		
Cephalopholis urodeta	130	0.013	0.79
Epinephelus hexagonatus	50	0.005	0.22
Epinephelus melanostigma	Out of Transect		
Epinephelus spilotoceps	2	0.0002	0.039
Gracila albomarginata	Out of Transect		
Siganidae	**571**	**0.057**	**24.83**
Siganus argenteus	571	0.057	24.83
Sphyraenidae	**0**	**0**	**0**
Sphyraena barracuda	Out of Transect		
Zanclidae	**173**	**0.017**	**9.17**
Zanclus cornutus	173	0.017	9.17

Appendix 17

MEAN PERCENT BENTHIC COVER FOR REEF SITES SURVEYED IN NAURU

The number of 20m transects surveyed (n) along each 100m transect at depth (shallow < 11m, and deep 12m plus), biota/substrata were categorized as: Hard Coral (HC), Macro Algae (MA), Turf Algae (TA), Calcareous Algae (CCA), cyanobacteria (Cyano), Rubble (RB), Sand (SD). Other category represents invertebrates such as echinoderms, anemones etc. Percent mean is given with standard error below in parentheses. In cases where there were less than three replicates, no standard error is given.

Site	N	Depth	HC	CCA	MA	TA	Cyano	Sand	RB	Other
1	2	deep	21.2	42.5	0	3.7	0	18.7 (1.2)	13.7 (11.2)	0
1	4	shallow	40 (4.6)	36.2 (4.8)	0	18 (2.8)	0	5.6 (3.3)	0	0
2	4	deep	18.7 (8.6)	33.1 (7.6)	0	15.6 (1.6)	0.6 (0.6)	13.7 (3.9)	18.1 (2.4)	0
2	4	shallow	54.4 (17)	16.9 (7.4)	0	7.5 (4.4)	0.6 (0.6)	10.6 (6.5)	10 (4.2)	0
3	2	deep	76.2	11.2	7.5	1.2	0	0	3.7 (3.7)	0
3	4	shallow	80.6 (1.9)	8 (0.6)	5 (1.8)	2.5 (1.8)	0	1.8 (1.2)	1.9 (1.2)	0
4	4	deep	13.7 (2.2)	51.9 (2.1)	23.1 (7.5)	1.9 (0.6)	0	6.9 (2.8)	2.5 (1.4)	0
4	4	shallow	35 (7.6)	51.2 (8.1)	0.6 (0.6)	6.9 (3.3)	0	0	6.2 (3.0)	0
5	4	deep	45 (4.2)	23.1 (4.5)	25 (6.7)	0	0	4.4 (0.6)	2.5 (1.0)	0
5	4	shallow	63.7 (3.1)	11.2 (3.1)	25 (3.2)	0	0	0	0	0
6	4	deep	23.7 (3.6)	51.9 (3.1)	20.6 (2.8)	0	0	1.2 (1.2)	2.5 (1.4)	0
7	4	deep	30.6 (5.7)	41.2 (4.3)	24.4 (3.1)	0.6 (0.6)	0	3.1 (1.9)	0	0
8	3	deep	45 (7.2)	30.8 (3.6)	12.5 (2.5)	0	0	1.7 (1.7)	10 (5.0)	0
9	4	deep	60.6 (3.7)	10.6 (3.3)	20 (3.2)	3.7 (2.4)	1.2 (1.2)	1.2 (1.2)	1.9 (1.2)	0.6 (0.6)
9	4	shallow	75 (4.4)	3.7 (1.2)	10.6 (4.1)	8.7 (3.1)	0	1.9 (1.2)	0	0
10	4	deep	56.2 (5.8)	11.2 (4.7)	14.4 (3.1)	0	0	2.5 (1.4)	15.6 (5.1)	0
11	4	deep	56.9 (8.4)	15 (9.6)	0	0	0	5 (1.8)	23.1 (12.4)	0
11	4	shallow	78.1 (4.1)	6.2 (3.3)	0	3.1 (2.4)	0.6 (0.6)	0.6 (0.6)	11.2 (5.1)	0

Site	N	Depth	HC	CCA	MA	TA	Cyano	Sand	RB	Other
12	4	deep	34.4 (4.0)	15.6 (9.1)	31.2 (1.6)	0	0	1.9 (1.2)	16.9 (9.5)	0
13	4	deep	55 (6.2)	12.5 (1.8)	10 (2.7)	0	0	5 (5)	17.5 (6.0)	0
13	4	shallow	74.4 (5.6)	3.7 (2.4)	13.7 (3.0)	0	0	1.2 (1.2)	6.9 (4.2)	0
14	4	deep	88.7 (8.7)	2.5 (0)	0	0	0	3.1 (3.1)	5.6 (5.6)	0
14	4	shallow	89.4 (4.1)	6.9 (1.9)	1.2 (1.2)	2.5 (2.5)	0	0	0	0
15	4	deep	78.7 (4.6)	8.7 (2.2)	0	1.9 (1.2)	1.2 (1.2)	0	0	0
15	4	shallow	91.2 (3.1)	5.6 (4.0)	0	0	0	0.6 (0.6)	2.5 (1.4)	0
16	4	deep	87.5 (2.7)	6.2 (3.1)	0	1.9 (1.2)	0.6 (0.6)	0	0	0
16	4	shallow	85 (1.0)	10 (1.0)	0	1.9 (1.2)	1.2 (1.2)	1.2 (0.7)	0.6 (0.6)	0
17	4	deep	61.9 (5.8)	13.1 (4.8)	3.7 (3.0)	0	1.9 (1.2)	1.2 (1.2)	17.5 (7.4)	0.6 (0.6)
17	4	shallow	68.1 (6.9)	9.4 (3.4)	0	6.2 (4.7)	0	0.6 (0.6)	15.6 (5.7)	0
18	4	deep	58.1 (2.1)	10 (5.9)	0	0.63 (0.63)	0	1.7 (0.8)	24.2 (6.8)	0
19	4	deep	36.2 (4.8)	26 (2.4)	1.2 (1.2)	27 (4.4)	0.6 (0.6)	2.5 (1.0)	5 (1.8)	1.2 (0.7)
20	4	deep	11.2 (2.4)	31.9 (5.1)	23 (4.0)	0	0.6 (0.6)	16.2 (4.6)	16.9 (5.5)	0
21	4	shallow	16.9 (2.8)	16.2 (6.0)	0	41.2 (5.1)	1.2 (0.7)	10 (3.1)	14.4	0

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