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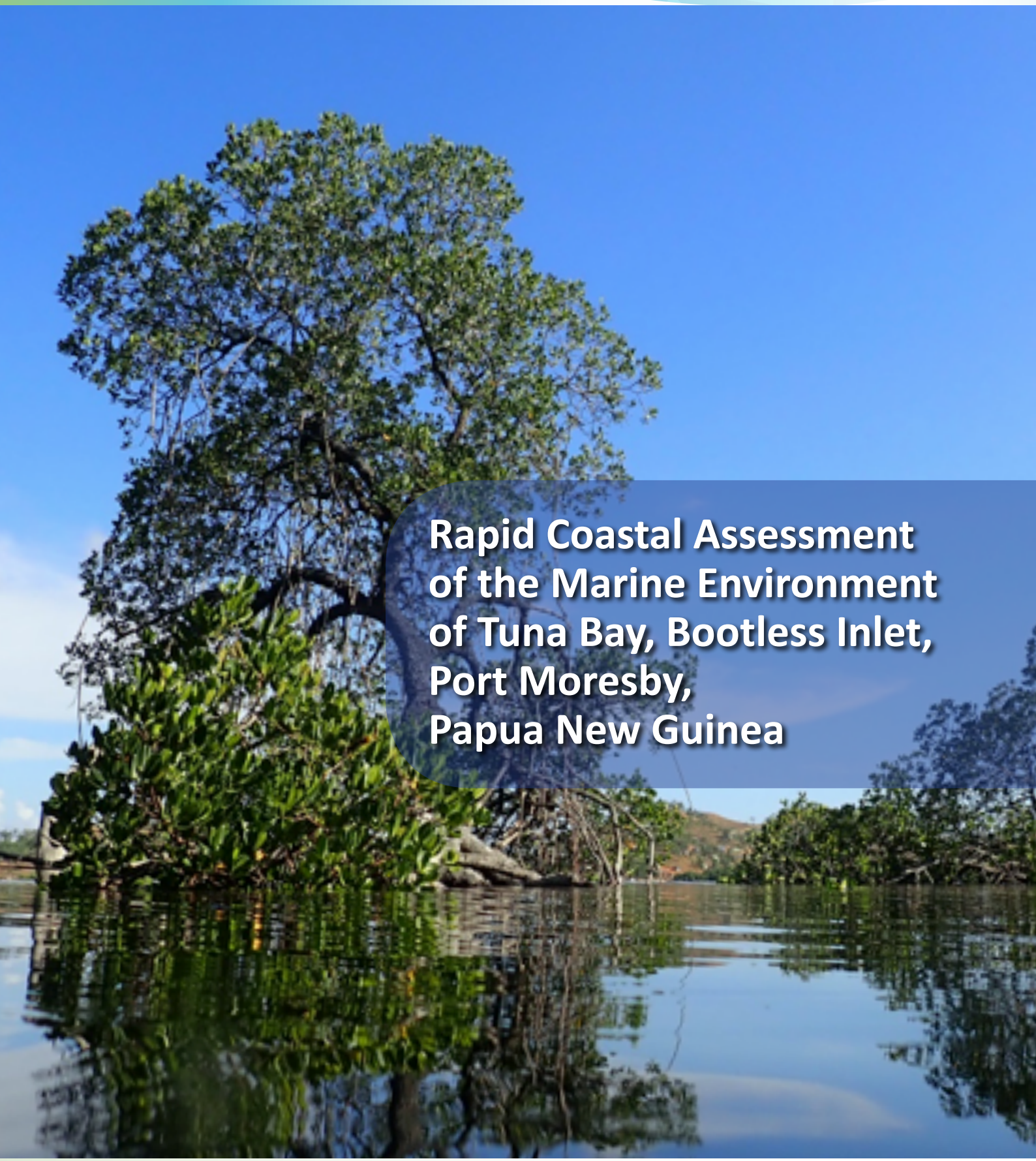

Rapid Coastal Assessment of the Marine Environment of Tuna Bay, Bootless Inlet, Port Moresby, Papua New Guinea

Conservation and Environment Protection Authority

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Rapid Coastal Assessment of the Marine Environment of Tuna Bay, Bootless Inlet, Port Moresby, Papua New Guinea

Prepared for the Pacific Ridge to Reef Programme,
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Pacific Community (SPC), Suva, Fiji

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ABBREVIATIONS

BOD	biological oxygen demand
CBNP	Centre for Biodiversity and Natural Products
CEPA	Conservation and Environment Protection Authority
CFU	colony forming units
COD	chemical oxygen demand
CPUE	catch per unit effort
DO	dissolved oxygen
GEF	Global Environment Facility
HCV	high conservation value
IW R2R	International Waters Ridge to Reef project
MPN	most probable number
UPNG	University of Papua New Guinea
SPC	Pacific Community
TDS	total suspended solids
NCD	National Capital District
NCDC	National Capital District Commission
NGO/CBO	non-government organisation/community-based organisation
TBC	total bacteria count

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ACKNOWLEDGEMENTS

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INTRODUCTION

This report presents the review and rapid coastal assessment results of the Tuna Bay biodiversity and water quality conducted from 27 November to 10 December, 2018.

The Conservation and Environment Protection Authority (CEPA) initiated the Tuna Bay marine biodiversity and water quality rapid assessments. However, the actual work and evaluations were carried out by the Centre for Biodiversity and Natural Products (CBNP) and the University of Papua New Guinea (UPNG).

The area of Tuna Bay is approximately 2.0 km^2 of land and seascape on the waterfront of Port Moresby South Electorate in the National Capital District (NCD), Papua New Guinea. Eucalyptus-savannah grasses and mangrove forests of high biodiversity surround Tuna Bay. There is a relatively small and shallow (15 m depth) inlet on the Northwest side of Bootless Bay, a historical site and area for tuna spawning and feeding. Figure 1 shows the features of Tuna Bay relative to Central Province and Capital District.

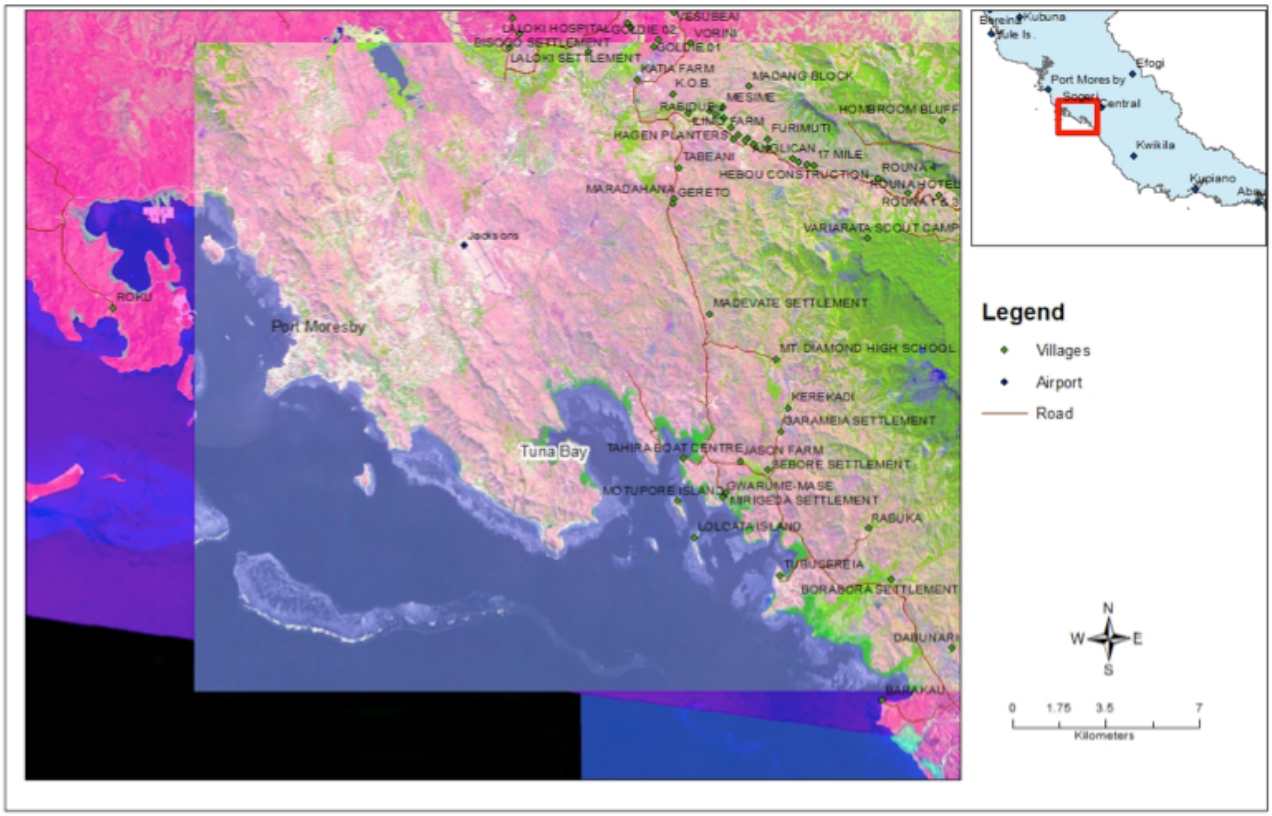


Figure 1. Tuna Bay relative to Central Province and the National Capital District.

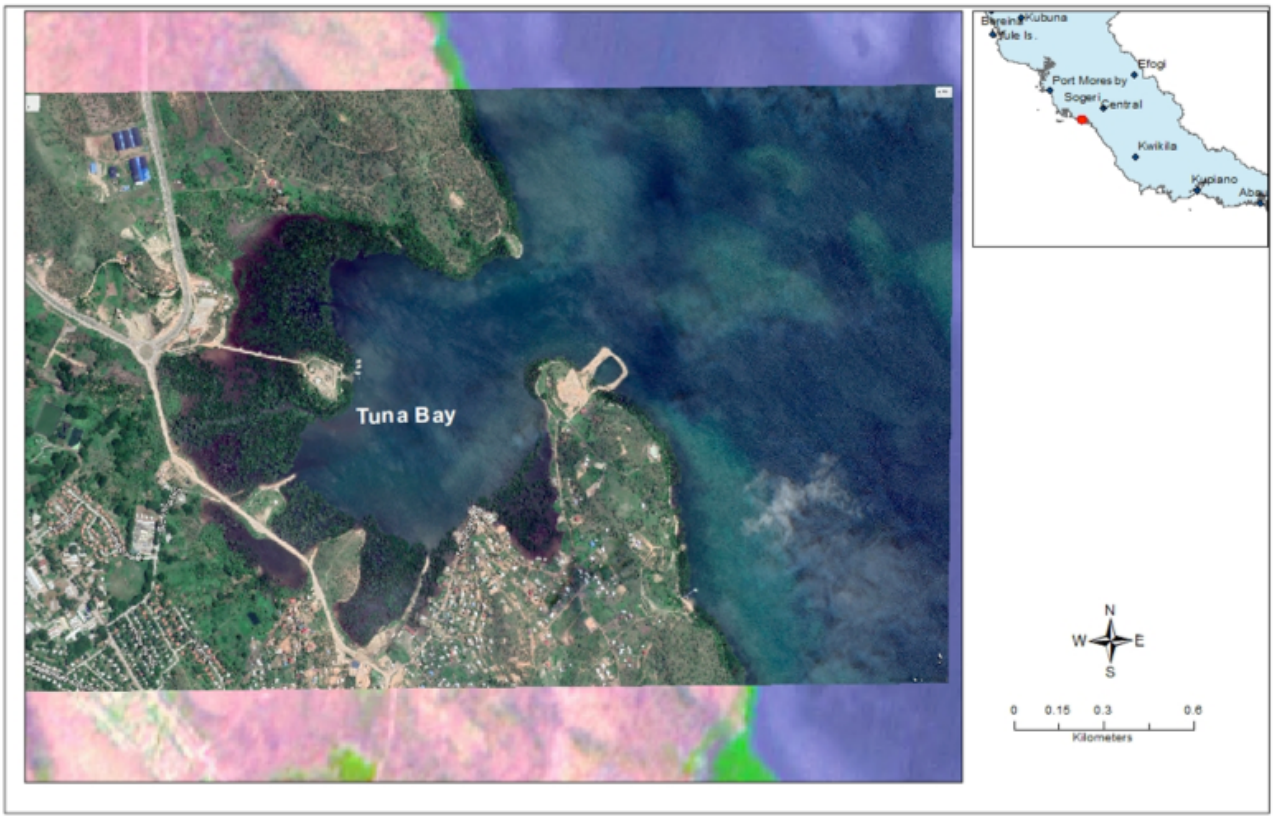


Figure 2. Tuna Bay area

Tuna Bay hosts the last remaining cultural heritage of the Motu-Koita people who are the landowners of the Tuna Bay and Port Moresby areas. There are villages within the vicinity of the bay and surrounding areas such as Pari and Tuna Bay/Taurama Villages.

The Tuna Bay area is under imminent threat from the expansion of the city as well as from settlements that are sprawling around the bay and city area. This would lead to rapid environmental degradation that is facilitated by weak governance and increasing land sales by the local landowners.

Project Background

CEPA is the host agency of the PNG National International Waters Ridge to Reef (IW R2R) project. The IW R2R project is coordinated and administered by the Pacific Community (SPC) and reports to the United Nations Development Programme as the implementing Agency. The Global Environment Facility (GEF) funds the IW R2R project along with the STAR[1] R2R project, as child projects of the GEF Pacific R2R Program.

The GEF Pacific R2R Program's objective is to maintain and enhance ecosystem goods and services of Pacific islands countries through integrated approaches to land, water, forest, biodiversity, and coastal management that contribute to poverty reduction, sustainable livelihoods and climate resilience. This report is the result of a rapid assessment of priority coastal areas conducted in Tuna Bay, and is an activity of the IW R2R project. The GEF funded IW R2R project tests the mainstreaming of R2R, climate resilience approaches to integrated land, water, forest and coastal management in 14 PICs through strategic planning, capacity building and piloted local actions to sustain livelihoods and preserve ecosystem services.

[1] STAR is the GEF System for Transparent Allocation of Resources

The PNG IW R2R demonstration project site is the Tuna Bay Area, which aimed to deliver on stress reduction target of 220 ha area conserved and protected. The IW R2R project site runs alongside the Bootless Bay Marine Conservation Initiative (BBMCI) Project, which includes the entire Bootless Bay supported by JICA.

The PNG Project Coordination Unit (PCU), with supervision from CEPA and the Regional Project Coordination Unit housed with the Pacific Community (RPCU-SPC), set up a Project Steering Committee (PSC) to provide oversight and guidance to the PNG IW R2R Project. The PSC membership is cross-sectoral and multi-disciplinary, covering relevant agencies in government and civil society, including representatives from community groups, landowners and settlers. The current members are representatives from CEPA as Chair, National Fisheries Authority (NFA), University of PNG (UPNG), National Capital District Commission (NCDC), and relevant Government Agencies with support and collaboration from non-government and community-based organisations (NGOs/CBOs) and private sector.

Project Terms of Reference

There are two main terms of reference (TORs) for this IW R2R Project on Rapid Coastal Assessment for the Tuna Bay Project, which are the Rapid (i) Biodiversity Assessments (mangroves and marine ecosystems) and (ii) Water Quality Assessment.

PROJECT OBJECTIVES

This project will enable CEPA to test its Protected Area Policy. This policy ensures sustainable livelihood development for the local communities within the Tuna Bay area, the Bootless Bay area and both the National Capital District and Central Province. If successfully implemented and targets are achieved, the IW R2R project would have assisted in delivering PNG's first Marine Protected Area.

Rapid Assessment Approach

In this rapid coastal assessment, the Consultants considered several assessment approaches, planned and executed a study strategy. The assessment team conducted scoping and initial visits to the sites. The group visited and held discussions with traditional landowners and the new settlers to reach mutual understanding and agreement for the rapid coastal assessment to proceed. All stakeholders were advised of their roles in the project implementation.

The Consultants conducted two reconnaissance visits before sampling, the first on 8 November, 2018, and the second on 27 November, 2018. We accessed Tuna Bay from land on the first visit and by sea on a follow-up visit. There was considerable degradation of mangrove habitats on the eastern portion of the bay (Figure 3, 4).

Figure 3. Pictures from the first site visit to Tuna Bay. Removal of back mangroves were observed on the western portion of Tuna Bay.

Figure 4. Pictures from the second site visit. Healthy mangroves were observed at the western portion of Tuna Bay.

For the biodiversity assessment, the initial approach was to conduct an inventory assessment of the biodiversity of the entire area encompassing all habitats observed in Tuna Bay. The focus of the inventory assessment was on overall biodiversity patterns rather than an extensive or detailed assessment of specific taxa or habitats.

We compared the results from the assessment of Tuna Bay with the results of a recent biodiversity survey (Piskaut et al. 2018) conducted on the adjacent Bogoro Inlet and Motupore Island 5.0 km south-east of Tuna Bay, within Bootless Bay.

GENERAL BACKGROUND TO TUNA BAY

Geology

The geology of the general Port Moresby area consists of Late to Middle Eocene beds, separated into three distinct beds – Paga beds, Baruni limestone and Nebiri Limestone (JICA 1998). The Paga Beds are common throughout the Tuna Bay area.

Topography

Tuna Bay is generally within a denudational landform, mainly characterised by undulating hills, ridges and low coastal plains. The bay area is also flat to gently sloping with some roving hills, and ridges mostly inland of Pari and Taurama have more relief. Elevations throughout the Bay area generally range from sea level to 120 m (Bryan and Shearman 2008).

Hydrology

Within the bay area, there are several existing creeks and waterways discharging into the bay. For most of these creeks and waterways, during the rainy periods, large volumes of freshwater, sediment and debris export downstream at various flow rates and enter the bay (Hall 1984). In the last 10 years, the quantities of rainwater and sediments passing through these creeks and waterways and discharging into the bay have increased due to denudation of land cover from vegetation by settlements (Pacific Climate Change Science Program 2011; Papua New Guinea National Weather Service 2021). This also includes domestic and some industrial wastes – an additional source of pollution into the bay.

Soils

The Tuna Bay area is characterised by the surrounding low mountains, hills and valleys with different soil compositions and depth in each landform (Bleeker 1983). The hilly regions have *Ustorthents* soils, which are typical of relatively dry and strongly seasonal climate areas and vary in colour from black, dark grey to greyish brown sandy loams and clays (McIntosh and Doyle 2015). The plains and valley areas are prominently *Tropopsamments.* This is a well-drained soil with thin dark topsoil. These soils are generally poorly graded and sometimes contain moderate amounts of erodible materials (Bleeker 1988).

Vegetation

Apart from the mangroves surrounding the Tuna Bay area, much of the area is generally featured by disturbed eucalyptus-savannah grassland vegetation.

Biodiversity within Tuna Bay area

The biodiversity status within the Tuna Bay is yet to be determined by this study. However, past research around the Bootless Bay area of which Tuna Bay is a part (Baine and Harasti 2007, Drew et al. 2012), suggests that Tuna Bay may have a high biodiversity of marine and terrestrial plants and animals. This study seeks to identify sites of high conservation values within the bay and its surrounding areas.

Population

The original landowners of Tuna Bay area, before the recent migrations of people settling in the area, live in the villages of Pari and Taurama (Stone 1876). They are the Motu and Koita speaking people (Groves et al. 1958). Recent demographic data put the Port Moresby population at around 365,000 inhabitants, or 5 per cent of the total PNG population, with an annual growth rate of around 3 per cent (National Statistical Office 2015). Such a large influx of population would inevitably stress available natural resources in the larger Port Moresby and Bootless Bay area, especially if liquid and solid waste disposal methods are not adequately controlled.

Land- and Seascapes Use Patterns

Due to the increasing demand for housing in Port Moresby, the traditional landowners of the Taurama area have been issuing leasehold agreements to settlers, mainly from Port Moresby. They have been building homes with no proper settlement plan (Tull 2011). Originally, people accessed the Taurama area through the Taurama Army Barracks, which is strictly controlled by the Papua New Guinea Defence Force (PNGDF). In 2012, a road was built around the Taurama Barracks through the mangroves. This road has enabled secure access to the Taurama area. Recently in 2015, a sealed road linking the Taurama and Dogura areas has enabled more people to have access to lands surrounding the Tuna Bay.

Since 2012, more people have moved into Taurama, and this trend will continue until demand for settling in the area subsides. In contrast to the Taurama Army Barracks, the new settlers in the area have no municipal services. While the new settlers will demand municipal services from Port Moresby city, many residents of Port Moresby now access Taurama and Tuna Bay areas for recreation. Several stakeholders in the Taurama area are concerned about the unregulated, unapproved and unplanned development (Tull 2011). This concern is a management issue of paramount importance due to anthropogenic impacts related to these issues. As more people have access to the Taurama area, there will be an increase in the demand for resources to sustain the needs brought about by this change. Consequently, the degradation of habitats and waste pollution will increase over time.

Dogura and Taurama Development Plans

In time, the expanding city of Port Moresby will inevitably engulf Tuna Bay. The National Capital District Commission (NCDC) has proposed the Dogura and Taurama Local Development Plan (Tull 2011). The plan (Figure 5) is currently being implemented, and the locals (traditional landowners) within the development areas are responding to these new societal changes.

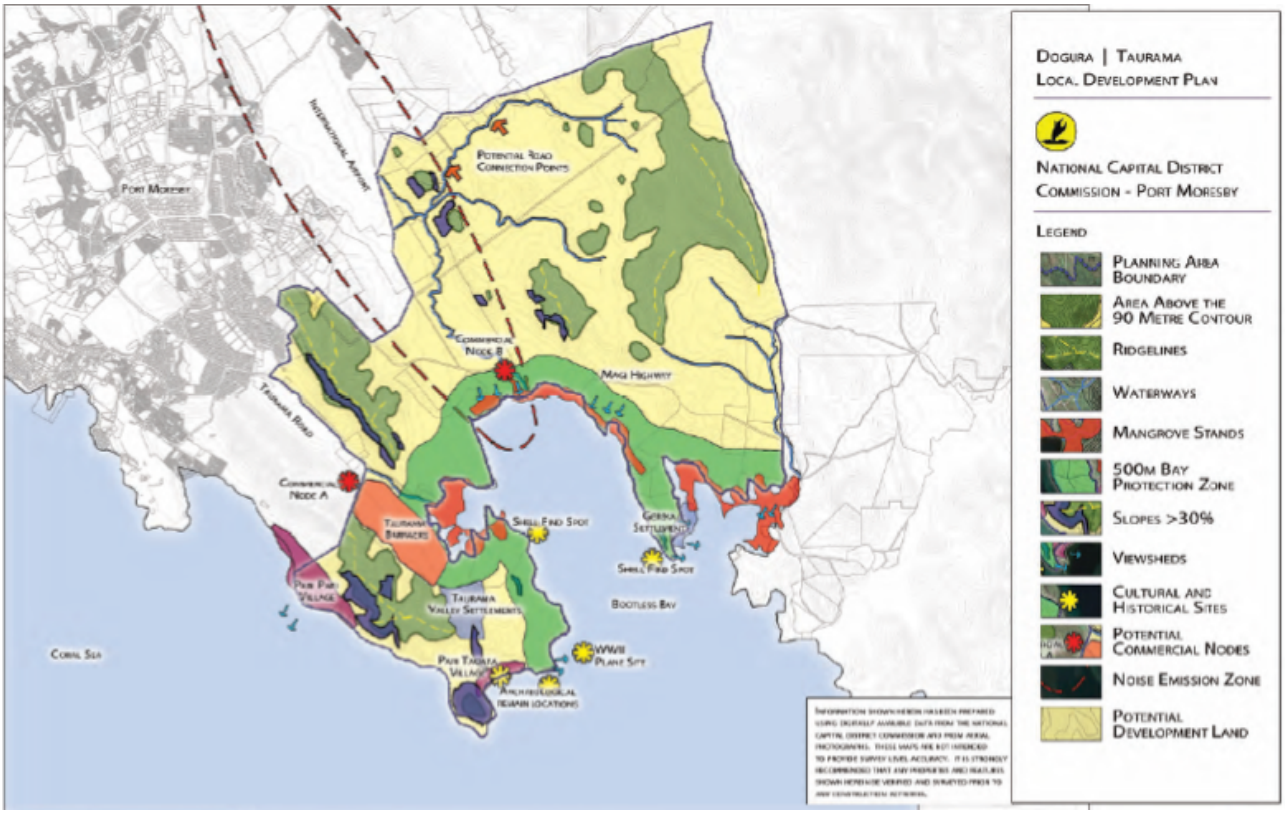


Figure 5. Dogura/ Taurama local development plan. Source: NCDC.

From 2012 to 2015, the Government constructed roads linking Port Moresby with the Taurama and Dogura areas. These roads have enabled people to have easy access to the lands and natural resources of the north-west side of Bootless Bay. The Tuna Bay area features prominently here, providing space for settlements.

Consequently, the Tuna Bay ecosystem is changing rapidly, but changes have not been monitored and documented. Therefore, relevant ecological information is lacking, which is necessary to ensure that changes brought about by the development plan are environmentally friendly while allowing the natural resources to continue supporting the original and new inhabitants of the area.

Large scale changes such as removal of mangroves are visible and receive immediate attention. Still, changes to habitats will change the environmental (trophic structures) systems in the long term with ramifications on human livelihoods. Importantly, the negative impacts of the Dogura/Taurama local development plan on natural resources, such as loss of local species and degradation of habitats and subsequent impact on the local people, in these areas, are of concern to all stakeholders and need to be prevented or alleviated.

The local development plan has a 500 m protection zone around the NCD's north-west side of Bootless Bay. However, this zone is probably not implementable since much of it is under customary land tenure, and consent is required to avoid future legal challenges.

The development plan should also include strategies for the sustainable use and development of natural resources, especially natural scenic land and seascapes and essential food and commercial species. In the absence of such policies, the changes relating to development prospects are increasing the pressures on natural resources. Currently, the sustainability of natural resource utilisation in Tuna Bay is uncertain, and it is a significant challenge for both the landowners and the government.

BIODIVERSITY ASSESSMENT

The Tuna Bay biodiversity assessment has two components:

1. Mangrove Ecosystem Assessment.
2. Marine Ecosystem Assessment.

The Terms of Reference for this biodiversity assessment are: -

i. Conduct a desktop review of historical and present environmental, socioeconomic and cultural information of the area;

ii. Sample and assess the landscape, mangroves, estuaries and the sea of the Tuna Bay area; and

iii. Provide in a report a bibliography; and lists of habitat types and of known species of mangroves, seagrasses, macroalgae, corals, crustaceans, echinoderms, fishes, reptiles, mammals and birds of the Tuna Bay area. The list of observed species fauna and flora is annexed to the report and their spatial distributions indicated on maps.

This report documents the biodiversity of Tuna Bay. It establishes a baseline status of the area, and the outcomes useful to inform policy planning and decision making for Tuna Bay and to upscale future R2R investments and Integrated Coastal Management planning to other regions in the country.

Mangrove Ecosystems

Introduction

Mangrove ecosystems occur in the estuaries and intertidal zones of many coastal areas in the tropics, including the Tuna Bay near Port Moresby (Ellison 1997; Maniwavie 2007 and Piskaut et al. 2018). Estuaries and intertidal zones are often characterised by freshwater runoff, sedimentation, tidal currents, waves and weather. These environmental factors are highly variable and their patterns affect salinity, temperature, pH, nutrient levels and microbial community. Despite this variability and changing trends, mangrove species are well adapted to the estuaries and intertidal zones, forming integrated ecosystems capable of functions comparable to that of marine and terrestrial ecosystems.

Mangrove ecosystems function as habitat for both terrestrial and marine fauna (Nagelkerken et al. 2008). Mangroves provide ecosystem services such as foods, fuelwoods and construction materials for many people who dwell in the mangrove ecosystems area (Raga 2006). The mangrove ecosystem of Tuna Bay is relatively small compared to the adjacent Galey Reach mangrove area. However, Tuna Bay mangroves contribute potentially to the overall ecological functions of the broader field of Bootless Bay. They also prevent soil erosion and sedimentation, which harms the seagrass beds and coral reefs; provide foraging, breeding and nursery grounds for many important food fishes (Laegdsgaard and Johnson 1995; Paillon et al. 2014); space for human habitation and are an important resource for supporting livelihoods in the area (Aye et al. 2019).

Mangrove litter is transformed into detritus, which (together with plankton and algae) supports the mangrove ecosystem food-web. Mangrove detritus also supports the food-webs of the surrounding ecosystems of seagrass and coral reefs (along with algae and seagrass) (Muro-Torres et al. 2020).

There are over thirty (30) mangrove species recorded within the Bootless Bay area (Maniwavie 2007 and Piskaut et al. 2018). True mangroves account for about 23 species in the Bogoro Inlet area, including the islands (Piskaut et al. 2018). The majority of these species possibly coexist with other resources in residence in Tuna Bay.

However, casual observations of the Tuna Bay area since 2010 indicate that the mangrove ecosystem there is deteriorating rapidly. There are relatively large tracks of mangrove ecosystems transformed into human-occupied settlements and constructions of linear structures such as roads.

Observed fauna within Tuna Bay mangrove ecosystem include birds, reptiles, mammals, insects, crustaceans (crabs and shrimps), gastropods (shells), echinoderms (sea urchins and starfish), marine worms, and fishes. This biological diversity is recorded under different taxa groups and listed in appendices to this report.

Study Sites

Sites were preselected during the reconnaissance visits to Tuna Bay. A total of five sites were marked as indicated in Figure 6.

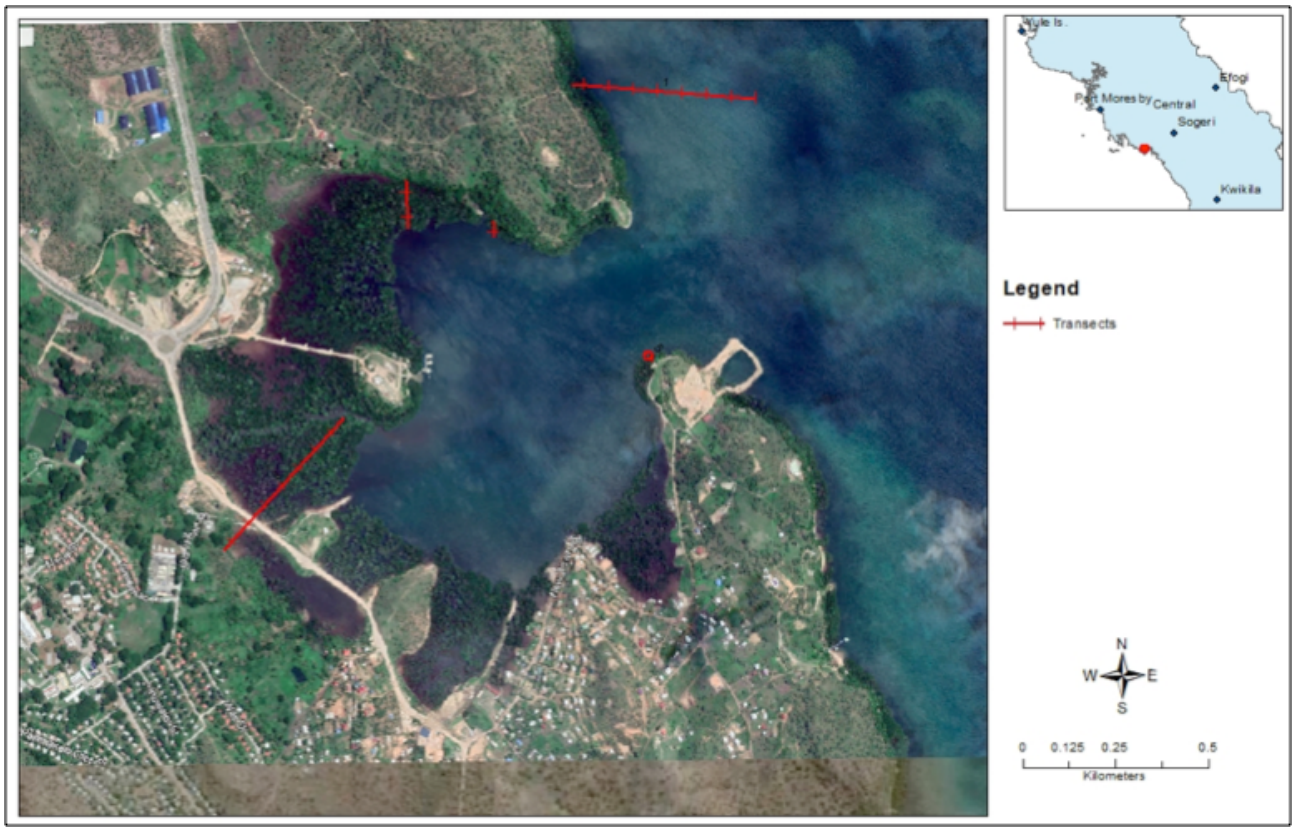


Figure 6. Mangrove belt transects

Methodology

Four belt transects of 10 m width and varying lengths, traversing perpendicular to the coastline, were established (Figure 6). In each belt transect, all plants >1 m tall were identified to species level if possible (using available field guides and/or consulting with botanical experts at UPNG) and enumerated. The coordinates of each plant, relative to the tape measure, were recorded. Additionally, total height, bole height and stem diameter were taken at 1.3 m above ground or above prop roots, which were all recorded.

All data were input to MS10 Excel spreadsheets and migrated into STATISCA 10 and SPSS 22 for analysis. Profile diagram of the mangrove forest was prepared from XY scatter plot in Excel and drawn in Paintbrush (MS Windows Accessories). Diameter analysis was categorised in STATISTICA and a pooled histogram produced (to avoid biases to recruitment, shrubs with diameter ≤5 cm, were excluded from the analysis).

The mangrove percentage cover was assessed through satellite imagery (earth.google.com) and confirmed by ground truthing the entire area. The mangrove cover was scored from 0 per cent (bare land) to 100 per cent mangrove and classified into 10 classes, with intervals of 10 units. The percentage cover classes are: 0–10, 11–20, 21–30, 31–40, 41–-50, 51–60, 61–70, 71–80, 81–90, 91–100. These classes were verified in ArcGIS 10.1 (Ezri 2012), then rectified through ground truthing.

Results

A total of 785 mangrove individuals was recorded from the 4 transects, comprising 23 species. Of this total, 7 species are mangrove associates (Table 1).

Table 1. Mangrove and mangrove-associated floral diversity of Tuna Bay.

Species	Frequency	Proportion	Status
Eucalyptus confertiflora	1	0.13	Savanna grassland
Desmodium umbellatum	1	0.13	Mangrove associate
Clerodendron inerme	2	0.25	Mangrove associate
Xylocarpus granatum	5	0.64	True mangrove
Ceriops decandra	173	22.04	True mangrove
Rhizophora apiculata	202	25.73	True mangrove
Bruguiera gymnorrhiza	225	28.66	True mangrove
Bruguiera sexangula	3	0.38	True mangrove
Rhizophora stylosa	32	4.08	True mangrove
Canthium suborbiculare	1	0.13	Endemic, mangrove associate
Avicennia marina	62	7.90	True mangrove
Osbornia octodonta	1	0.13	True mangrove
Ceriops tagal	26	3.31	True mangrove
Rhizophora mucronata	7	0.89	True mangrove
Pluchea indica	4	0.51	True mangrove
Azadirachta indica	2	0.25	Invasive, mangrove associate

Species	Frequency	Proportion	Status
Acrostichum aureum	9	1.15	Fern, true mangrove
Excoecaria agallocha	9	1.15	True mangrove
Bruguiera cylindrica	2	0.25	True mangrove
Scyphiphora hydrophylacea	10	1.27	True mangrove
Bruguiera exaristata	1	0.13	True mangrove
Albizia carii	1	0.13	Endemic, mangrove associate
Bruguiera x hybrid	6	0.76	Hybrid

The dominant mangrove species are *Bruguiera gymnorrhiza, Ceriops decandra* and *Rhizophora apiculata.* Several mangrove individuals recorded in the middle zone of transect 4 appeared to be a hybrid of *Bruguiera gymnorrhiza* x *B. cylindrica*; and has been given an identification of *Bruguiera x hybrid.* There were also a few true mangrove species not recorded in the transects but which were observed in other parts of Tuna Bay.

Two endemic species (*Albizia carrii* and *Canthium suborbiculare*) were observed at sites 2 and 3 (eastern mangrove forest), while an introduced/invasive species was recorded as back-mangrove associate at site 4, near the Taurama Army Barracks.

As shown in the figure below, a good portion of the mangrove forest (south-eastern portion) is deteriorating rapidly due to clearance for human settlement. Mangrove cover analysis indicates a prevalence of less than 50 per cent cover at the south-eastern coastline of Tuna Bay, where new settlements are quickly emerging.

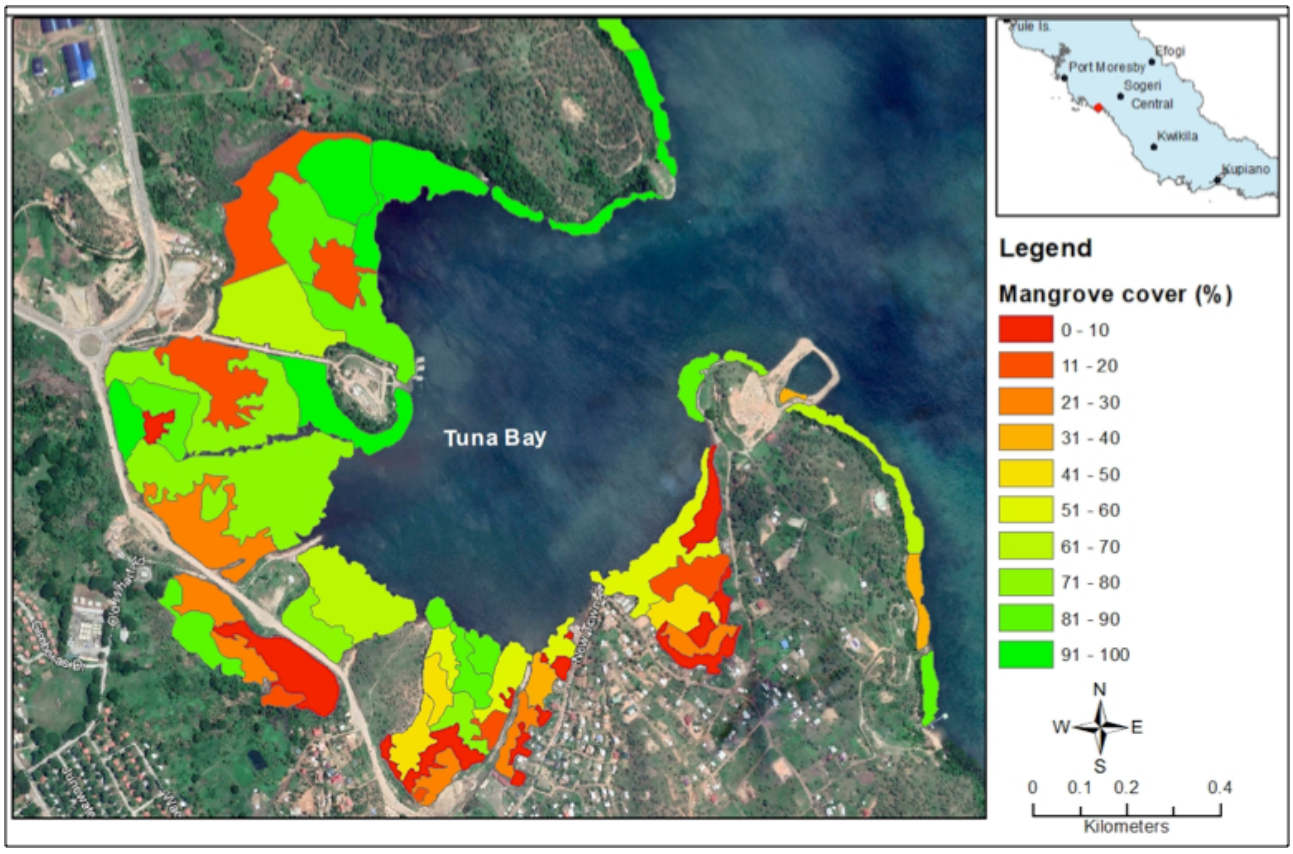


Figure 7. Mangrove percentage cover relative to disturbances.

Overall, the mangrove forest displayed a very depauperate structure (Figure 6 and 7). Diameter size analysis shows plants, ≤10 cm diameter, attributed over 80 per cent of the total stems sampled (Figure 8). The mangrove profile diagram shows smaller, stunted trees at the back, and progressively increases in height toward the sea edge (Figure 9). The forest is also fragmented as indicated by mangrove cover analysis (Figure 7) and the profile diagram (Figure 9).

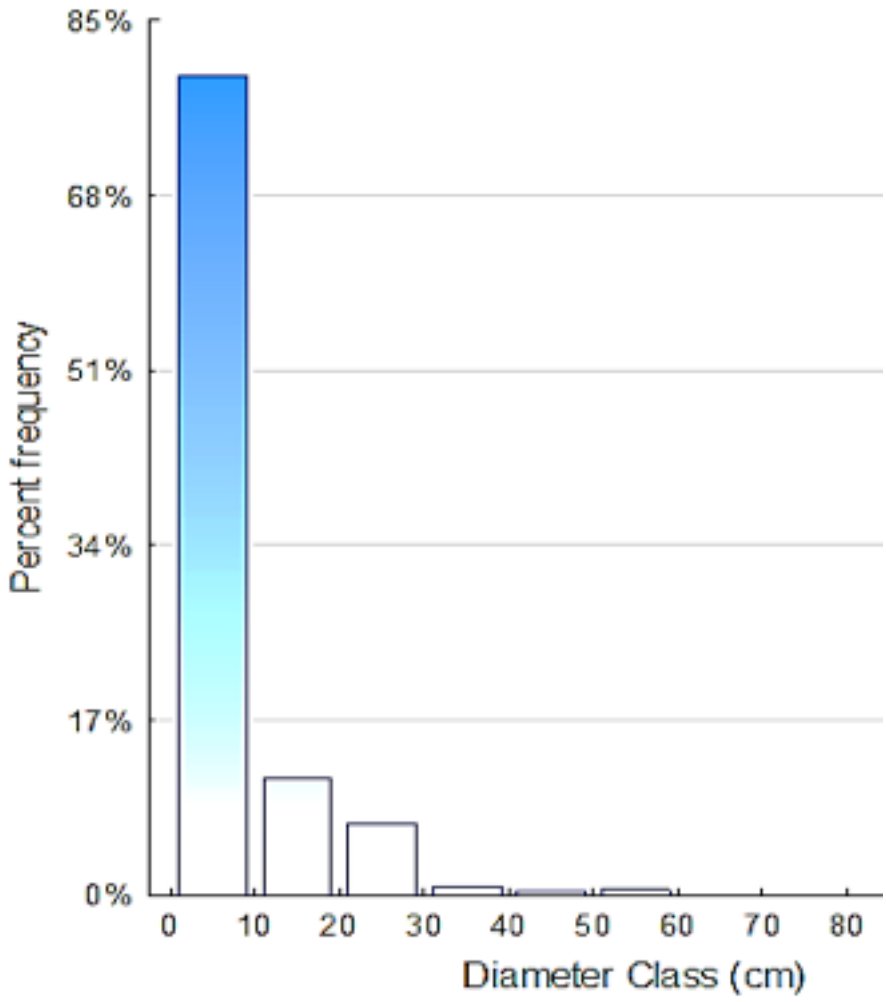


Figure 8. Diameter class distribution for Tuna Bay mangrove forest (all sites pooled).

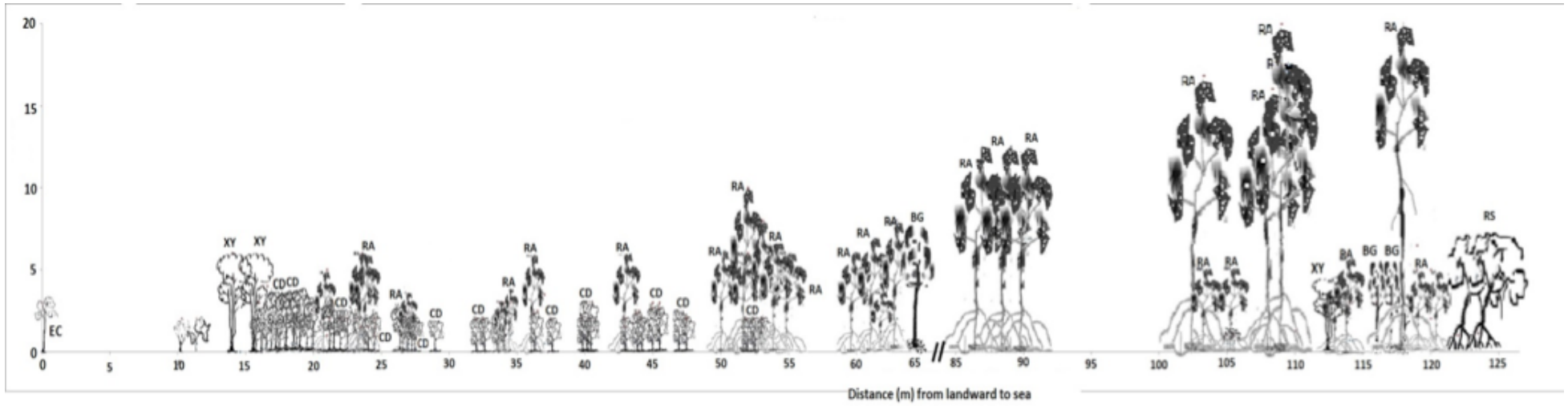


Figure 9. Mangrove profile diagram of site 3, depicting the community structure. Codes: EC = *Eucalyptus confertiflora*; BG = *Bruguiera gymnorrhiza*; CD = *Ceriops decandra*; RA = *Rhizophora apiculata*; RS = *Rhizophora stylosa*

Discussion

Maniwavie et al. (2007) and Piskaut et al. (2018) recorded 31 mangrove species within the entire Bootless Inlet. This study identified 15 true mangroves species occurring at the Tuna Bay and the surrounding Taurama area (Table 2).

Table 2. True mangrove species sampled and observed at Tuna Bay and around the Taurama area.

Family	Scientific name	Common name
Combretaceae	*Lumnitzera racemosa*	White-flowered black mangrove
Meliaceae	*Xylocarpus granatum*	Cannonball mangrove
Myrtaceae	*Osbornia octodonta*	Myrtle mangrove
Rhizophoraceae	*Bruguiera gymnorrhiza*	Large-leaf orange mangrove
	Ceriops decandra	
	Ceriops tagal var. tagal	Rib-fruited yellow mangrove
	Rhizophora apiculata	Corky stilt mangrove
	Rhizophora lamarckii	Southern hybrid stilt mangrove
	Rhizophora mucronata	Upstream stilt mangrove
	Bruguiera sexangula	Upriver orange mangrove
	Bruguiera x hybrid	
	Rhizophora stylosa	Long-styled stilt mangrove
Sonneratiaceae	*Sonneratia alba*	White-flowered apple mangrove
Verbenaceae	*Avicennia marina*	Grey/white mangrove
	Avicennia eucalyptifolia	Grey/white mangrove

Frodin (1983), Hopkins and Menzies (1995) and Piskaut et al. (2018) recorded 11 endemic species occurring within the Bootless Bay area. Within Tuna Bay, only two endemic species were recorded behind the mangrove on raised rocky outcrops at the western part (mouth) of the bay. Confined to rocky outcrops are the endemic plant species of the Eastern Papua coastline. Mangroves dominate coverage of the mudflat in the bay. Rocky outcrops are uncommon in the bay, but most had been cleared for human settlement, hence, the demise of other endemic flora and fauna.

The mangrove forest displays a very depauperate community. The abundance of mangrove plants, <10 cm diameter, indicate disturbances from clearing and sedimentation from upland activities.

Conclusion

The mangrove community of Tuna Bay is highly disturbed. Human settlement within the bay has a considerable influence on the depauperate state of mangroves. Large portions of back mangroves have been or are being cleared to make way for building and linear constructions.

Recommendation

Develop policies and legislations to conserve and sustainably use mangroves for the regular supply of ecosystem goods and services to the human community. A management plan is needed to manage and curtail the deteriorating mangrove ecosystem.

Marine Ecosystems

Introduction

The marine ecosystems of Bootless Bay are comprised of estuaries (saltmarshes and mudflats), exposed and sheltered rocky shores, intertidal flats consisting mainly of seagrass beds and sand flats, fringing coral reefs, and the barrier reef.

The sea surface temperature, salinity and pH ranges are 25°C–31°C (average about 28°C), 28 ppt–35 ppt (average about 32 ppt), and 7.92–8.24 respectively (Ko'ou 2014). The salinity has commonly been recorded at approximately 35 ppt with estuarine hypersaline conditions reaching up to 38 ppt, especially during dry seasons.

The tidal fluctuations caused by high and low tides, winds and waves are the main forces driving the sea surface current within Bootless Bay. The high tide reaches up to 2 m high, and tidal flushing keeps the bay saltwater clean.

Tuna Bay is an estuarine and marine ecosystem, which provides many essential goods and services to the local population even as far as Port Moresby. Essentially, every component of marine biodiversity has an important ecological role to play in maintaining ecosystem health and function (Baine and Harasti 2007). The integrity, stability and sustainability of marine biodiversity cannot be compromised by humans whose lives depend on this biodiversity.

While the Tuna Bay environment is dynamic and changes to its marine ecosystems are inevitable, its inhabitants need to understand these changes and adapt in ways that ensure long-term sustainable livelihoods. Ecological information and understanding of Tuna Bay area dynamics and its biodiversity is critical as a sound basis for the conservation of threatened biodiversity, spatial management of natural resources, and development planning.

Biodiversity is defined as the diversity of life forms and includes the richness, evenness and composition of species, genes and ecological processes, which make up the terrestrial, freshwater and marine ecosystems (Nagelkerken et al. 2008). The functions (productivity), integrity and stability of these ecosystems depend on the existing biodiversity in these ecosystems. Unfortunately, available evidence suggests that biodiversity is rapidly declining in many areas of the world (Nagelkerken et al. 2008) including PNG, where declines are obvious and prevalent in the settlement, mined and logged areas. Biodiversity decline through species loss and habitat degradation is directly affecting human wellbeing as a result of decrease in the services that ecosystems can provide.

The causes and consequences of biodiversity decline have been the focus of discussions in the past two decades and are well documented (Nagelkerken et al. 2008). However, causes and consequences of biodiversity decline are location-specific and requires local inhabitants to understand this so that appropriate development and management strategies can be implemented at local scales to mitigate the causes and prevent their consequential impacts. Indeed, the natural and anthropogenic processes that influence biodiversity decline and their consequences on both the natural systems and human livelihoods need to be understood and managed where it is possible. The people's and government's ability to understand these processes helps in the prevention of biodiversity decline and sustainable management of the biodiversity that many livelihoods depend upon.

Generally, there has been limited research on the marine biodiversity of Tuna Bay. Optimistically, Tuna Bay is part of Bootless Bay and is expected to have biodiversity assemblages similar to that for other sites (i.e., Bogoro Inlet) within Bootless Bay. Therefore, extrapolations of available information from studies done in Bootless Bay as well as adjacent to Port Moresby Harbour and Caution Bay, will

help document the biodiversity of Tuna Bay. Inventory assessment of biodiversity of Tuna Bay can distinguish which species and ecological processes are active within the Tuna Bay area.

Known species and biodiversity inhabiting Bootless Bay, including the Tuna Bay area, are listed in the ensuing subsections and in the appendices. Bootless Bay has 283 species of terrestrial plants, 24 species of mangroves, 10 species of seagrasses, 81 species of birds, 4 species of marine mammals, 1 species of crocodile, 3 species of sea snakes, 3 species of turtles, 512,488 species of marine fishes, 284 species of reef corals, and many species of marine algae, crustaceans, echinoderms and molluscs (Piskaut et al. 2018; Drew et al. 2012; Baine and Harasti 2007; Coleman 1998).

The biodiversity of Bootless Bay is comparable to many marine ecosystems in PNG and the region and is characterised by many important features of high socio-economic and conservation value. These features include:

- many ecosystems, for example, forest, saltmarsh, mangrove, mudflats, seagrass beds and coral reefs;
- presence of seven endemic plant species;
- breeding and nursery grounds for many species, for example, turtle nesting site;
- foraging grounds for many species, for example, pelagic tuna species; and
- presence of valuable commercial species, e.g., sea cucumbers.

Piskaut et al. (2018) noted that these important features are slowly being wiped out through the destruction of natural habitats and over-exploitation of natural resources. This may be a result of the expansion of Port Moresby City and the increasing population of Central Province (Piskaut et al. 2018).

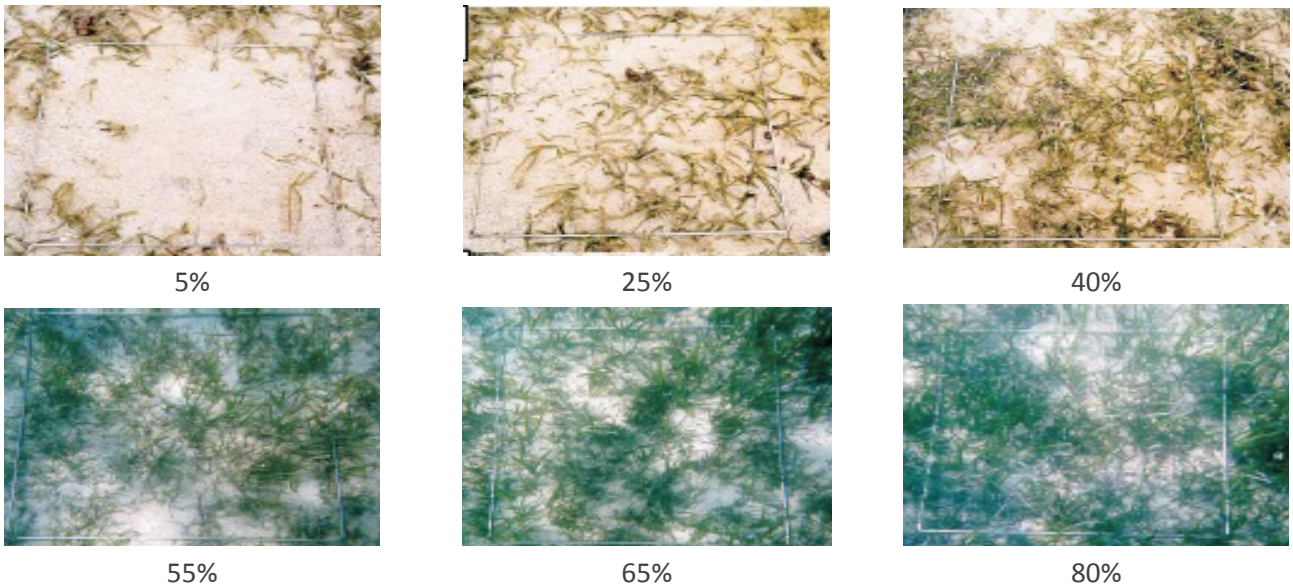


Figure 11. Example of seagrass cover.

Study Site

Using maps, seven sites were preselected based on the distribution of observed habitats. These are indicated in Figure 10, including placement of fishing nets.

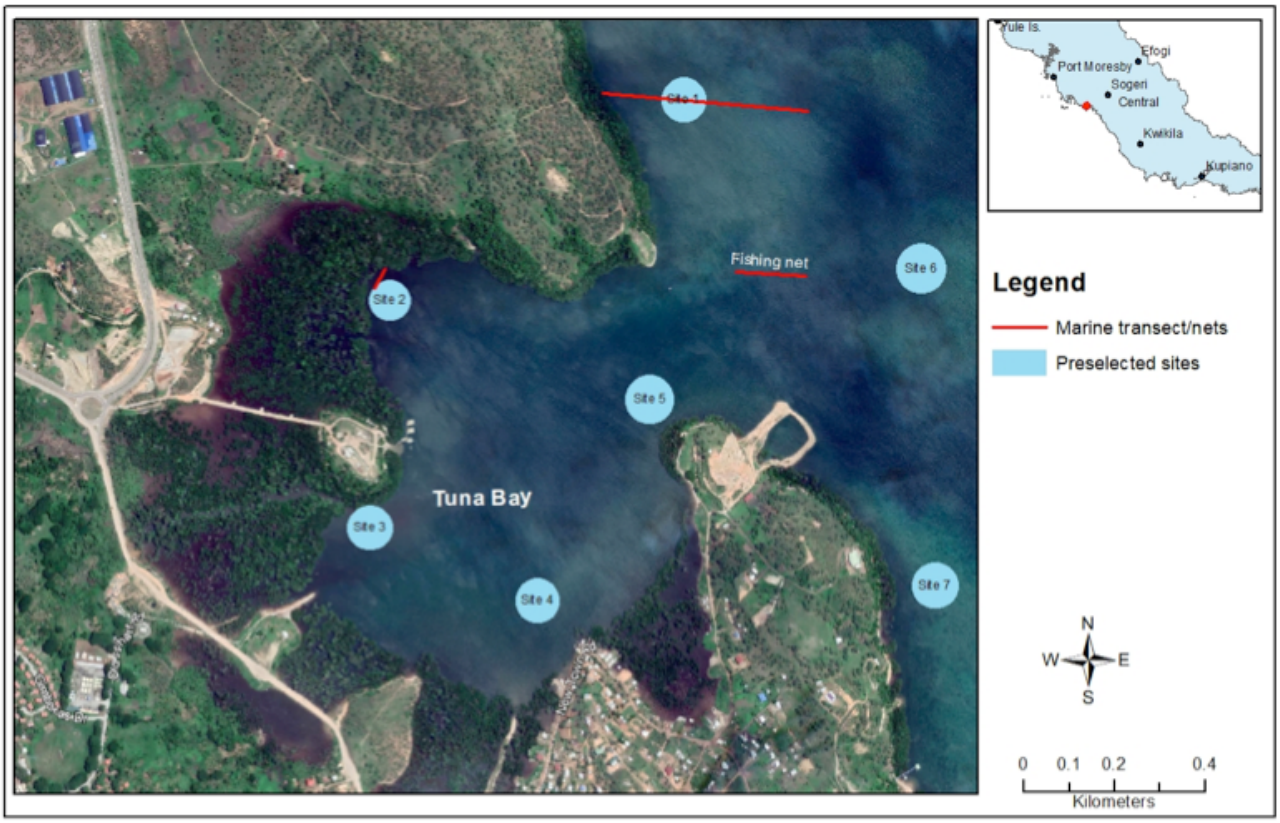


Figure 10. Marine survey points transect survey and fishing net layouts.

Methodology

Marine Cover and Species Diversity

Within the bay enclosure, visibility was very poor due to high turbidity during the survey period (28 November to 15 December, 2018), making it impossible to survey all the sites. A detailed survey was conducted at site 1 while other sites were visually observed, where observations of seagrasses, corals, substrates and fish species were casually recorded. Two fishing nets (1" and 4") were placed as indicated in Figure 10.

Benthic cover was assessed at site 1. Transects of 40 m x 1 m were employed to determine the cover type and biodiversity. Seven transects were established perpendicular to the coastline and placed at 50 m intervals from each other. Figure 10 shows a schematic layout of the transects.

Cover types were assessed in 1 m x 1 m quadrats. Forty (40) quadrats were established along the transect. In each quadrat, the percentage cover, relative to the quadrat, was scored for the following cover categories: seagrass, coral, macroalgae, sand, mud, rubble, and rocks (Figure 11). The cover categories represent the microhabitats common within the bay. All organisms (seagrasses, macroalgae, fishes, sea cucumbers, sea stars, molluscs, etc.) present in the 1 m x 1 m quadrats were also recorded.

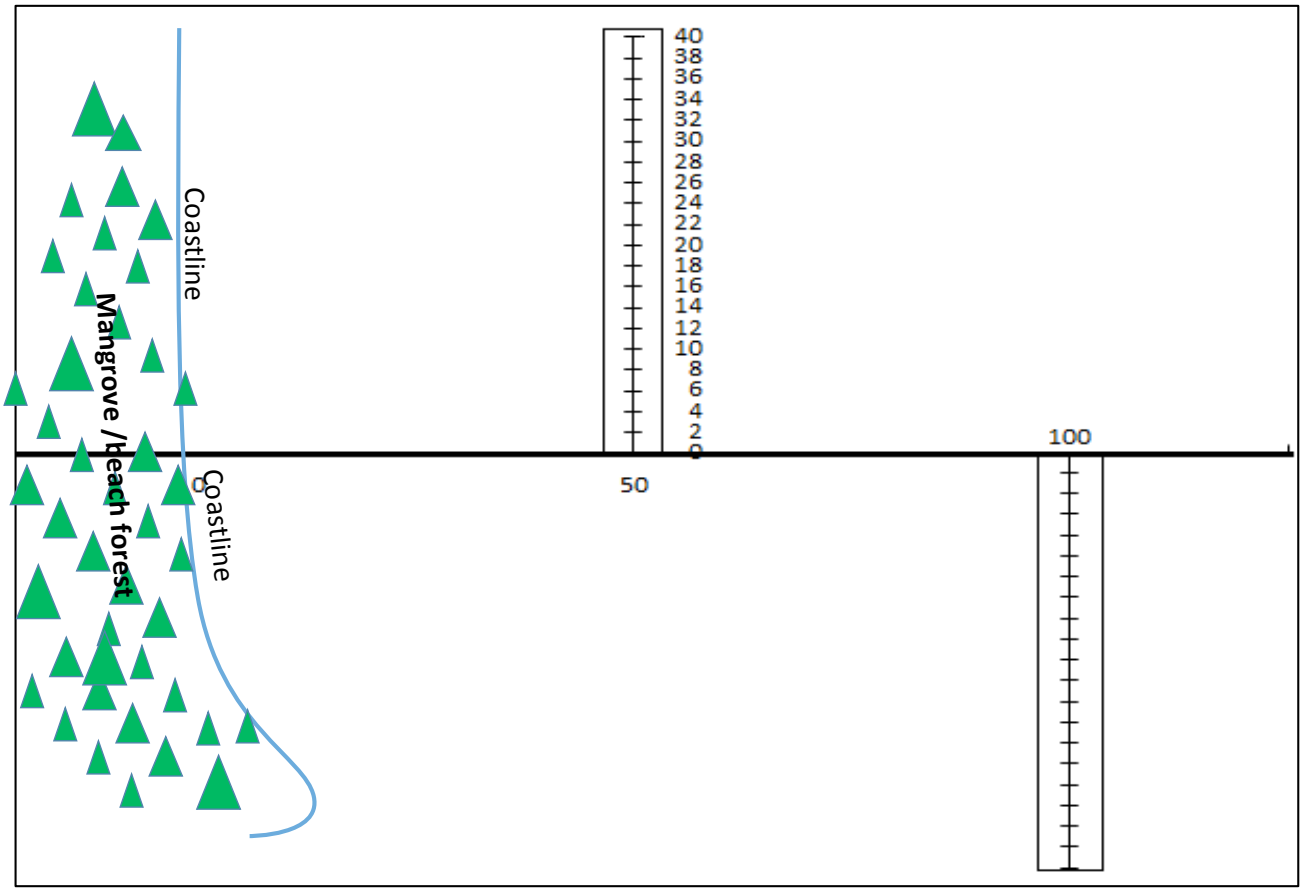


Figure 12. Schematic diagram illustrating the marine sampling method.

Fish Survey

Underwater visual census (UVC) was used to conduct the fish survey. Commonly, 5 m x 40 m transects were established parallel to the coastline at site 1 (Figure 8) and set at 50 m intervals toward the reef slope at depths of approximately 1 m (low tide) to 5 m. Six such transects were established. At each transect, the recorder snorkels along the transect and records any fish that is seen along the line of travel.

The study also employed a capture method through the use of the fishing net and handline fishing techniques. A 4" mesh size gillnet (5 m x 50 m) was set at the mouth of the bay, and a smaller 1" mesh-size net was utilised at the mangrove edge of site 3 (see Figure 8). The net soak times were 2 hours for the 1" net and 5 hours for the 4" net.

Handline fishing was conducted at site 1. The fishermen spent up to one hour of fishing using 10 pounds to 20 pounds nylon strings.

The researchers also conducted an ad-hoc survey to determine fish commonly caught. Parameters recorded included the time of day, type of fishing method used (diving, line, fishing nets and dynamite) and vessel type (canoe or dinghy).

Data Analysis

All data were entered into an MS Excel spreadsheet and, for each site, the average cover was calculated. Records of other organisms were also entered into the same spreadsheet. All data were subjected to quality checks to verify correct identification, spelling and correct site of collection.

Descriptive statistics of mean cover types and species occurrences were performed in the JMP 7 Statistical package (SAS 2001). The characterisation of the mangrove forest structure was plotted in MS Excel 10 and drawn in MS Paint Brush. Each selected sampling site was also observed and characterised accordingly. Based on the observed characteristics, the sites were delineated and mapped using ArcGIS 10.1.

The parameters selected for the rapid biodiversity assessment included species lists of all taxa as specified in the term of references, results of the fish survey and an evaluation of the sampling data. All observed species and disturbances were recorded, analysed and reported accordingly.

Results

Habitat and Species Diversity

The marine environment within the bay enclosure is comprised of a sediment-covered reef with patches of seagrasses and boulder corals. A typical reef system occurs at the mouth of the bay, particularly the eastern portion of the bay. Healthier reef complexes begin to appear outside, including barrier reefs (Figure 13). Within the bay enclosure, the sediment-buried reef comprising dead boulders dominate much of the mangrove edges. A small patch of seagrass meadow occurs on the western side of the mangrove forest (Figure 13).

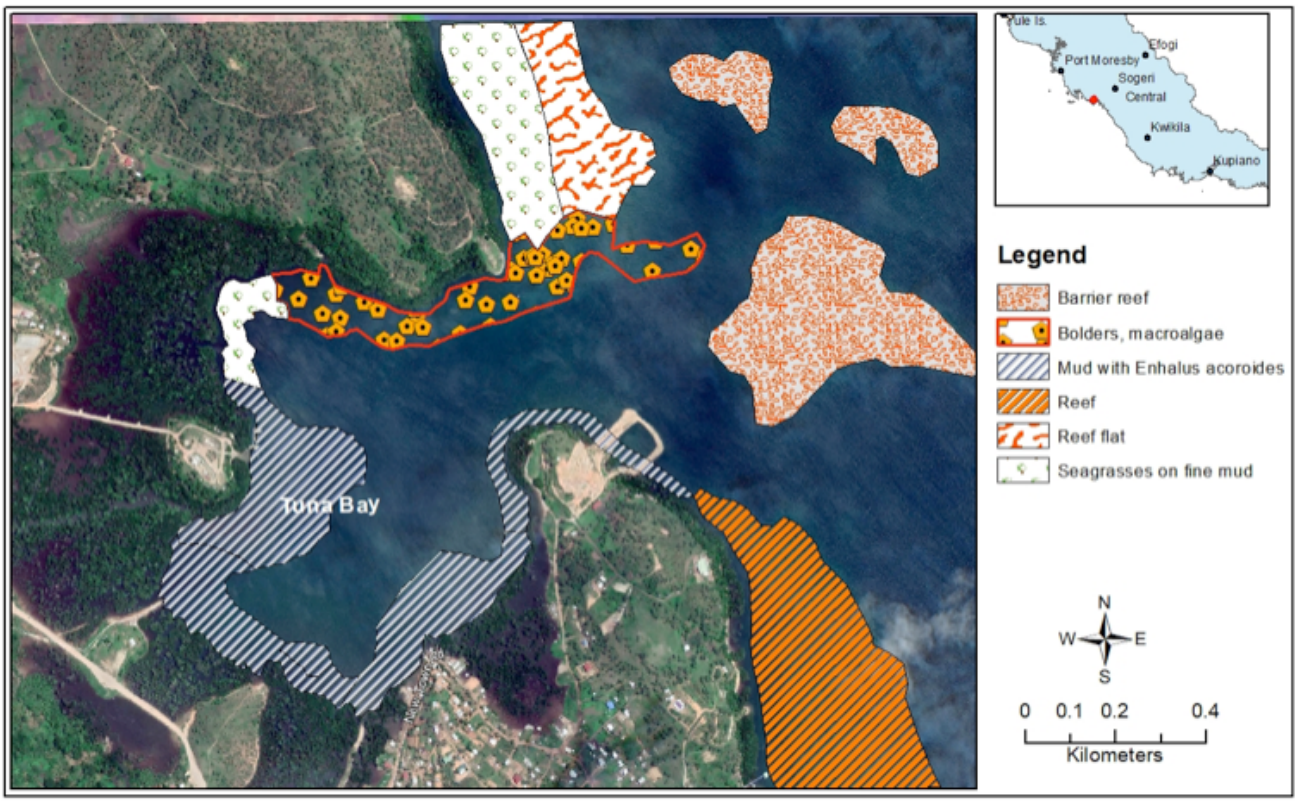


Figure 13. The marine environment within Tuna Bay and its peripheries.

Seagrasses

Seagrass meadows are poorly developed within the bay enclosure, but are well established in the surrounding areas. Only six species were recorded, with *Enhalus acoroides* and *Thalassia hemprichii* being the dominant species (Table 3). Within the bay enclosure, only *Enhalus acoroides* is common with very sparsely distributed *Thalassia hemprichii*. The brackish condition limits most seagrass species from occurring in the bay.

Table 3. Seagrasses species recorded in 1 m x 1 m plots (data pooled).

Species	No. of Plots	Percent Occurrence
Enhalus acoroides	30	75.00
Thalassia hemprichii	29	72.50
Cymodocea rotundata	7	17.50
Cymodocea serrulata	2	5.00
Syringodium isoetifolium	1	2.50
Halodule uninervis	1	2.50

Macroalgae

Four main genera of macroalgae were observed during the survey: *Halimeda* spp., *Turbinaria* spp., *Padina* spp. *and Sargassum* spp. (Table 4).

Table 4. Common macroalgae recorded at Tuna Bay.

Genus	No. of plots	Percent Occurrence
Halimeda sp.	8	20.00
Turbinarina sp.	1	2.50
Padina sp	1	2.50
Sargassum sp.	10	25.00

Coral Diversity

The coral diversity is poorly represented within Tuna Bay. The reef system mainly comprises boulder corals (back reef). Boulders are massive corals of the genus *Porites.* From the survey transects, few corals were recorded and their forms categorised as massive, branching, bushy or encrusting.

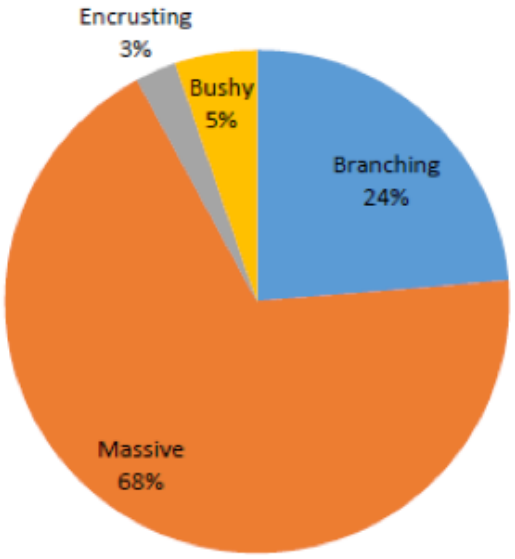


Figure 14. The occurrence of coral forms per 40 plots of 1 m x 1 m magnitude.

Massive corals attributed almost 70 per cent of the corals observed at Tuna Bay. Branching, bushy and encrusting corals were fewer, occurring as isolated individuals/colony at the back reef. Of the massive coral, *Porites* spp appeared to be the dominant hard coral. Some soft corals were observed at the reef slope but fall outside the transect lines. The major genera are listed in Table 5 below.

Table 5. Common corals recorded at Tuna Bay.

	No. of plots	Percent Occurrence
Acropora spp.	4	10.53
Porites spp.	21	52.50
Fungia spp.	5	12.50
Favia spp.	5	12.50
Leather corals *(Sarcophyton, Lobophytum, Sinularia* spp.*)*	1	2.50
Palm Lettuce Coral *(Pectinia* spp.*)*	1	2.50

Fish Assemblage

From UVC analysis only a few species were observed in anyone transect. Species composition/ richness ranged from 4 to 13 species per 0.02 ha of reef, with an overall mean of 10± 4 species. The species composition varied according to habitat type (Table 6). Pooled data from all transects gave a total of 40 species recorded at site 1.

Table 6. Species richness in seven transects established at site 1.

Parameters	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	Transect 6	Transect 7
Species Richness/0.008 ha	4	12	13	10	5	11	13
Area Surveyed (ha)	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Dominant Habitat	Mud/ sand	Seagrass/ Sand	Seagrass	Seagrass	Reef flat	Reef/ Seaweed	Reef crest/ slope
Common Family	Gobiidae	Pomacentridae	Pomacentridae, Gobiidae, Shaol of Siganidae	Pomacentridae, Gobiidae	Pomacentridae	Acanthuridae, Pomacentridae	Acanthuridae

Overall, species richness was slightly lower compared to other sites within the larger Bootless Bay. The barracudas (*Sphyraena qenie*), mullet (*Valamugil seheli*) and shoals of juvenile fish were in abundance along the eastern mangrove areas of Bootless Bay. At the western mouth of Tuna Bay, juvenile rabbitfish (*Siganus* spp) were in abundance grazing in the seagrass meadows. Based on the presence of many juvenile fish, Tuna Bay can be considered an important nursery area for fish and other organisms. Table 6 lists common fish caught within Tuna Bay and its peripheries. Of particular interest is the tuna fish that enter the bay as claimed by the local fishers.

Table 7. Common fish catch in Tuna Bay and surrounding areas (Kailolo, unpublished data).

Family	Genus	Species	Common Name
Balistidae	*Abalistes*	*stellatus,*	triggerfish
Acanthuridae	*Acanthurus*	*nigricauda*	surgeonfish
Scaridae	*Bolbometopon*	*muricatum*	parrot fish
Carangidae	*Carangoides*	*ferdau*	jacks
Carangidae	*Carangoides*	*fulvoguttatus*	jacks
Carangidae	*Caranx*	*lugubris*	jacks
Carangidae	*Caranx*	*melampygus*	jacks
Carangidae	*Caranx*	*tille*	jacks
Carcharhinidae	*Carcharinus*	sp.	shark
Serranidae	*Cephalopholis*	*sonnerati*	Sea bass
Labridae	*Cheilinus*	*chlorourus*	wrasse
Chirocentridae	*Chirocentrus*	*dorab*	wolf herring
Serranidae	*Epinephelus*	*corallicola*	Sea bass
Scombridae	*Euthynnus*	*affinis*	tuna
Scombridae	*Katsuwonus*	*pelamis*	tuna
Leiognathidae	*Leiognathus*	*equula*	slipmouth
Lethrinidae	*Lethrinus*	*erythropterus*	bream
Lethrinidae	*Lethrinus*	*olivaceus*	bream
Lutjanidae	*Lutjanus*	*gibbus*	snapper
Lutjanidae	*Lutjanus*	*kasmira*	snapper
Lutjanidae	*Lutjanus*	*rivulatus*	snapper
Lutjanidae	*Lutjanus*	*semicinctus*	snapper
Lutjanidae	*Lutjanus*	*Argenti-maculatus*	snapper
Megalopidae	*Megalops*	*cyprinoides*	tarpon
Holocentridae	*Myripristis*	*violacea*	squirrelfish
Acanthuridae	*Naso*	*unicornis*	surgeonfish
Mullidae	*Parupeneus*	*indicus*	Goat fish
Polynemidae	*Polydactylus*	*plebius*	threadfin
Priacanthidae	*Priacanthus*	*hamrur*	bigeye
Scombridae	*Rastrelliger*	*kanagurta*	mackerel
Holocentridae	*Sargocentron*	*spiniferum*	squirrelfish
Scaridae	*Scarus*	*forsteni*	Parrot fish
Scaridae	*Scarus*	*rivulatus*	Parrot fish
Scombridae	*Scomberomorus*	*commerson*	Spanish mackerel
Siganidae	*Siganus*	*argenteus*	rabbitfish
Siganidae	*Siganus*	*doliatus*	rabbitfish

Family	Genus	Species	Common Name
Sphyraenidae	*Sphyraena*	*qenie*	barracuda
Sphyrnidae	*Sphyrna*	*lewini*	shark
Scomberidae	*Thunnus*	*albacares*	tuna
Hemigaleidae	*Triaenodon*	*obesus*	shark
Belonidae	*Tylosurus*	*crocodilus*	needlefish
Mugilidae	*Valamugil*	seheli	mullet

Researchers recorded an average of 1.29 kg of fish caught at the mangrove edge of site 1 using the handline fishing technique. Therefore, the catch per unit effort (CPUE) equates to 590.43 g/person-hour fishing. The dominant family caught include Nemipteridae and Lethrinidae. Attempts to catch fish using fishnets were unsuccessful.

Discussion

The level of artisanal fisheries (three to four fishers at any one time of day and five nights a week) within the Bootless Bay is comparatively high. The rate of deforestation of the mangrove ecosystem in Tuna Bay has resulted in local extinction of several species. Building a road in 2012 that crosses the mangrove forest has caused the loss of the entire half of the mangrove forest. Several large tracts of cleared mangroves and young mangroves regrowing in the survey sites indicate that deforestation of mangroves in Tuna Bay is an ongoing activity. The rate of deforestation and uses of mangroves in Tuna Bay need to be understood so that appropriate management actions can be instituted to address the situation.

The accumulation of inorganic wastes (plastics, metals, clothes, etc.) in the mangroves and along the shores of Tuna Bay is of concern due to their potential impacts on the ecological systems. The consequences are captured in the data where diversity is generally lower (e.g., Table 8).

Table 8. Common coral families and other benthic life forms observed in all sites

Site	Common Coral Families	Other Common Benthics
1	Acroporidae (branching, tabulate), Faviidae, Poritidae (Boulder)	Macroalgae (*Sargassum* sp., *Halimeda* spp., *Padina minor*), Seagrasses (*Thalassia hemprichii*, *Syringodium isoetifolium*), Nerites snails
2	None (mud buried reef)	Seagrasses (*Enhalus acoroides*), Nerites snails, Conidae (cone snails)
3	None (mud buried reef)	Seagrasses (*Enhalus acoroides*)
4	None	Seagrasses (*Enhalus acoroides*)
5	None	Seagrasses (*Enhalus acoroides*), Nerites snails

The increasing population of Port Moresby city has increased the market value of the marine resources in Tuna Bay and significantly increased the rate of marine resource exploitation. Observed fishing efforts (7–8 fishers per day) in and around Tuna Bay is extensive. However, the day's effort of 590 g/person-hour is lower than other areas along the Papuan Coastline. At Caution Bay, several kilometres north-west of Tuna Bay, the fisher's efforts range from 1.5 kg to 2 kg per person-hour (Esso Highlands Ltd 2012). Piskaut et al. (2018) also found lower catch effort in Bootless Bay indicating over-harvesting of the fish resources.

Historically, several tuna species have been observed and caught by local fishers within the Tuna Bay. Although it has been stated that their presence in the bay is related to their spawning activities, there is no empirical evidence of their larvae nor juveniles recorded in the waters of Tuna Bay. This is partly due to lack of studies to determine and confirm this speculation.

Conclusions

The following conclusions are based on the findings of this biodiversity assessment:

i. Tuna Bay is slightly less diverse compared to adjacent areas such as Bogoro Inlet and Caution Bay.

ii. Tuna Bay is not a tuna spawning area, as previously stated. The reef structure (channel) leading to Tuna Bay directs the tuna to the bay. Restructuring of the reef has diverted the tuna away from the Tuna Bay inlet. The structures along the mouth of Tuna Bay inlet may be responsible for the decrease in the number of tuna entering the inlet.

iii. Tuna Bay is continuously filled with sediments from runoff from land clearing and coastal developments including roads and new settlements.

The limitations of this assessment have repercussions on the recommendations, and further investigation of the highlighted issues will certainly enhance decision-making in future.

Recommendations

To ensure protection and sustainable use of the marine resources and prevention of further degradation of the mangrove forest and coral reefs around Tuna Bay, the following actions should be given priority:

i. The local people and settlers must take ownership of the environment and its resources and their management using an Ecosystem-Based Management approach in the context of the Reef to Ridge concept.

ii. The development plan proposed by NCD must ensure the protection of Tuna Bay and enhancement of the local people and settlers' livelihoods through the use of adequately managed renewable resources.

iii. Continue monitoring the environmental and social-demographic changes taking place at Tuna Bay and have an adaptive management plan in place that accommodates the observed changes.

iv. Alternative and sustainable livelihoods not entirely dependent on the marine resources of Tuna Bay must be pursued to alleviate the stress level associated with the marine resources harvest trend. For instance, replanting of softwood riparian vegetation as alternative firewood sources.

v. Resource accessibility must be managed to avoid the "Tragedy of the Commons" which is associated with the marine resource use in the Central Province.

SIGNIFICANT SITES

Introduction

Tuna Bay hosts a number of sites of high conservation value. The term 'conservation value' is defined as an element of the environment identified as a key ecological feature. The key ecological feature identified in this assessment is based on a system approach whereby each system identified is examined in the context of its biodiversity (species, habitats, functional groups), ecological processes (energy and biogeochemical cycle), and changes to the feature due to impacts from natural and anthropogenic induced stressors (Piskaut et al. 2018). In addition, a key ecological feature also includes provision of ecosystem services (daily sustenance, erosion control, recreation and cultural sites).

Based on the results, combined with local knowledge, this section describes the significant sites within the bay.

Methods

Prioritising and designating protected areas will be based on the principles of comprehensiveness, adequacy, representation and resilience, where key areas and values are identified and prioritised.

The high conservation value (HCV) toolkit was employed to assess the proposed Tuna Bay "ridge to reef" project of Tuna Bay. The HCV toolkit is based on habitats, species of significance, ecosystem values and areas of cultural significance to the landowners. The HCV protocol involved assessing biodiversity for their conservation value using six (6) criteria (Neugarten and Savy 2012; ProForest 2008). They are:

i. The area containing significant concentrations of biodiversity values (e.g., endemism, rare, endangered, or threatened species, refugia).
ii. Significant large landscape/seascape-level areas where viable populations of most, if not all, naturally occurring species exist in natural patterns of distribution and abundance.
iii. The areas containing rare, threatened or endangered ecosystems.
iv. The areas that provide basic ecosystem services in critical situations (e.g., watershed, erosive coast, or hilly slopes).
v. The areas fundamental to meeting basic needs of Tuna Bay and Pari communities (e.g., subsistence, health).
vi. The areas critical as the traditional and cultural identity of Tuna Bay and Pari communities (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities).

Analysis

Significant areas were identified and marked on the map. Site coordinates were transferred into ArcMap 10.1 (Esri 2000), overlaying satellite imagery acquired from Google Earth (www.googleearth Pro Plus).

Results

According to the HCV concept, any area that meets any of the six criteria qualifies itself for management purposes. Tuna Bay falls under HCV 1, 3, 4, 5 and 6 (Table 9). Figure 15 shows significant sites and possible tuna routes within the Tuna Bay.

Table 9. High conservation value criteria for Tuna Bay.

HCV Criteria	Descriptions	Status at Tuna Bay
HCV 1	Endemic, threatened, rare species or refugia of species	· Crocodile · Endemic plant species · Spawning area · Refuge for tuna, barracuda
HCV 3	An area or habitat that is locally important refugia	· Refuge for crocodile, tuna, barracuda
HCV 4	A unique feature with known or presumed ecological properties of local significance	· Tuna migration into the bay · Remnants of fish stone trap (fish garden)
HCV 5	Areas fundamental to meeting basic needs of Tuna Bay and Pari communities (e.g., sub-sistence, health)	· Mangroves as spawning ground for fish species · Mangrove as pollution control for marine environment
HCV 6	Cultural identity	· The legend of the cave and the tuna migration

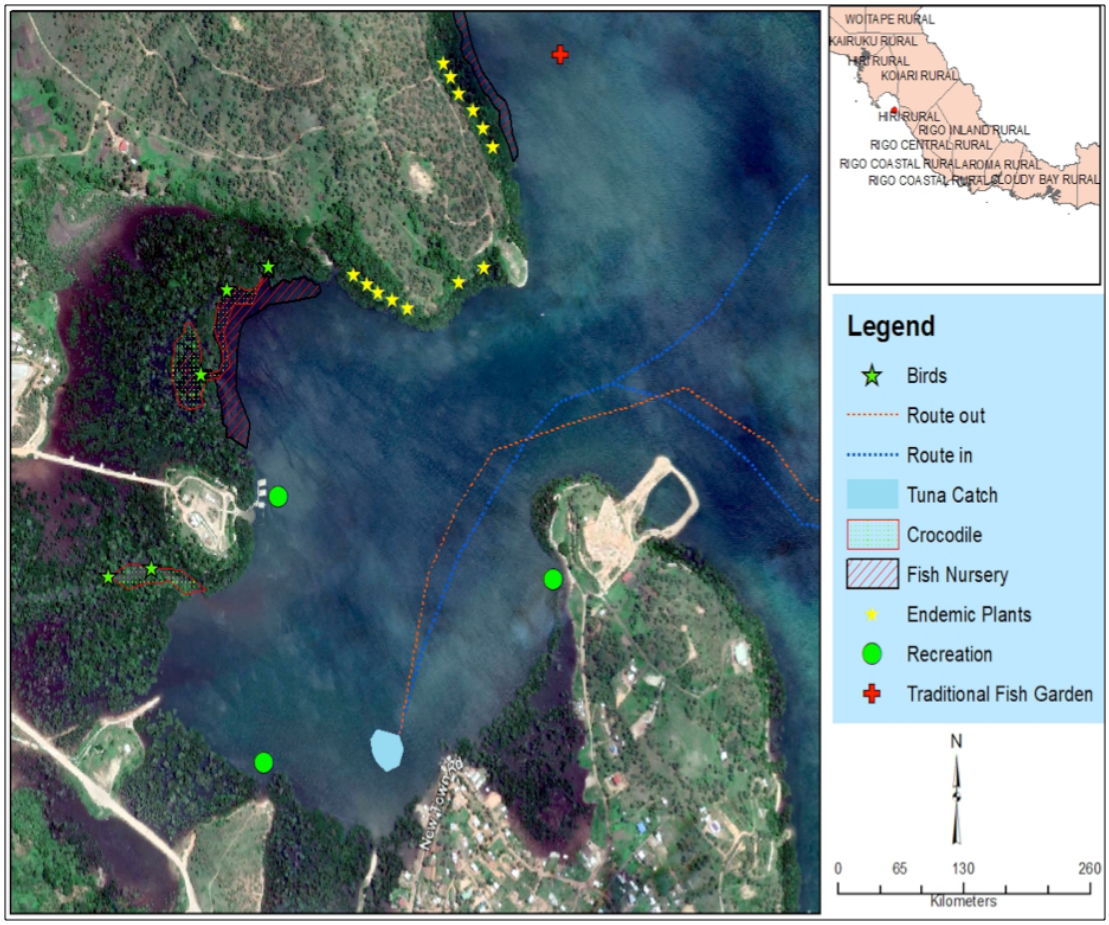


Figure 15. Significant sites within Tuna Bay.

Discussion

Tuna Bay hosts significant sites, as indicated in Figure 15. Juvenile fishes were observed in abundance amongst the mangrove roots and along the mangrove edges and were often sighted on the western side of the bay.

Saltwater crocodiles (*Crocodylus* spp.) used to be a common sight within Bootless Bay, however, due to the degradation of their habitats, they now occur as isolated populations within the bay.

The remnant monsoonal forest on the west, lining the back mangrove, harbours endemic plant species such as *Albizia carii* and *Canthium suborbiculare*. Additionally, the mangrove forest supports wildlife fauna such as mangrove monitor (*Varanus* sp.), birds (egrets, kingfishers) and three nerites species.

Three sites were recorded as the main recreational areas. During the reconnaissance and survey periods, sea-bathing was the main activity by the public. Just outside the bay, a remnant of a permanent stone fish trap or fish garden was observed on the reef flat (Figure 15). The fish garden involved permanently arranged and piled stones that created a refuge for fish. Fish are chased toward the stone trap where larger fishes then take refuge in gaps under the arranged stones. The trapped fish are then stunned with traditional fish poison and speared. This practice has not been recorded along the Papuan coastline, (see Pernetta and Hill 1981) however, it has been recorded in the Torres Straits (Haddon 1912) and elsewhere in the New Guinea Islands.

The migration of yellowfin tuna (*Thunnus albacares*) in the bay is very well known to the locals. Based on folklore stories, the fish comes into the bay at certain times of the year, and through this knowledge, the locals have set up points that mark the species foraging grounds. Studies carried out by the students of the University of Papua New Guinea confirmed the migration status of yellowfin tuna in the bay to be from May to October (Raph Mana *pers. com*).

Attempts to establish whether or not the yellowfin tuna spawn within the bay have been unsuccessful. The shoals travel into the bay where some are caught at the end of their journey. Figure 15 shows the probable route into the bay and the location where some yellowfin tuna is netted. Reports and presentations by the locals during the Bootless Bay Marine Conservation Initiative meeting (BBMCI, meet No.7) reported a decline in the tuna catch. Accordingly, the locals attribute this decline to the development at the eastern mouth of the bay. However, this claim needs to be verified.

Figure 16. Tuna Bay. The 4 poles mark the site where yellowfin tuna are caught as they travel in shoals (school) into the bay (see Figure 15).

Figure 17. Reclamation of land at the east mouth of the bay. See also Figure 15

Conclusion

Tuna Bay is an essential ethnographic area. There is an interconnectivity between the locals and their surrounding environment. While development and changes are inevitable, it often leads to the degradation of the environment and alters the ecosystem processes and cultural values that have sustained the livelihoods of the people for many generations.

Recommendation

It is recommended that Tuna Bay must come under some management regime to protect the biodiversity and cultural values of the bay.

WATER QUALITY ASSESSMENT

Introduction

Under the IW R2R programme, Tuna Bay was proposed to be a management site based on anecdotal evidence that the bay supports migrating tuna species during the months of May to October.

Tuna Bay is seeing an increase in urbanisation and this will have some bearing on the aquatic systems (marine and freshwater). The poor water quality will have an impact on the migration pattern of tuna and other marine organisms within the surrounding area.

The water quality depends on the environment and it is determined by the physico-chemical and biological (microbiology) parameters of the waters. Under the IW R2R programme, baseline information on selected parameters is gathered to provide benchmarks for future monitoring.

This section describes the sea water quality of Tuna Bay, a rapidly expanding area of human settlement.

Study Site

The study site is as described in the sections above. Figure 13 shows the general location, which also indicates the sampling sites.

Methodology

Physico-chemical

Water quality samples were collected using sample bottles provided by the Kilakila NARI Laboratory (see Figure 13). Two sets of six plastic sample bottles were used: one set with 500 mL capacity was specifically used to collect Biological Oxygen Demand (BOD) samples and the second set with 1 L capacity was used to collect water for all other parameters.

All water samples were collected from about 10 cm – 20 cm below the surface. For BOD samples the sample bottle was filled completely and topped below the surface to avoid trapping air bubbles. The samples were placed in a cooler and kept below 10^{o}C overnight and delivered to NARI the next day for analysis. Parameters tested were as listed in the terms of reference.

Microbiological Tests

Water was collected in 100 mL sterile bottles and returned to the lab for analysis commencing the same day. The three (3)-tube Most Probable Number (MPN) method was used to determine the presence of coliform bacteria and further subjected to selective media to confirm the presence of *E.coli*. Samples were subjected to other selective media to determine the presence of *Vibrio* sp and *Salmonella* sp, without enumeration. All samples were subjected to 10-fold dilution in 10 mL and plated on general purpose medium to determine Total Bacteria Counts (TBC) for each site at both low and high tide periods.

Biological water sampling of eight (8) sites (as seen in Figure 18) was done at three independent times and at both low and high tide times for each sampling period.

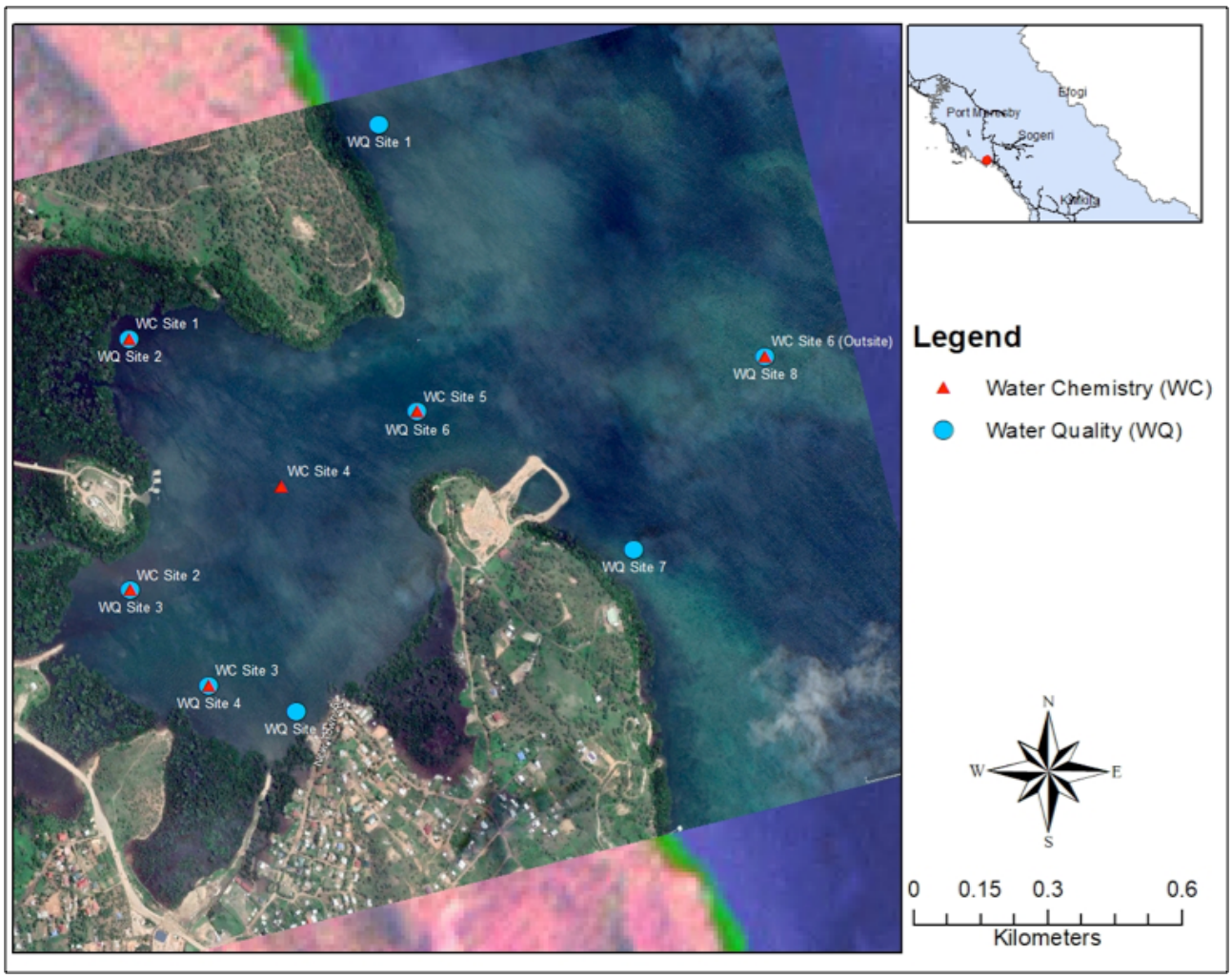


Figure 18. Tuna Bay showing water sampling sites. WQ represents microbial water quality tests. WC stands for water chemistry where major elements of interest and water parameters were tested.

Results

Physico-Chemical Parameters

A total of 18 water physico-chemical parameters was tested. There are no previously known water quality data of Tuna Bay. Thus, these parameters will form the baseline data for the bay. The results of the water quality parameters are listed below (Table 10). The values of all parameters tested appeared similar in all sites except site 2 (indicated by yellow shade), which is located at the mouth of a creek.

Table 10. Water quality tests of parameters. Tests performed by NARI Chemistry Laboratory.

Parameters	Site 1	Site 2	Bay 3	Site4	Site 5	Average	Outside
Conductivity(µs)	67400	65300	70500	68100	70500	68360	61800
Phosphorous (mg/L)	0.058	0.265	0.07	0.05	0.053	0.0992	0.067
Total Hardness (mg $CaCO_3$/L	2489	**2459**	2499	2483	2527	2491.4	2527
Chlorine (mg/L)	19218	**18030**	18605	18378	18279	18502	18633

Parameters	Site 1	Site 2	Bay 3	Site4	Site 5	Average	Outside
Salinity(mg/L)	43136	**41792**	45120	43584	45120	43750.4	39552
Nitrate(mg/L)	0.442	**0.040**	**0.045**	0.379	0.467	0.275	0.425
Nitrite(mg/L)	0.007	**0.026**	0.003	0.007	0.004	0.0094	0.004
Calcium (mg/L)	291	**284**	295	292	303	293	311
Magnesium (mg/L)	428	**425**	428	426	430	427.4	425
Sodium (mg/L)	7440	**7150**	7370	7350	7750	7412	7950
Manganese (mg/L)	<0.001	**0.012**	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
TSS (mg/L)	184	207	186	194	172	188.6	146
DO (mg/L)	7.16	6.64	7.18	7.58	7.81	7.274	7.76
BOD (mg/L)	1.08	1.32	0.86	1.06	1.00	1.06	1.04
COD (mg/L)	1.34	1.40	1.01	1.29	1.90	1.39	1.32
TOC (mg/L)	<50.0	<50.0	<50.0	<50.0	<50.0	<50.0	<50.0
pH	7.97	7.88	8.08	8.09	8.16	8.036	8.17

Salinity and Conductivity

Any of these two parameters should suffice for monitoring as they are very closely related. In Figure 19, the green bar is the average readings from sites 1–5. These sites are all within the Tuna Bay, therefore, the average of the five sites is used to compare against the reference site (red bar) labelled "Outside" (see map for the location of this reference site). Both conductivity and salinity readings appear higher within the bay than at the reference site (Figure 19).

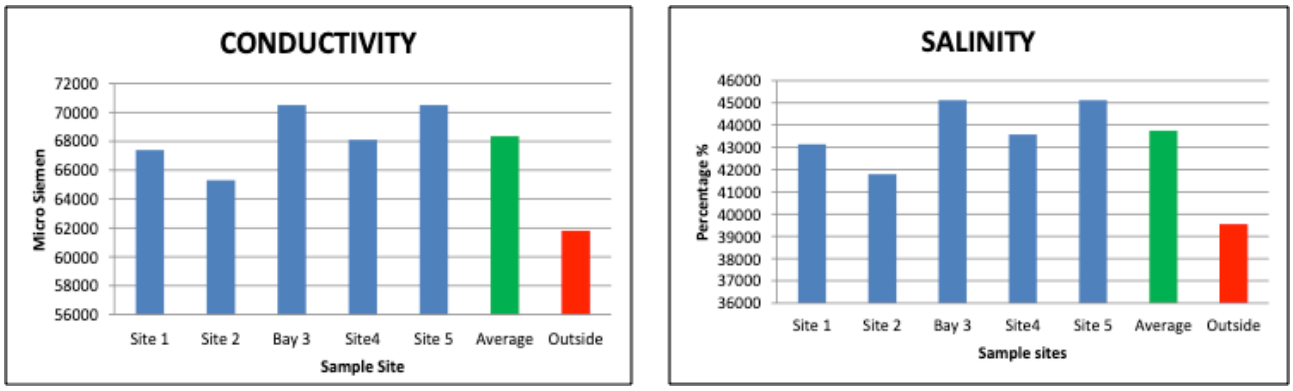


Figure 19. Results of salinity and conductivity analysis of water samples from various at sites Tuna Bay.

Nitrate and Nitrite

The averages for these two parameters are presently questionable because of the anomaly in readings from sites 2 and 3 for nitrate and reading from site 2 for nitrite. A re-run test yielded similar results. There appeared to be similar concentrations of NO_2 and NO_3 at all sites (Figure 20).

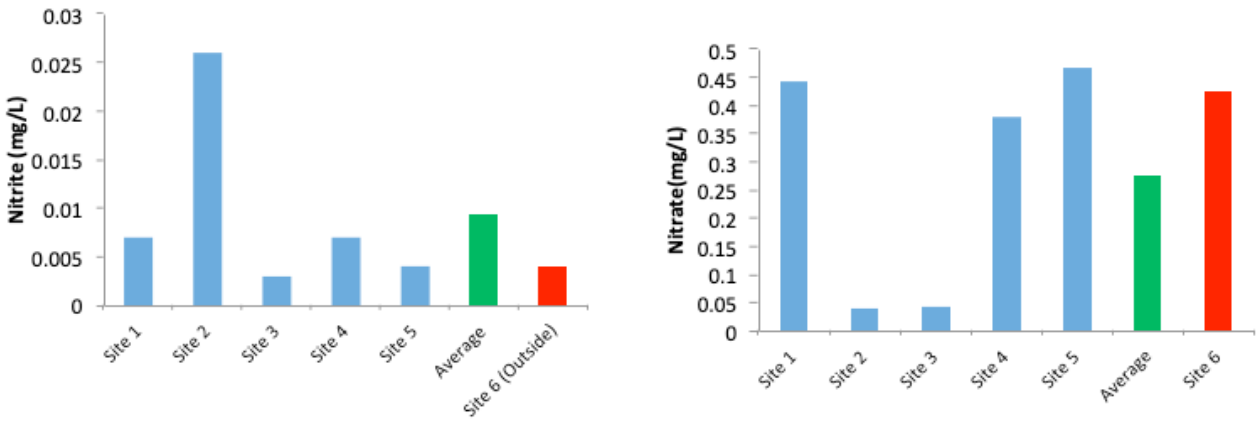


Figure 20. Results of nitrate and nitrite concentration (mg/L) in water samples of Tuna Bay.

However, NO_2 level at site 2 is slightly higher, indicating pollution. This site is right at the mouth of the creek. NO_3 is lower at site 2, which is expected due to conversion (NO_3^- to NO_2^-) under anaerobic condition (DO is also lower at site 2).

Total Suspended Solids (TDS)

The total suspended solids (TSS) are higher in the bay and at the reference site outside (Table 10, Figure 21). This is reflective of the anthropogenic activities occurring upland, coupled with mangrove clearance.

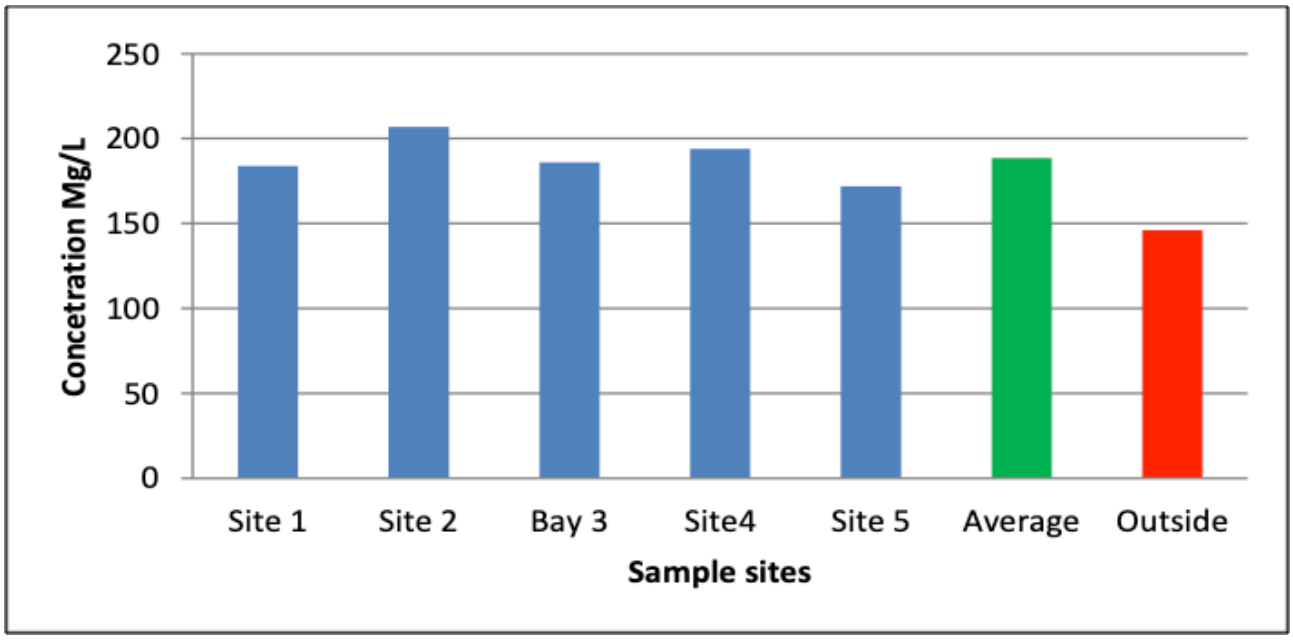
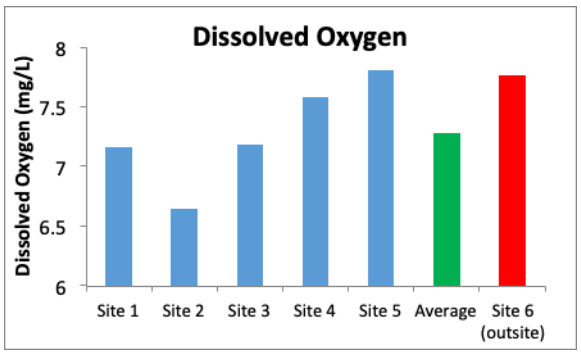
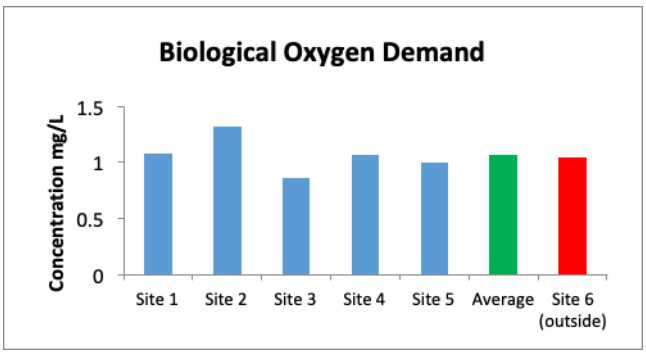


Figure 21. Total suspended solids in the bay.

Dissolved Oxygen (DO), Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD)

On average DO is slightly lower within the bay than the reference site outside. At site 2, DO is slightly lower. COD and BOD appeared similar in all sites (Figure 22).





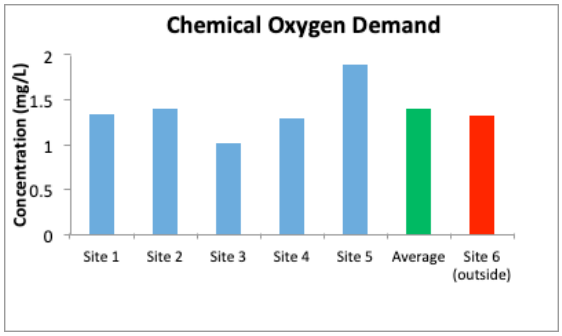


Figure 22. Dissolved oxygen, biological oxygen demand and chemical oxygen demand.

Overall, the results of the tested parameters indicate a very polluted environment within the bay, including the reference site. The inclusion of lead (Pb) was to determine the input from transportation, however, the Pb concentration was below the acceptable levels.

Microbiological Tests

Coliform Counts

Findings from the eight sites in dry and wet seasons as well as at low and high tide periods are presented in Table 11. Corresponding graphs of the data are shown in Figure 23 and Figure 24.

Positive MPN test results saw colour changes to the medium, with gas production in the Durham tubes and some degree of frothing and fermentation odour. All sites scored positive results. Positive tubes were scored and the 3-tube MPN table used to determine the counts per 100 mL. The positive tubes were further subjected to selective medium (BGBB and EMBA) and incubated to confirm the presence of *E.coli* bacteria upon staining in samples from Sites 1, 5 and 6 only. According to results in Table 12, Site 1 had the heaviest presence of *E.coli* compared to Sites 5 and 6. *Vibrio* and *Salmonella* spp were not detected at any site.

Coliform counts for both high and low tide sampling during the dry season had similar, low counts (<250 cfu/100 mL) for all 8 sites, as seen in Figure 23. Conversely, sampling during the wet season at both high and low tides showed relatively high coliform counts (>1000 cfu/100 mL) for all 8 sites.

Table 11. Preliminary results for MPN and TBC from the 8 sites with respective seasons and tides. abnormal readings are Highlighted in yellow.

Site	Season	MPN /100 mL		TBC cfu/100 mL	
		High Tide	Low Tide	High Tide	Low Tide
1	Dry	240	93	32000	67500
	Wet	1100	1100	2400	300
2	Dry	240	240	55000	61000
	Wet	1100	1100	6000	8500
3	Dry	240	240	3000	310000
	Wet	1100	1100	14750	50000
4	Dry	240	93	49000	58000
	Wet	1100	1100	15000	12500
5	Dry	240	93	50000	11000
	Wet	1100	1100	10000	13000
6	Dry	240	93	28000	2000
	Wet	1100	1100	6500	5500
7	Dry	240	240	29000	5000
	Wet	1100	1100	7000	450
8	Dry	240	240	190000	1000
	Wet	1100	1100	4100	550

Table 12. Results of Positive *E.coli*, *Salmonella* and *Vibrio detection* in all 8 samples.

Site	E. coli	Salmonella spp.	Vibrio spp.
1	++++	negative	negative
2	negative	negative	negative
3	negative	negative	negative
4	negative	negative	negative
5	+++	negative	negative
6	+	negative	negative
7	negative	negative	negative
8	negative	negative	negative

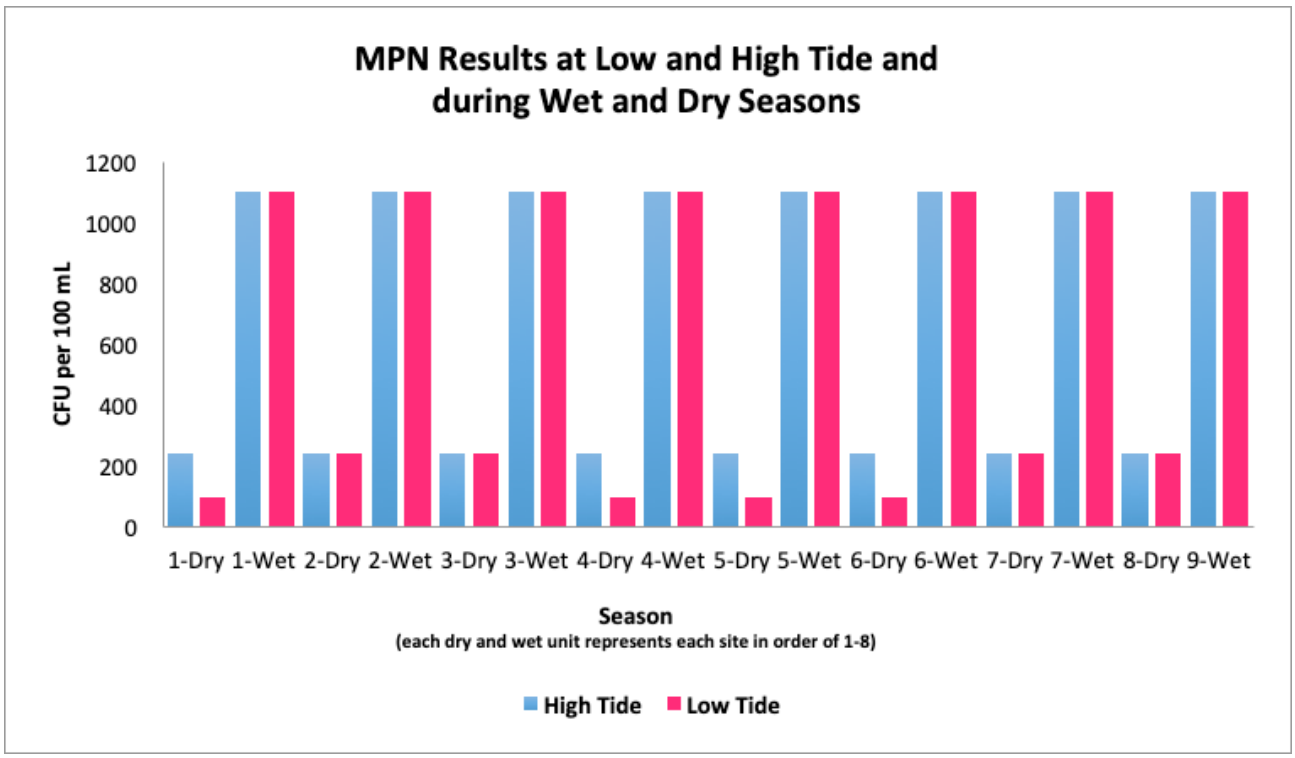


Figure 23. MPN results during wet and dry seasons and at high and low tides for all 8 sites.

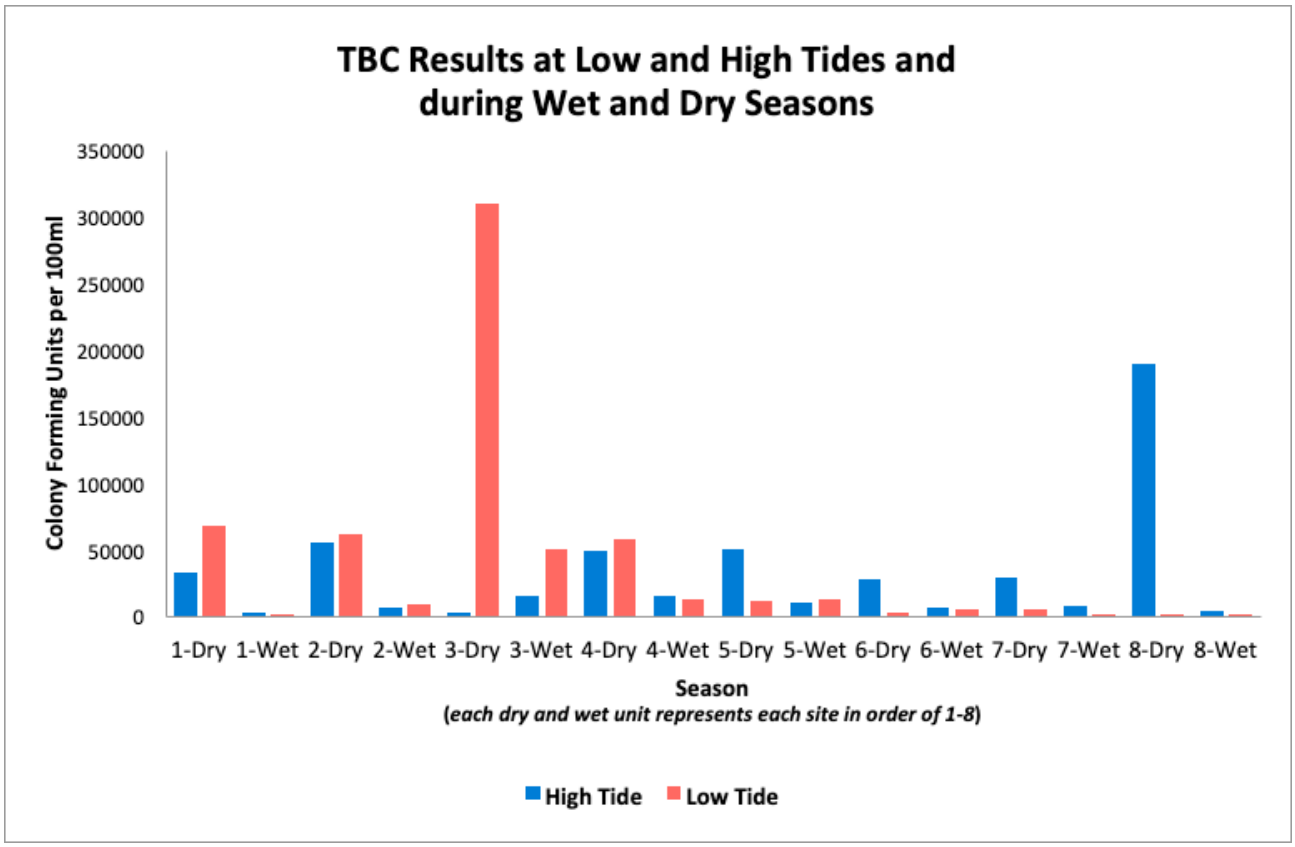


Figure 24. TBC results during high and low tide and wet and dry seasons for all 8 sites.

Total bacteria count (TBC) was done on general purpose medium to show total bacteria presence in waters sampled.

Results from Figure 23 reflect that sampling done during the dry season, irrespective of high or low tide, generally had higher TBC compared to wet season sampling at the respective sites. The TBC at site 3 was the highest ($3.1x10^5$ cfu/100 mL) of all the sites in the dry season at low tide. Wet season results at sites 1, 7 and 8 had the lowest TBC (<$5.5x10^2$ cfu/100 mL) as highlighted in yellow. The lowest dry season counts were from site 8 with a reading less than $1x10^3$ cfu/100 mL).

All readings were standardised to the number of colony-forming units per 100 mL of the water sample. Overall, results show that the TBC was higher at each sampled site, compared to coliform counts at the same sites. This is as expected due to the differences in the media used for each test.

Discussion

No previous studies have been conducted at Tuna Bay to determine seawater quality. Casual observations so far, indicate that the bay is very polluted. During the time of sampling, turbidity was high regardless of tide levels.

While the results are inconclusive, and strong inferences cannot be made, they do indicate a moderately high level of pollution within the bay. Turbidity alone is very high. In areas along the tropical belt, default values for suspended particles in the marine environment range from 20 mg/L (coral and seagrasses) to 80 mg/L (mangrove) (JICA 2011). The values recorded at Tuna Bay are beyond these thresholds.

Nitrates occur in water as the end product in the biological breakdown of organic nitrogen, produced through the oxidation of ammonia. Although not particularly toxic to fish and beneficial for the growth of algae, excess nitrates in the water can lead to eutrophication and algal blooms and are often used as an indicator of poor water quality. In marine environments, levels of 0.1 mg/L to 0.2 mg/L are considered ideal**.**

Nitrite on the other hand, occurs as an intermediate product in the biological breakdown of organic nitrogen. The presence of large quantities of nitrite is indicative of wastewater pollution. The level considered ideal for marine fish and aquatic life is between 0.01 ppm and 0.04 ppm (www.Alken-murray.com).

Oxygen is vital to aquatic life. It enters the water by diffusion from the atmosphere or through plants via photosynthesis. The dissolved oxygen level in water is constantly changing as a consequence of respiration and decomposition (deplete oxygen) and photosynthetic activity (increase oxygen). Organic waste may overload the natural system, causing a serious depletion of the oxygen supply in the water, which often leads to fish getting killed. Similarly, eutrophic waters achieve the same result by causing massive proliferation of algae (algal blooms), which eventually decompose, using up the available dissolved oxygen. The recommended minimum dissolved oxygen level to support aquatic life is >5 mg/L (www.Alken-Murray.com).

Chemical Oxygen Demand (COD) measures organic and inorganic content as indicators of the amount of dissolved oxygen that will be removed from the water column or sediment due to bacterial and/or chemical activity. Normal COD should be less than 10 mg/L. At Tuna Bay, COD results indicate levels below 2 mg/L.

Biological Oxygen Demand (BOD) measures the amount of oxygen utilised by organisms in the biochemical oxidation of organic matter in a wastewater sample in a specified time (usually 5 days),

and at a specified temperature. BOD measurements are used as a measure of the organic strength of the water. Typical natural water has a BOD from 0.8 mg/L to 5 mg/L. At Tuna Bay, BOD falls between the ranges.

The microbiological tests and results show that coliforms are present within the bay, with some indication of presence of *E. coli* at sites 1, 5 and 6. Site 1 is outside the Tuna Bay cove and the *E.coli* and other coliform presence could be an effect of the circulation of water currents coming out of Tuna Bay cove or from nearby settlements. Site 5 is close enough to human settlement and this could account for the presence. Site 6 is just at the mouth of the Tuna Bay entrance and current circulation could account for the presence in the mouth of the bay. Coliform numbers, in general, are seen to be higher in the wet seasons throughout the day and irrespective of tide levels. There are potential adverse impacts on the human population that uses the water source for swimming and fishing if the coliform numbers remain at high levels during wet season and increase in numbers during dry season. As it is now, the numbers appear to be low during the dry season, which could be attributed to heat from the sun warming up the waters to a level that helps to keep the coliform numbers in check.

Total bacterial loads were higher in the dry season compared to the wet season. The high counts at sites 3 and 8 are most likely due to sampling locations in closer proximity to excessive human activity associated with dumping of rubbish or soil into nearby waters.

GENERAL CONCLUSION

The water quality analysis is the first dataset for Tuna Bay. Results indicate the bay is polluted and perhaps contaminated by high levels of harmful bacteria. However, sampling over time is required to confirm this.

Status of Tuna Bay

The rapid assessment of the biodiversity of Tuna Bay in light of the conservation values is presented in this section. For the purposes of conservation, a key ecological feature is defined as any feature of biodiversity (species or ecosystems) that meets one or more of the following assessment criteria:

i. A species, group of species, or community with important ecological role (e.g., parrotfish helps in the production of sand) or a predatory species (e.g., shark, barracuda) that affects a large biomass or number of other species); or

ii. A species, group of species, or community that is locally or regionally important for maintaining a high concentration of biodiversity (e.g., mangroves or keystone species); or

iii. An area or habitat that is locally or regionally important for:

   a maintaining high concentrations of biodiversity values (endemism, rare, endangered or threatened species; refugia);

   b maintaining large aggregations of life forms (such as feeding, breeding or nursery areas);

   c maintaining high biological productivity (for example upwelling); or

iv. A unique feature (e.g., barrier reef) with known or presumed ecological properties of local or regional significance.

These assessment criteria determine the biodiversity and conservation values of a proposed protected area and also add values to the design of the management plans.

Biodiversity

Tuna Bay is less diverse than the entire Bootless Bay. Most taxa are not well defined within the bay enclosure. The number of mangrove species and seagrasses are lower than Motupore Island. Out of the 36 true mangrove species recorded so far in PNG, this study recorded 16 species of all true mangroves. Of special interest is the *Bruguera* x hybrid which needs further attention. Of the 14 species of seagrasses recorded in the waters of PNG, 7 species (79 per cent) occur around the Tuna Bay area.

In regards to fish diversity, about 3000 species are known to dwell in the waters of PNG. Within the Bootless Bay, Drew et al. (2012) recorded 488 fish species in 2012, while Piskaut et al. (2018) recorded a total to 512 species representing 17 per cent of the known PNG fishes within such a small area. Tuna Bay, given its location within Bootless Bay, shares this fish diversity.

The coral reefs within the Tuna Bay enclosure are impacted by sedimentation from land activities such as clearing for agriculture and the deforestation of riparian vegetation. A portion of the reef flat is buried under mud. The reef flat consists of dead boulder corals, thus allowing macroalgae to become dominant in some areas.

While corals are major components of the reef ecosystem, their identification is problematic due to variations in morphology and colouration (IUCN 2012). So far, 90 species, representing 17 per cent of the 600 species known in PNG are found in Tuna Bay (see Appendices).

The presentation of other taxa is given in the appendices.

Water Quality

The water quality in the bay is moderately polluted, with elevated nitrite levels in some sites. Turbidity is high throughout the day.

Coliforms are dominant in the bay, becoming acutely high during wet season. This could be attributed to higher runoffs during rainy periods. It was observed that most settlers have pit toilets, and sewage could be leaching into the bay through rainfall and tidal incursions.

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APPENDICES

Appendix 1: Mangrove Species of Bootless Bay

Family	Scientific Name	Common Name	IUCN Status
Combretaceae	*Lumnitzera racemosa*	White-flowered black mangrove	Least concern
Meliaceae	*Xylocarpus granatum*	Cannonball mangrove	Least concern
Myrsinaceae	*Aegiceras corniculatum*	River mangrove	Least concern
Myrtaceae	*Osbornia octodonta*	Myrtle mangrove	Least concern
Plumbaginaceae	*Aegialitis annulata*	Club mangrove	Not evaluated
Rhizophoraceae	*Bruguiera gymnorrhiza*	Large-leaf orange mangrove	Not evaluated
Rhizophoraceae	*Bruguiera sexangula*	Upriver orange mangrove	Not evaluated
Rhizophoraceae	*Bruguiera cylindrica*		
Rhizophoraceae	Bruguiera costaritata		
Rhizophoraceae	*Ceriops decandra*		
Rhizophoraceae	*Ceripos tagal*	Rib-fruited yellow mangrove	Not evaluated
Rhizophoraceae	*Rhizophora apiculata*	Corky stilt mangrove	Least concern
Rhizophoraceae	*Rhizophora lamarckii*	Southern hybrid stilt mangrove	Not evaluated
Rhizophoraceae	*Rhizophora mucronata*	Upstream stilt mangrove	Least concern
Rhizophoraceae	*Rhizophora stylosa*	Long-styled stilt mangrove	Least concern
Sonneratiaceae	*Sonneratia alba*	White-flowered apple mangrove	Least concern
Sterculiaceae	*Heritiera littoralis*	Looking-glass mangrove	Least concern
Acanthaceae	*Avicennia marina*	Grey/white mangrove	Least concern
Acanthaceae	*Avicennia eucalyptifolia*	Grey/white mangrove	Not evaluated

Source: adapted from Piskaut et al. 2018; Maniwavie 2006.

Appendix 2: Seagrasses of Bootless Bay

Family	Scientific Name	Common Name	IUCN Status
Cymodoceaceae	*Halodule uninervis*	Needle seagrass	Least concern
Cymodoceaceae	*Halodule pinifolia*		Least concern
Cymodoceaceae	*Cymodocea rotundata*	Ribbon seagrass	Least concern
Cymodoceaceae	*Cymodocea serrulata*		Least concern
Cymodoceaceae	*Syringodium isoetifolium*		Least concern
Cymodoceaceae	*Thalassodendron ciliatum*		Least concern
Hydrocharitaceae	*Halophila ovalis*	Paddle grass	Least concern
Hydrocharitaceae	*Halophila minor*		Least concern
Hydrocharitaceae	*Enhalus acoroides*	Tape seagrass	Least concern
Hydrocharitaceae	*Thalassia hemprichii*	Turtle seagrass	Least concern

Source: Piskaut et al. 2018.

Appendix 3: Cnidarians of Bootless Bay

Family	Scientific Name	Common Name	IUCN Status
Plumaridae	*Macrorhynchia philippina*	Philippine hydroid	Not assessed
Sertuariidae	*Idiellana pristis*		Not evaluated
Milleporidae	*Millepora* sp.	Fire coral	
Stylasteridae	*Distichopora* sp.	Lace coral	Not evaluated
Stylasteridae	*Distichopora violacea*	Violet hydrocoral	Not evaluated
Stylasteridae	*Stylaster cf. papuensis*		Not evaluated
Physaliidae	*Physalia physalis*	Portugese man of war	Not evaluated
Cassiopeidae	*Cassiopea* sp.	Upside down sea jelly	Not assessed
Mastigiidae	*Mastigias papua*	Papuan sea jelly	Not evaluated
Alcyoniidae	*Sarcophyton* sp.	Leather coral	Not evaluated
Alcyoniidae	*Lobophytum* sp.	Lobed leather coral	Not evaluated
Alcyoniidae	*Sinularia flexibilis*	Flexible leather coral	Not evaluated
Alcyoniidae	*Sinularia* sp.	Finger leather coral	Not evaluated
Briareidae	*Briareum* sp.	Green star polys	Not evaluated
Nephtheidae	*Dendronephthya* sp.	Tree coral	Not evaluated
Nephtheidae	*Dendronephthya* sp.	Carnation coral	Not evaluated
Nephtheidae	*Stereonephthea* sp.		Not evaluated
Nidaliidae	*Chironephthya* sp.		Not evaluated
Nidaliidae	*Siphonogorgia* sp.		Not evaluated
Xeniidae	*Anthelia* sp.		Not evaluated
Ellisellidae	*Junceela fragilis*	Delicate sea whip	Not assessed
Ellisellidae	*Ellisella* sp.	Sea whip	Not evaluated
Anthothelidae	*Alertigorgia orientalis*	Bushy gorgonian fan	Not evaluated
Gorgoniidae	*Rumphella* sp.	Gorgonian fan	Not evaluated
Plexauridae	*Astrogorgia* sp.		Not evaluated
Pteroeididae	*Pteroeides* sp.	Sea pen	Not evaluated
Virgularidae	Unidentified sp.	Sea pen	Not evaluated
Veretillidae	*Cavernularia* sp.	Sea pen	Not evaluated
Acroporidae	*Acropora c.f caroliniana*		Not assessed
Acroporidae	*Acropora elseyi*	Christmas coral	Not assessed
Acroporidae	*Acropora grandis*	Staghorn coral	Not assessed
Acroporidae	*Acropora intermedia*	Staghorn coral	Not assessed
Acroporidae	*Acropora loripes*		Not assessed
Acroporidae	*Acropora millepora*	Bushy staghorn	Not assessed

Family	Scientific Name	Common Name	IUCN Status
Acroporidae	*Acropora muricata*	Staghorn coral	Not assessed
Acroporidae	*Acropora tennalis*	Purple-tip acropora	Not assessed
Acroporidae	*Acropora valenciennesi*	Branching coral	Not assessed
Acroporidae	*Acropora* sp.	Bottlebrush coral	Not assessed
Acroporidae	*Acropora* sp.	Table coral	
Acroporidae	*Astreopora* sp.	moon coral	
Agariciidae	*Pachyseris speciosa*	phonograph coral	Not assessed
Agariciidae	*leptoseris explanata*		Not assessed
Dendronphylliidae	*Tubastrea faukneri*	Sun coral	Not assessed
Dendronphylliidae	*Tubastrea micranthus*	Black sun coral	Not assessed
Dendronphylliidae	*Turbinaria frondens*	Cup coral	Not assessed
Dendronphylliidae	*Turbinaria reniformis*	Scroll coral	Not assessed
Dendronphylliidae	*Turbinaria* sp.	Vase coral	
Euphyllidae	*Euphyllia cristata*	Whire grape coral	Not assessed
Euphyllidae	*Physogyra lichtensteini*	Pearl coral	Not assessed
Faviidae	*Diploastrea heliopora*		Not assessed
Faviidae	*Echinopora horrida*		Not assessed
Faviidae	*Echinopora lamellosa*		Not assessed
Faviidae	*Favia* sp.	Moon coral	Not assessed
Faviidae	*Platygyra lamellina*	Maze coral	Not assessed
Fungiidae	*Ctenactis echinata*		Not assessed
Fungiidae	*Fungia* sp.		
Fungiidae	*Heliofungia actiniformis*		Not assessed
Fungiidae	*Herpolitha limax*	Tongue coral	Not assessed
Fungiidae	*Herpolitha* sp.	Mole coral	
Fungiidae	*Polyphyllia talpina*	Slipper coral	Not assessed
Merulinidae	*Merulina ampliata*	Ruffled coral	Not assessed
Mussidae	*Lobophyllia hemprichii*		Not assessed
Mussidae	*Scolymia* sp.	Disc coral	Not evaluated
Mussidae	*Symphyllia agaricea*	Brian coral	Not assessed
Mussidae	*Symphyllia c.f recta*	Brian coral	Not evaluated
Oculinidae	*Galaxea fascicularis*	Crystal coral	Not evaluated
Pectiniidae	*Pectinia paeonia*	Palm lettuce coral	Not evaluated
Pocilloporidae	*Pocillopora damicornis*	Cauliflower coral	Not evaluated
Pocilloporidae	*Pocillopora* sp.		Not evaluated
Pocilloporidae	*Seriotopora* sp.	Brush coral	Not evaluated

Family	Scientific Name	Common Name	IUCN Status
Pocilloporidae	*Stylophora pistillata*	Cluster coral	Not evaluated
Poritidae	*Alveopora* sp.	Daisy coral	Not evaluated
Poritidae	*Goniopora* sp.	Daisy coral	Not evaluated
Poritidae	*Porites cylindrica*	Cylinder coral	Not evaluated
Poritidae	*Porites* sp.	Boulder coral	Not evaluated
Trachyphylliidae	*Trachyphyllia geoffroyi*	Crater coral	Not evaluated
Discosomatidae	*Corallimorph* sp. 2		Not evaluated
Actiniidae	*Entacmea quadricolor*	Bubble - tip coral	Not evaluated
Actinodendriidae	*Actinodendron arboreum*	Abominate anemone	Not evaluated
Edwardsiidae	*Edwardsiantus pudica*		Not evaluated
Stichodactylidae	*Heteractis magnifica*	Magnificent anemone	Not evaluated
Stichodactylidae	*Heteractis aurora*	Beaded sea anemone	Not evaluated
Stichodactylidae	*Stichodactyla giganteum*	Gigantic sea anemone	Not evaluated
Stichodactylidae	*Stichodactyla mertensii*	Carpet anemone	Not evaluated
Thelassianthidae	*Cryptodendrum adhaesivum*	Pizza anemone	Not evaluated
Thelassianthidae	*Unidentified* sp.		Not evaluated
Cerianthidae	*Cerianthus* sp.	Tube anemone	Not evaluated
Epizoanthidae	*Epizoanthus* sp.	Branching zoanthid	Not evaluated
Zoanthidae	*Palythoa ceasia*		Not evaluated
Antipathidae	*Cirrhipathes c.f contorta*	Corkscrew black coral	Not evaluated
Antipathidae	*Antipathes* sp. 1		Not evaluated
Antipathidae	*Antipathes* sp. 2		Not evaluated
Antipathidae	Unidentified sp.		Not evaluated
Myriopathidae	*Myriopathes* sp.		Not evaluated

Appendix 4: Crustaceans of Bootless Bay

Family	Scientific Name	Common Name	IUCN Status
Lepadidae	*Lepas anserifera*	Goose barnacle	Not evaluated
Tetraclitidae	*Tetraclita squamosa*	Common barnacle	Not evaluated
Odontodactylidae	*Odontodactylus scyllarus*	Peacock mantis shrimp	Not evaluated
Penaeidae	*Penaeus japonicus*	Kuruma prawn	Not evaluated
Callianassidae	*Neocallichirus* sp.	Ghost shrimp	Not evaluated
Alpheidae	*Alpheus ochrostriatus*	Snapping shrimp	Not evaluated
Alpheidae	*Synalpheus* sp.	Snapping shrimp	Not evaluated
Hippolytidae	*Lysmata amboinensis*	White banded shrimp	Not evaluated
Hippolytidae	*Thor amboinensis*	Squat anemone shrimp	Not evaluated
Hymenoceridae	*Hymenocera picta*	Harlequin shrimp	Not evaluated
Palaemonidae	*Dasycaris zanzibarica*	Bumblebee shrimp	Not evaluated
Palaemonidae	*Laomenes* sp.	Crinoid shrimp	Not evaluated
Palaemonidae	*Manipontonia psamathe*	Commensal shrimp	Not evaluated
Palaemonidae	*Periclimenes emboinensis*	Crinoid shrimp	Not evaluated
Palaemonidae	*Periclimenes brevicarpalis*	Snow-capped shrimp	Not evaluated
Palaemonidae	*Periclimenes holthuisi*	Holthuis's shrimp	Not evaluated
Palaemonidae	*Periclimenes imperator*	Imperial shrimp	Not evaluated
Palaemonidae	*Periclimenes inornatus*	Mirror shrimp	Not evaluated
Palaemonidae	*Periclimenes magnificus*	Magnificent shrimp	Not evaluated
Palaemonidae	*Periclimenes soror*	Sea star shrimp	Not evaluated
Palaemonidae	*Periclimenes tosaensis*	Red-eyed shrimp	Not evaluated
Palaemonidae	*Periclimenes tenuipes*	Glass shrimp	Not evaluated
Palaemonidae	*Periclimenes* sp.1		Not evaluated
Palaemonidae	*Periclimenes* sp.2		Not evaluated
Palaemonidae	*Stegopontonia commensalis*	Sea urchin shrimp	Not evaluated
Palaemonidae	*Vir philippinensis*	Philippine shrimp	Not evaluated
Rhynchocinetidae	*Rhychocinetes durbanensis*	Durban shrimp	Not evaluated
Stenopodidae	*Stenopus hispidus*	Banded coral shrimp	Not evaluated
Palinuridae	*Panulirus ornatus*	Ornate spiny lobster	Least Concern
Palinuridae	*Panulirus versicolor*	Painted lobster	Least concern
Diogenidae	*Calcinus minutus*	Minute hermit crab	Not evaluated
Diogenidae	*Clibanarius* sp.	Green hermit crab	Not evaluated
Diogenidae	*Dardanus lagopodes*	Red hairy hermit crab	Not evaluated
Diogenidae	*Dardanus megistos*	Spotted hermit crab	Not evaluated

Family	Scientific Name	Common Name	IUCN Status
Diogenidae	*Dardanus pedunculatus*	Anemone hermit crab	Not evaluated
Diogenidae	*Dardanus* sp.	Hermit crab	Not evaluated
Diogenidae	*Diogenes* sp.	Hermit crab	Not evaluated
Galatheidae	*Allogalathea elegans*	Elegant squat lobster	Not evaluated
Galatheidae	*Galathea* sp.	Squat lobster	Not evaluated
Porcellanidae	*Neopetrolisthes oshimai*	Oshima's porcellanid crab	Not evaluated
Calappidae	*Calappa hepatica*	Livid box crab	Not evaluated
Calappidae	*Calappa* sp.1	Box crab	Not evaluated
Calappidae	*Calappa* sp.2	Box crab	Not evaluated
Majidae	*Achaeus* sp.	Delicate decorator crab	Not evaluated
Majidae	*Hoplophrys oatesii*	Oate's soft coral crab	Not evaluated
Majidae	*Hyastenus* sp.	Decorator crab	Not evaluated
Majidae	*Oncinopus* sp.	Orangutan crab	Not evaluated
Majidae	*Xenocarcinus tuberculatus*	Black coral crab	Not evaluated
Matutidae	*Ashtoret lunaris*	Speckled surf crab	Not evaluated
Ocypodidae	*Uca perplexa*	Fiddler crab	Not evaluated
Ocypodidae	*Uca* sp.	Fiddler crab	Not evaluated
Portunidae	*Lissocarcinus laevis*	Sea anemone crab	Not evaluated
Portunidae	*Lissocarcinus polyboides*	Sea star crab	Not evaluated
Portunidae	*Portunus pelagicus*	Blue swimmer crab	Not evaluated
Trapexiidae	*Quadrella boopsis*	Red trapeze crab	Not evaluated
Xanthidae	*Actaeodes tomentosus*	Velvet reef crab	Not evaluated

Appendix 5: Echinoderms of Bootless Bay

Family	Scientific Name	Common Name	IUCN list
Acanthasteridae	*Acanthaster planci*	Crown of thorns starfish	Not evaluated
Archasteridae	*Archaster typicus*	Typical sand star	Not evaluated
Echinasteridae	*Echinaster callosus*	Thick skinned sea star	Not evaluated
Echinasteridae	*Echinaster luzonicus*	Luzon sea star	Not evaluated
Luidiidae	*Luidia c.f savignyi*	Savigny's sea star	Not evaluated
Ophidiasteridae	*Celerina heffernani*	Heffernan's sea star	Not evaluated
Ophidiasteridae	*Fromia hadracatha*	Hadra star	Not evaluated
Ophidiasteridae	*Fromia indica*	Indian sea star	Not evaluated
Ophidiasteridae	*Fromia milleporella*	Thousand-pores star	Not evaluated
Ophidiasteridae	*Fromia monilis*	Necklace sea star	Not evaluated
Ophidiasteridae	*Gomophia egeriae*	Egeri's sea star	Not evaluated
Ophidiasteridae	*Gomophia watsoni*	Watson's sea star	Not evaluated
Ophidiasteridae	*Linckia guildingi*	Yellow sea star	Not evaluated
Ophidiasteridae	*Linckia laevigata*	Blue sea star	Not evaluated
Ophidiasteridae	*Linckia multifora*	Multi-pore sea star	Not evaluated
Ophidiasteridae	*Nardoa novaecaledonia*	Yellow mesh sea star	Not evaluated
Ophidiasteridae	*Nardoa tuberculata*	Tuberculate star	Not evaluated
Ophidiasteridae	*Neoferdina cumingi*	Cumming's sea star	Not evaluated
Ophidiasteridae	*Ophidiaster granifer*	Grainy star	Not evaluated
Oreasteridae	*Bothriaster primigenius*	Pentagonal sea star	Not evaluated
Oreasteridae	*Choriaster granulatus*	Pillow sea star	Not evaluated
Oreasteridae	*Culcita novaeguinea*	Pin-cushion sea star	Not evaluated
Oreasteridae	*Protoreaster nodosus*	Nodose sea star	Not evaluated
Ophiocomidae	*Ophiarthrum pictum*	Painted brittle star	Not evaluated
Ophiocomidae	*Ophiarthrum* sp.		Not evaluated
Ophiocomidae	*Ophiocoma erinaceus*	Spiny britle star	Not evaluated
Ophiothrichidae	*Macrophiothrix* sp.		Not evaluated
Ophiothrichidae	*Ophiothrix purpurea*	Purple brittle star	Not evaluated
Ophiothrichidae	*Ophiothrix* sp. 1		Not evaluated
Ophiothrichidae	*Ophiothrix* sp. 2		Not evaluated
Colobometridae	*Cenometra bella*	Pretty feather star	Not evaluated
Colobometridae	*Colobometra perspinosa*	Spinose feather star	Not evaluated
Colobometridae	*Oligometra carpenteri*	Carpenter's feather star	Not evaluated
Colobometridae	*Oligometra serripinna*	Winged feather star	Not evaluated

Family	Scientific Name	Common Name	IUCN list
Comasteridae	*Comanthus alternans*		Not evaluated
Comasteridae	*Comanthus suavia*		Not evaluated
Comasteridae	*Comaster* sp.		Not evaluated
Comasteridae	*Oxycomanthus bennetti*	Bennett's feather star	Not evaluated
Himerometridae	*Himerometra rubustipinna*	Robust feather star	Not evaluated
Himerometridae	*Himerometra* sp.		Not evaluated
Arachnoididae	*Arachnoides placenta*	Cake sand dollar	not assessed
Astriclypeidae	*Echinodiscus auritus*	Pancake urchin	not assessed
Laganidae	*Peronella lesueuri*	Lesueur's sand dollar	not assessed
Diadematidae	*Astropyga radiata*	Radiant sea urchin	not assessed
Diadematidae	*Diadema savignyi*	Savigny's sea urchin	not assessed
Diadematidae	*Echinothrix calamaris*	Stinging sea urchin	not assessed
Diadematidae	*Echinothrix diadema*	Crowned sea urchin	not assessed
Echinometridae	*Echinometra mathaei*	Mathae's sea urchin	not assessed
Echinometridae	*Echinostrephus aciculatus*	Needle spined sea urchin	not assessed
Parasaleniidae	*Parasalenia pohlii*	Pohli's sea urchin	not assessed
Temnopleuridae	*Salmacis sphaeroides*	Bicolor urchin	not assessed
Toxopneustidae	*Toxopneustes pileolus*	Flower urchin	not assessed
Toxopneustidae	*Toxopneustes gratilla*	Cake urchin	not assessed
Holothuriidae	*Actinopyga* sp.		not assessed
Holothuriidae	*Bohadschia argus*	Eyed sea cucumber	least concern
Holothuriidae	*Bohadschia similis*	Chalkfish	data deficient
Holothuriidae	*Bohadschia vitiensis*	Brown sandfish	data deficient
Holothuriidae	*Holothuria atra*	Lolly fish	least concern
Holothuriidae	*Holothuria coluber*	Snakefish	least concern
Holothuriidae	*Holothuria edulis*	Pinkfish	least concern
Holothuriidae	*Holothuria fuscogilva*	White teatfish	vulnerable
Holothuriidae	*Holothuria hilla*	Papillate sea cucumber	least concern
Holothuriidae	*Holothuria leucospilota*	Black fringed cucumber	least concern
Holothuriidae	*Holothuria scabra*	Sandfish	endangered
Holothuriidae	*Holothuria erinacea*	not assessed	not assessed
Holothuriidae	*Pearsonothuria graeffei*	Flower fish	least concern
Stichopodidae	*Stichopus chloronotus*	Green fish	least concern
Stichopodidae	*Stichopus herrmanni*	Curry fish	vulnerable
Stichopodidae	*Stichopus horrens*	Dragon fish	data deficient
Stichopodidae	*Thelenota ananas*	Prickly red fish	endangered

Family	Scientific Name	Common Name	IUCN list
Stichopodidae	*Thelenota anax*	Amber fish	data deficient
Stichopodidae	*Thelenota rubralineata*	Red-lined sea cucmber	data deficient
Synaptidae	*Euapta godeffroyi*	Godeffroy's sea cucumber	not assessed
Synaptidae	*Synapta maculata*	Spotted sea cucumber	not assessed

Appendix 6: Molluscs of Bootless Bay

Family	Scientific Name	Common Name	IUCN Status
Chitonidae	*Acanthopleura gemmata*	Gemmulate chiton	Not evaluated
Haliotidae	*Haliotis ovina*	Ovate abalone	Not evaluated
Buccinidae	*Phos senticosus*	Common Pacific phos	Not evaluated
Cerithiidae	*Pseudovertagus aluco*	Aluco creeper	Not evaluated
Columbellidae	*Euplica turturina*	Crouching dove snail	Not evaluated
Conidae	*Conus eburneus*	Spotted cone snail	Least concern
Conidae	*Conus marmoreus*	Marbled cone snail	Least concern
Conidae	*Conus virgo*	Virgin cone snail	Least concern
Costellariidae	*Vexillium castum*	Ribbed mitre snail	Not assessed
Costellariidae	*Vexillium exasperatum*	Exasperating mitre snail	Not assessed
Costellariidae	*Vexillium luculentum*	Banded mitre snail	Not assessed
Cypraeidae	*Cypraea annulus*	Gold-ringed money cowry	Not evaluated
Cypraeidae	*Cypraea arabica*	Arabian cowry	Not evaluated
Cypraeidae	*Cypraea argus*	Eyed cowry	Not assessed
Cypraeidae	*Cypraea carneola*	Carnelian cowry	Not evaluated
Cypraeidae	*Cypraea humphreysii*	Humphrey's cowry	Not assessed
Cypraeidae	*Cypraea moneta*	Money cowry	Not evaluated
Cypraeidae	*Cypraea tigris*	Tiger cowry	Not evaluated
Cypraeidae	*Cypraea erosa*	Eroded cowry	Not evaluated
Harpidae	*Harpa harpa*	Articulate harp	Not evaluated
Littorinidae	*Littoraria articulata*	Tessellated periwinkle	Not evaluated
Mitridae	*Mitra mitra*	Giant mitra	Not evaluated
Mitridae	*Subcancilla flammea*	Flamed mitre snail	Not evaluated
Muricidae	*Chicoreus microphyllus*	Short-fronded murex snail	Not evaluated
Muricidae	*Mancinella echinata*	White rock snail	Not evaluated
Muricidae	*Morula granulata*	Oyster borer	Not evaluated
Muricidae	*Thais tuberosa*	Tuber-like rock shell	Not evaluated
Nassariidae	*Nassarius arcularia*	Box-like dog whelk	Not evaluated
Naticidae	*Naticarius onca*	Spotted moon snail	Not evaluated
Naticidae	*Naticarius orientalis*	Oriental moon snail	Not evaluated
Naticidae	*Sinum* sp.	Internal-shelled moon snail	Not evaluated
Naticidae	*Tanea undulata*	Wavy moon snail	Not evaluated
Turbinidae	*Lunella cinerea*	Smooth moon turban snail	Not evaluated
Neritidae	*Nerita chamaeleon*	Variable nerita	Not evaluated

Family	Scientific Name	Common Name	IUCN Status
Neritidae	*Nerita polita*	Polished nerita	Not evaluated
Olividae	*Oliva miniacea*	Orange-mouthed olive snail	Not evaluated
Olividae	*Oliva reticulata*	Reticulate olive snail	Not evaluated
Ovulidae	*Cymbovula deflexa*	Canoe spindle cowry	Not assessed
Ovulidae	*Phenacovolva coarctata*	Compressed spindle cowry	Not assessed
Ovulidae	*Phenacovolva tokioi*	Tokio's spindle cowry	Not assessed
Ovulidae	*Phenacovolva* sp.	Spindle cowry	Not assessed
Ovulidae	*Prionovolva* sp.	Soft coral egg cowry	Not assessed
Ovulidae	*Prosimnia* sp.	Gorgonian cowry	Not assessed
Ovulidae	*Pseudosimnia culmen*	Gold spotted egg cowry	Not assessed
Ovulidae	*Pseudosimnia* sp.	Egg cowry	Not assessed
Planaxidae	*Planaxis sulcatus*	Sulcate periwinkle	Not assessed
Ranellidae	*Charonia tritonis*	Triton's trumpet shell	Not assessed
Strombidae	*Conomurex luhanus*	Red-mouthed stromb	Not assessed
Strombidae	*Lambis lambis*	Common spider snail	Not assessed
Strombidae	*Lambis scorpius*	Scorpion spider snail	Not evaluated
Strombidae	*Strombus aratrum*	Black mouthed stromb	Not evaluated
Strombidae	*Strombus gibberulus gibbosus*	Hump-back conch	Not evaluated
Strombidae	*Strombus gibbosus*	Hump-back conch	Not evaluated
Strombidae	*Strombus vomer*	Vomer stromb	Not evaluated
Terebridae	*Hastula albula*	White auger snail	Not evaluated
Terebridae	*Terebra areolata*	Subulate auger	Not evaluated
Terebridae	*Terebra cingulifera*	Girdled auger snail	Not evaluated
Terebridae	*Terebra crenulata*	Crinkled auger snail	Not evaluated
Terebridae	*Terebra dimidiata*	Dimidiate auger snail	Not evaluated
Terebridae	*Terebra subulata*	Spotted auger snail	Not evaluated
Terebridae	*Terebra undulata*	Wavy auger snail	Not evaluated
Hexabranchidae	*Hexabranchus sanguineus*	Spanish dancer	Not evaluated
Polyceridae	*Nembrotha lineolata*	Lined nembrotha	Not evaluated
Aegridae	*Notodoris minor*	Minor notodoris	Not evaluated
Discodorididae	*Discodoris fragilis*	Fragile nudibranch	Not evaluated
Discodorididae	*Halgerda aurantiomaculata*	Gold spoted halgerda	Not evaluated
Discodorididae	*Jorunna funebris*	Funeral jorunna	Not evaluated
Discodorididae	*Kentrodoris rubescens*	Reddish nudibranch	Not evaluated
Chromodorididae	*Ceratosoma sinuatum*	Sinuate ceratosoma	Not evaluated
Chromodorididae	*Ceratosoma trilobatum*	Three horned ceratosoma	Not evaluated

Family	Scientific Name	Common Name	IUCN Status
Chromodorididae	*Chromodoris annae*	Anna's chromodoris	Not evaluated
Chromodorididae	*Chromodoris fidelis*	Faithful chromodoris	Not evaluated
Chromodorididae	*Chromodoris geometrica*	Geometric chromodoris	Not evaluated
Chromodorididae	*Chromodoris kuniei*	Kunie's chromodoris	Not evaluated
Chromodorididae	*Chromodoris lochi*	Loch's chromodoris	Not evaluated
Chromodorididae	*Chromodoris magnifica*	Magnificent chromodoris	Not evaluated
Chromodorididae	*Chromodoris strigata*	Strigate chromodoris	Not evaluated
Chromodorididae	*Glossodoris atromarginata*	Black-margined glossodoris	Not evaluated
Chromodorididae	*Hypselodoris bullockii*	Bullock's hypselodoris	Not evaluated
Chromodorididae	*Hypselodoris maculosa*	Spo□ed hypselodoris	Not evaluated
Chromodorididae	*Hypselodoris nigrostriata*	Black-striped hypselodoris	Not evaluated
Chromodorididae	*Hypselodoris infucata*	Inky hypselodoris	Not evaluated
Chromodorididae	*Mexichromis multituberculata*	Pustuled mexichromis	Not evaluated
Chromodorididae	*Risbecia godeffroyana*	Godeffroy's nudibranch	Not evaluated
Chromodorididae	*Risbecia tryoni*	Tryon's nudibranch	Not evaluated
Bornellidae	*Bornella anguilla*	Eel-like Bornella	Not evaluated
Facelinidae	*Phidiana indica*	Indian phidiana	Not evaluated
Facelinidae	*Phyllodesmium longicirrum*	Long cirri phyllodesmium	Not evaluated
Facelinidae	*Pteraeolidia ianthina*	Blue dragon	Not Evaluated
Flabellinidae	*Flabellina bilas*	Spear-point flabellina	Not evaluated
Flabellinidae	*Flabellina exoptata*	White-tipped flabellina	Not evaluated
Flabellinidae	*Flabellina rubrolineata*	Red-lined flabellina	Not evaluated
Phyllidiidae	*Phyllidia coelestis*	Celestial phyllidia	Not evaluated
Phyllidiidae	*Phyllidia elegans*	Elegant phyllidia	Not evaluated
Phyllidiidae	*Phyllidia ocellata*	Ocellate phyllidia	Not evaluated
Phyllidiidae	*Phyllidia varicosa*	Varicose phyllidia	Not evaluated
Phyllidiidae	*Phyllidiella lizae*	Liz's phyllidiella	Not evaluated
Phyllidiidae	*Phyllidiella nigra*	Black phyllidiella	Not evaluated
Phyllidiidae	*Phyllidiella pustulosa*	Warty phyllidiella	Not evaluated
Phyllidiidae	*Phyllidiella rudmani*	Rudman's phyllidiella	Not evaluated
Phyllidiidae	*Phyllidiopsis pipeki*	Pipek's phyllidiopsis	Not evaluated
Phyllidiidae	*Phyllidiopsis shireenae*	Shireen's phyllidiopsis	Not evaluated
Phyllidiidae	*Reticulidia fugia*	Mushroom coral phyllidia	Not assessed
Phyllidiidae	*Reticulidia halgerda*	Halgerda-like phyllidia	Not evaluated
Aplysiidae	*Aplysia occulifera*	Eyed sea hare	Not assessed
Aplysiidae	*Dolabella auricularia*	Eared sea hare	Not evaluated

Family	Scientific Name	Common Name	IUCN Status
Aglajidae	*Chelidonura electra*	Electric tailed slug	Not evaluated
Aglajidae	*Chelidonura inornata*	Ornate tailed slug	Not evaluated
Aplustridae	*Micromelo undata*	Wavy lined bubble shell	Not evaluated
Plakobranchidae	*Thuridilla bayeri*	Bayer's sap-sucker	Not evaluated
Plakobranchidae	*Thuridilla splendens*	Splendid sap-sucker	Not evaluated
Polybranchidae	*Cyerce nigricans*	Black and gold cyerce	Not evaluated
Pleurobranchidae	*Berthella martensi*	Martens' berthella	Not evaluated
Pleurobranchidae	*Pleurobranchus forskalii*	Forskal's side-gilled slug	Not evaluated
Onchidiidae	*Onchidium* sp.	Mangrove slug	
Arcidae	*Barbatia foliata*	Leafy ark clam	Not evaluated
Chamidae	*Chama* sp.	Jewel-box clam	
Gryphaeidae	*Hyotissa hyotis*	Giant coxcomb oyster	Not evaluated
Ostreidae	*Lopha cristagalli*	Cock's comb oyster	Not evaluated
Ostreidae	*Saccostrea mordax*	Rock oyster	Not evaluated
Pectinidae	*Pedum spondyloideum*	Coral scallop	Not evaluated
Pinnidae	*Atrina vexillum*	Black razor clam	Not evaluated
Pinnidae	*Pinna muricata*	Razor clam	Not evaluated
Spondylidae	*Spondylus sinensis*	Asian thorny oyster	Not assessed
Spondylidae	*Spondylus* sp.	Thorny oyster	
Pteriidae	*Pteria cypsellus*	Winged oyster	Not evaluated
Tridacnidae	*Tridacna crocea*	Crocus giant clam	Least concern
Tridacnidae	*Tridacna maxima*	Elongate giant clam	Least concern
Tridacnidae	*Tridacna squamosa*	Fluted giant clam	Least concern
Loliginidae	*Sepioteuthis lessoniana*	Common reef squid	Not evaluated
Octopodidae	*Octopus* sp.	Octopus	
Sepiidae	*Sepia latimanus*	Broadclub cuttlefish	Data deficient
Sepiidae	*Sepia* sp.	Cuttlefish	
Sepiidae	*Metasepia pfefferi*	Flamboyant Cuttlefish	Data deficient

Appendix 7: Sponges of Bootless Bay

Family	Scientific Name	Common Name	IUCN Status
Agelasidae	*Agelas* sp.	None	Not evaluated
Ancorinidae	*Rhabdastrella globostellata*	None	Not evaluated
Callyspongiidae	*Callyspongia aerizusa*	None	Not evaluated
Callyspongiidae	*Callyspongia* sp.	None	Not assessed
Chalinidae	*Haliclona nematifera*	None	Not assessed
Chalinidae	*Haliclona velina*	None	Not assessed
Chalinidae	*Heliclona* sp.	None	
Clionaidae	*Spheciospongia vagabunda*	None	Not evaluated
Clionaidae	*Spheciospongia* sp.	None	
Crambidae	*Monanchora ungiculata*	None	Not assessed
Crellidae	*Crella* sp.	None	
Darwinellidae	*Chelonaplysilla violacea*	None	Not evaluated
Dictyonellidae	*Liosina granularis*	None	Not evaluated
Dysideidae	*Dysidea* sp.	None	
Leucettidae	*Leucetta chagosensis*	None	Not evaluated
Leucettidae	*Leucetta* sp.	None	
Leucettidae	*Pericharax heteroraphis*	None	Not evaluated
Microcionidae	*Clathria mima*	None	Not evaluated
Microcionidae	*Clathria (Thalysias) reinwardti*	None	Not evaluated
Niphatidae	*Gelliodes fibulata*	None	Not evaluated
Mycalidae	*Mycale (Arenochalina) humilis*	None	
Niphatidae	*Geliodes* sp. 1	None	
Niphatidae	*Geliodes* sp.2	None	
Petrosiidae	*Petrosia* sp.	None	
Petrosiidae	*Strongylophora sphaeroidea*	None	Not evaluated
Petrosiidae	*Xestospongia testudinaria*	None	Not evaluated
Petrosiidae	unidentified sp.1	None	
Phloeodictyidae	*Aka* sp.1	None	
Phloeodictyidae	*Aka* sp.2	None	
Phloeodictyidae	*Aka* sp.3	None	
Soleneiscidae	*Dendya* sp.	None	
Suberitidae	*Terpios* sp.	None	
Tetillidae	*Cinachyrella schulzei*	None	

Appendix 8: Macro-Algae of Bootless Bay

Family	Scientific Name	Common Name	IUCN Status
Caulerpaceae	*Caulerpa racemosa*	Sea grapes	Not evaluated
Caulerpaceae	*Caulerpa taxifolia*	Feather algae	Not evaluated
Halimedaceae	*Halimeda* sp. 1	Cactus algae	Not evaluated
Halimedaceae	*Halimeda* sp. 2	Cactus algae	Not evaluated
Halimedaceae	*Halimeda* sp. 3	Cactus algae	Not evaluated
Siphonocladaceae	*Boergesenia forbesii*	Green algae	Not evaluated
Siphonocladaceae	*Dictyosphaeria versluysii*	Buttonweed	Not evaluated
Udoteaceae	*Avrainvillea* sp.	Mermaid's fan	Not evaluated
Udoteaceae	*Chlorodesmis fastigiata*	Turtle weed	Not evaluated
Valoniaceae	*Valonia ventricosa*	Sailor's eyeball	Not evaluated
Galaxauraceae	*Actinotrichia fragilis*	Fragile algae	Not evaluated
Gracilariaceae	*Gracilaria salicornia*		Not evaluated
Hypneaceae	*Hypnea pannosa*	Tattered sea moss	Not evaluated
Rhodomelaceae	*Acanthophora spicifera*	Spiny seaweed	Not evaluated
Rhodomelaceae	*Dasya* sp.	Red algae	Not evaluated
Peyssonneliaceae	*Peyssonnelia* sp.	Red algae	Not evaluated
Phyllophoraceae	*Ahnfeltiopsis* sp.	Ahnfelt's seaweed	Not evaluated
Dictyotaceae	*Dictyota magneana*	Branched algae	Not evaluated
Dictyotaceae	*Dictyota* sp. 1	Branched algae	Not evaluated
Dictyotaceae	*Dictyota* sp. 2	Branched algae	Not evaluated
Dictyotaceae	*Padina* sp.	Funnelweed	Not evaluated
Sargassaceae	*Sargassum* sp. 1	Sargassum weed	Not evaluated
Sargassaceae	*Sargassum* sp. 2	Sargassum weed	Not evaluated
Sargassaceae	*Turbinaria decurrens*	Triangular sea bell	Not evaluated
Scytosiphonaceae	*Hydroclathrus clathratus*	Netweed	Not evaluated
Boodleaceae	*Boodlea* sp.		Not evaluated
Phormidiaceae	*Microcoleus lyngbyaceus*	Mermaid's hair	Not evaluated

Appendix 9: Fishes of Bootless Bay

Family	Scientific Name	Common Name	IUCN Status
Acanthuridae	*Acanthurus auranticavus*		Least Concern
Acanthuridae	*Acanthurus fowleri*		Least Concern
Acanthuridae	*Acanthurus grammoptilus*		Least Concern
Acanthuridae	*Acanthurus lineatus*	Striped surgeonfish	Least Concern
Acanthuridae	*Acanthurus nigrofuscus*		Least Concern
Acanthuridae	*Acanthurus nigroris*		Least Concern
Acanthuridae	*Acanthurus olivaceus*		Least Concern
Acanthuridae	*Acanthurus pyroferus*	Mimic surgeonfish	Least Concern
Acanthuridae	*Acanthurus triostegus*		Least Concern
Acanthuridae	*Ctenochaetus binotatus*		Least Concern
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	Least Concern
Acanthuridae	*Naso brevirostris*	Spotted unicornfish	Least Concern
Acanthuridae	*Naso lituratus*	Orange-spine unicornfish	Least Concern
Acanthuridae	*Naso vlamingii*		Least Concern
Anguilladae	*Anguilla obscura*		Data Deficient
Antennariidae	*Antennarius pictus*	Painted Angler Fish	Least Concern
Antennariidae	*Histrio histrio*	Sargassum Frogfish	Least Concern
Apogonidae	*Apogon aureus*	Ringtailed cardinalfish	Least Concern
Apogonidae	*Apogon crassiceps*		Not evaluated
Apogonidae	*Apogon cyanosoma*	Yellowstriped cardinalfish	Least Concern
Apogonidae	*Apogon exostigma*		Not evaluated
Apogonidae	*Apogon fraenatus*	Bridled cardinalfish	Not evaluated
Apogonidae	*Apogon fucata*	Orange lined cardinalfish	Not evaluated
Apogonidae	*Apogon kallopterus*	Iridescent cardinalfish	Not evaluated
Apogonidae	*Apogon nigrofasciatus*	Blackstriped cardinalfish	Not evaluated
Apogonidae	*Apogon perlitus*	Peraly cardinalfish	Not evaluated
Apogonidae	*Apogon rhodopterus*		Not evaluated
Apogonidae	*Apogon* sp. 1		
Apogonidae	*Apogon* sp. 2		
Apogonidae	*Apogon sp*. 3		
Apogonidae	*Archamia zosterophora*	Blackbelted cardinalfish	Not evaluated
Apogonidae	*Cheilodipterus alleni*	Allen's cardinalfish	Not evaluated
Apogonidae	*Cheilodipterus isostigmus*		Not evaluated
Apogonidae	*Cheilodipterus macrodon*	Large-toothed cardinalfish	Not evaluated

Family	Scientific Name	Common Name	IUCN Status
Apogonidae	*Cheilodipterus parazonatus*	Mimic cardinalfish	Not evaluated
Apogonidae	*Cheilodipterus quinquelineatus*	Five-lined cardinalfish	Not evaluated
Apogonidae	*Cheilodipterus sp.*		
Apogonidae	*Fowleria marmorata*		Not evaluated
Apogonidae	*Fowleria variegata*		Not evaluated
Apogonidae	*Pseudamia hayashii*		Not evaluated
Apogonidae	*Rhabdamia cypselurus*	Swallowtail cardinalfish	Not evaluated
Apogonidae	*Siphamia elongata*		Not evaluated
Apogonidae	*Siphamia versicolor*	Urchin cardinalfish	Not evaluated
Apogonidae	*Sphaeramia nematoptera*	Pyjama cardinalfish	Not evaluated
Apogonidae	*Sphaeramia orbicularis*	Orbiculate cardinalfish	Not evaluated
Aulostomidae	*Aulostomus chinensis*	Trumpetfish	Least Concern
Balistidae	*Abalistes stellatus*	Starry triggerfish	Least Concern
Balistidae	*Balistapus undulatus*	Orange-lined triggerfish	Not evaluated
Balistidae	*Balistoides conspicillum*	Clown triggerfish	Not evaluated
Balistidae	*Balistoides viridescens*	Titan triggerfish	Not evaluated
Balistidae	*Melichthys vidua*		Not evaluated
Balistidae	*Pseudobalistes flavimarginatus*		Not evaluated
Balistidae	*Rhinecanthus aculeatus*	Blackbar triggerfish	Not evaluated
Balistidae	*Rhinecanthus verrucosus*		Not evaluated
Balistidae	*Sufflamen bursa*	Boomerang triggerfish	Not evaluated
Balistidae	*Sufflamen chrysopterus*	Flagtail triggerfish	Not evaluated
Belonidae	*Tylosurus crocodilus*		Least Concern
Belonidae	*Zenarchopterus gilli*		Least Concern
Blenniidae	*Aspidontus taeniatus*		Least Concern
Blenniidae	*Blenniella cf. gibbifrons*		Least Concern
Blenniidae	*Crossosalarias macrospilus*		Least Concern
Blenniidae	*Ctenogobiops* sp.		
Blenniidae	*Ecsenius namiyei*	Black comb-tooth blenny	Least Concern
Blenniidae	*Ecsenius yaeyamaensis*	Yaeyama blenny	Least Concern
Blenniidae	*Meiacanthus grammistes*	Striped fangblenny	Least Concern
Blenniidae	*Meiacanthus vittatus*	One-striped fangblenny	Least Concern
Blenniidae	*Plagiotremus laudandus*	Bicolor fangblenny	Least Concern
Blenniidae	*Plagiotremus rhinorhynchos*	Bluestriped fangblenny	Least Concern
Bothidae	*Bothus mancus*		Least Concern
Caesionidae	*Caesio caerulaurea*	Blue and gold fusilier	Least Concern

Family	Scientific Name	Common Name	IUCN Status
Caesionidae	*Caesio cuning*	Yellowtail fusilier	Least Concern
Caesionidae	*Caesio teres*		Least Concern
Caesionidae	*Pterocaesio digramma*		Least Concern
Caesionidae	*Pterocaesio pisang*		Least Concern
Callionymidae	*Callionymus enneactis*		Not evaluated
Callionymidae	*Dactylopus dactylopus*	Fingered dragonet	Not evaluated
Callionymidae	*Synchiropus stellatus*	Starry dragonet	Not evaluated
Carangidae	*Carangoides plagiotaenia*	Barcheek trevally	Not evaluated
Carangidae	*Caranx melampygus*	Bluefin trevally	Not evaluated
Carangidae	*Caranx sexfasciatus*		Least Concern
Carcharhinidae	*Carcharinus melanopterus*	Black-tip reef shark	Near Threatened
Carcharhinidae	*Triaenodon obesus*	White-tip reef shark	Near Threatened
Chaetodonitdae	*Chaetodon auriga*		Least Concern
Chaetodonitdae	*Chaetodon baronessa*		Least Concern
Chaetodonitdae	*Chaetodon bennetti*	Bluelashed butterflyfish	Data Deficient
Chaetodonitdae	*Chaetodon citrinellus*		Least Concern
Chaetodonitdae	*Chaetodon ephippium*	Saddle butterflyfish	Least Concern
Chaetodonitdae	*Chaetodon kleinii*	Brown butterflyfish	Least Concern
Chaetodonitdae	*Chaetodon lunulatus*		Least Concern
Chaetodonitdae	*Chaetodon melannotus*		Least Concern
Chaetodonitdae	*Chaetodon ornatissimus*	Ornate butterflyfish	Least Concern
Chaetodonitdae	*Chaetodon pelewensis*	Sunset butterflyfish	Least Concern
Chaetodonitdae	*Chaetodon plebeius*	Blue-dash butterflyfish	Least Concern
Chaetodonitdae	*Chaetodon rafflesi*	Latticed butterflyfish	Least Concern
Chaetodonitdae	*Chaetodon speculum*		Least Concern
Chaetodonitdae	*Chaetodon trifascialis*	Melon butterflyfish	Near Threatened
Chaetodonitdae	*Chaetodon ulietensis*	Double-saddled butterflyfish	Least Concern
Chaetodonitdae	*Chaetodon unimaculatus*		Least Concern
Chaetodonitdae	*Chaetodon vagabundus*	Vagabond butterflyfish	Least Concern
Chaetodonitdae	*Chelmon rostratus*	Copperband butterflyfish	Least Concern
Chaetodonitdae	*Forcipiger flavissimus*	Longnosed butterflyfish	Least Concern
Chaetodonitdae	*Forcipiger longirostris*	Big longnosed butterflyfish	Least Concern
Chaetodonitdae	*Hemitaurichthys polylepis*	Pyramid butterflyfish	Least Concern
Chaetodonitdae	*Heniochus acuminatus*	Reef bannerfish	Least Concern
Chaetodonitdae	Heniochus chrysostomus	Pennant bannerfish	Least Concern
Chaetodonitdae	*Heniochus singularis*		Least Concern

Family	Scientific Name	Common Name	IUCN Status
Chaetodonitdae	*Heniochus varius*	Humphead bannerfish	Least Concern
Cirrhitidae	*Cirrhitichthys aprinus*	Spotted hawkfish	Least Concern
Cirrhitidae	*Cirrhitichthys falco*	Dwarf hawkfish	Least Concern
Cirrhitidae	*Cirrhitichthys oxycephalus*	Coral hawkfish	Least Concern
Cirrhitidae	*Oxycirrhites typus*	Longnose hawkfish	Least Concern
Cirrhitidae	*Paracirrhites arcatus*	Ring-eyed hawkfish	Least Concern
Cirrhitidae	*Paracirrhites forsteri*	Forster hawkfish	Least Concern
Congridae	*Heteroconger hassi*	Spotted Garden Eel	Not evaluated
Dasyatidae	*Dasyatis kuhlii*	Blue-Spotted Stingray	Data Deficient
Dasyatidae	*Taeniura lymma*	Blue-spotted Fantail Stingray	Near Threatened
Diodontidae	*Diodon hystrix*		Least Concern
Ephippidae	*Platax orbicularis*	Orbicular batfish	Not evaluated
Ephippidae	*Platax pinnatus*	Dusky batfish	Not evaluated
Ephippidae	*Platax teira*	Tail-fin batfish	Not evaluated
Fistulariidae	*Fistularia* commersonii		Least Concern
Gobiesocidae	*Diademichthys lineatus*	Urchin Clingfish	Least Concern
Gobiesocidae	*Discotrema crinophila*	Crinoid Clingfish	Least Concern
Gobiidae	*Amblyeleotris arcupinna*	Red-banded shriimpgoby	Not evaluated
Gobiidae	*Amblyeleotris guttata*	Spotted shrimpgoby	Not evaluated
Gobiidae	*Amblyeleotris randalli*	Randall's shrimpgoby	Not evaluated
Gobiidae	*Amblygobius decussatus*	Orange-striped goby	Not evaluated
Gobiidae	*Amblygobius phaelena*	Banded goby	Not evaluated
Gobiidae	*Amblygobius rainfordi*	Old glory	Least Concern
Gobiidae	*Bryaninops amplus*	Large whip goby	Least Concern
Gobiidae	*Bryaninops loki*	Loki whip goby	Least Concern
Gobiidae	*Calumia* sp. 1		
Gobiidae	*Calumia* sp. 2		
Gobiidae	*Cryptocerus* sp.		
Gobiidae	*Eviota* sp.		
Gobiidae	*Exyrias belissimus*	Beautiful goby	Least Concern
Gobiidae	*Fusigobius inframaculatus*	Blotched goby	Least Concern
Gobiidae	*Fusigobius signipinnis*		Not evaluated
Gobiidae	*Fusigobius* sp.		
Gobiidae	*Gobiodon okinawae*	Yellow coralgoby	Not evaluated
Gobiidae	*Istigobius goldmanni*		Not evaluated
Gobiidae	*Istigobius ornatus*	Ornate goby	Least Concern

Family	Scientific Name	Common Name	IUCN Status
Gobiidae	*Istigobius rigilius*		Least Concern
Gobiidae	*Oplopomus oplopomus*		Not evaluated
Gobiidae	*Paragobiodon xanthosomus*		Least Concern
Gobiidae	*Periophthalmus argentilineatus*		Not evaluated
Gobiidae	*Pleurosicya bilobata*		Least Concern
Gobiidae	*Pleurosicya micheli*	Stiny coral ghostgoby	Least Concern
Gobiidae	*Pleurosicya mossambica*	Common ghostgoby	Least Concern
Gobiidae	*Priolepis* sp.		
Gobiidae	*Signigobius biocellatus*	Signal gobyfish	Not evaluated
Gobiidae	*Trimma* sp. 1		
Gobiidae	*Trimma* sp. 2		
Gobiidae	*Trimma* sp. 3		
Gobiidae	*Trimma caesiura*	Dwarf goby	Least Concern
Gobiidae	*Trimma macrophthalma*		Least Concern
Gobiidae	*Trimma okinawae*		Least Concern
Gobiidae	*Trimma striatum*		Least Concern
Gobiidae	*Valenciennea helsdingenii*	Two stripe goby	Least Concern
Gobiidae	*Valenciennea puellaris*	Maiden goby	Least Concern
Gobiidae	*Valenciennea strigata*	Bluestreak goby	Least Concern
Haemulidae	*Plectorhinchus chaetodontoides*	Harlequin sweetlips	Not evaluated
Haemulidae	*Plectorhinchus chrysotaenia*	Yellow-striped sweetlips	Not evaluated
Haemulidae	*Plectorhinchus lineatus*	Yellow-banded sweetlips	Not evaluated
Haemulidae	*Plectorhinchus vittatus*	Oriental sweetlips	Not evaluated
Hemiramphidae	*Hemiramphus archipelagicus*		Not evaluated
Hemiramphidae	*Hemiramphus far*		Not evaluated
Hemiramphidae	*Hyporhamphus quoyi*		Not evaluated
Hemiscyllidae	*Hemiscyllium hallstromi*	Epaulette shark	Vulnerable
Holocentridae	*Myripristis berndti*	Blotcheye soldierfish	Least Concern
Holocentridae	*Myripristis kuntee*		Least Concern
Holocentridae	*Myripristis murdjan*	Pinecone soldierfish	Least Concern
Holocentridae	*Myripristis violacea*	Violet soldierfish	Least Concern
Holocentridae	*Myripristis vittata*	Whitetip soldierfish	Least Concern
Holocentridae	*Neoniphon argenteus*		Least Concern
Holocentridae	*Neoniphon sammara*	Sammara squirrelfish	Least Concern

Family	Scientific Name	Common Name	IUCN Status
Holocentridae	*Plectrypops lima*		Least Concern
Holocentridae	*Sargocentron caudimaculatum*	Silverspot squirrelfish	Least Concern
Holocentridae	*Sargocentron iota*		Least Concern
Holocentridae	*Sargocentron cornutum*		Least Concern
Holocentridae	*Sargocentron ensifer*	Yellow-striped soldierfish	Least Concern
Holocentridae	*Sargocentron rubrum*		Least Concern
Holocentridae	*Sargocentron spiniferum*	Sabre suirrelfish	Least Concern
Holocentridae	*Sargocentron tiereoides*		Least Concern
Holocentridae	*Sargocentron violaceum*		Least Concern
Kyphosidae	*Kyphosus cinerascens*		Least Concern
Labridae	*Anampses neoguinaicus*	New Guinea wrasse	Least Concern
Labridae	*Bodianus anthioides*	Lyretail hogfish	Least Concern
Labridae	*Bodianus axillaris*		Least Concern
Labridae	*Bodianus bimaculatus*	Two-spot slender hogfish	Least Concern
Labridae	*Bodianus diana*	Diana's hogfish	Least Concern
Labridae	*Bodianus mesothorax*		Least Concern
Labridae	*Cheilinus chlorourus*		Least Concern
Labridae	*Cheilinus digrammus*	Cheeklined wrasse	Least Concern
Labridae	*Cheilinus fasciatus*	Redbreast wrasse	Least Concern
Labridae	*Cheilinus oxycephalus*		Least Concern
Labridae	*Cheilinus trilobatus*		Least Concern
Labridae	*Cheilinus undulatus*	Napoleon wrasse	Endangered
Labridae	*Choerodon anchorago*		Least Concern
Labridae	*Cirrhilabrus punctatus*	Dotted wrasse	Least Concern
Labridae	*Coris batuensis*		Least Concern
Labridae	*Coris gaimard*	Yellowtail coris	Least Concern
Labridae	*Epibulus insidiator*	Slingjaw wrasse	Least Concern
Labridae	*Gomphosus varius*	Bird wrasse	Least Concern
Labridae	*Halichoeres argus*		Least Concern
Labridae	*Halichoeres biocellatus*	Red-lined wrasse	Least Concern
Labridae	*Halichoeres chloropterus*		Least Concern
Labridae	*Halichoeres hortulanus*	Checkerboard wrasse	Least Concern
Labridae	*Halichoeres leucurus*	Greyhead wrasse	Least Concern
Labridae	*Halichoeres melanurus*		Least Concern
Labridae	*Halichoeres prosopeion*		Least Concern
Labridae	*Halichoeres richmondi*		Least Concern

Family	Scientific Name	Common Name	IUCN Status
Labridae	*Halichoeres trimaculatus*	Threespot wrasse	Least Concern
Labridae	*Hemigymnus fasciatus*	Barred thicklip wrasse	Least Concern
Labridae	*Hemigymnus melapterus*		Least Concern
Labridae	*Hologymmnosus annulatus*	Ring wrasse	Least Concern
Labridae	*Labrichthys unilineatus*		Least Concern
Labridae	*Labroides dimidiatus*	Blue streak cleaner wrasse	Least Concern
Labridae	*Labropsis micronesica*		Least Concern
Labridae	*Macropharyngodon meleagris*	Leopard wrasse	Least Concern
Labridae	*Novaculichthys taeniourus*	Rockmover wrasse	Least Concern
Labridae	*Oxycheilinus bimaculatus*		Least Concern
Labridae	*Oxycheilinus digramma*		Least Concern
Labridae	*Pseudocheilinus evanidus*		Least Concern
Labridae	*Pseudocheilinus octotaenia*		Least Concern
Labridae	*Pseudocheilinus* sp.		
Labridae	*Stethojulis bandanensis*		Least Concern
Labridae	*Thalassoma hardwicke*	Six bar wrasse	Least Concern
Labridae	*Thalassoma lunare*	Moon wrasse	Least Concern
Labridae	*Thalassoma lutescens*	Sunset wrasse	Least Concern
Labridae	*Wetmorella nigropinnata*		Least Concern
Lethrinidae	*Lethrinus erythracanthus*	Longfin emperor	Least Concern
Lethrinidae	*Lethrinus harak*		Least Concern
Lethrinidae	*Lethrinus variegatus*		Least Concern
Lethrinidae	*Monotaxis grandoculis*	Humpnose bigeye bream	Least Concern
Lutjanidae	*Lutjanus argentimaculatus*	Mangrove jack	Least Concern
Lutjanidae	*Lutjanus biguttatus*	Two-spot banded snapper	Least Concern
Lutjanidae	*Lutjanus gibbus*		Least Concern
Lutjanidae	*Lutjanus semicinctus*		Least Concern
Lutjanidae	*Macolor macularis*	Midnight snapper	Least Concern
Lutjanidae	*Symphorichthys spilurus*	Sailfin snapper	Least Concern
Megalopidae	*Megalops* cyprinoides		Data Deficient
Mobulidae	*Manta birostris*	Manta Ray	Vulnerable
Monacanthidae	*Aluterus scriptus*	Srawled filefish	Least Concern
Monacanthidae	*Cantherhines dumerilii*		Least Concern
Monacanthidae	*Cantherhines pardalis*		Least Concern
Monacanthidae	*Monacanthus chinensis*		Least Concern
Monacanthidae	*Oxymonacanthus longirostris*	Harlequin filefish	Vulnerable

Family	Scientific Name	Common Name	IUCN Status
Monacanthidae	*Pervagor cf. melanocephalus*		Least Concern
Monacanthidae	*Pervagor janthinosoma*		Least Concern
Monacanthidae	*Rudarius minutus*		Least Concern
Mugilidae	*Moolgarda seheli*		Not evaluated
Mullidae	*Parupeneus barberinoides*		Least Concern
Mullidae	*Parupeneus crassilabris*		Least Concern
Mullidae	*Parupeneus indicus*		Least Concern
Mullidae	*Parupeneus multifasciatus*	Manybar goatfish	Least Concern
Mullidae	*Upeneus tragula*	Freckled goatfish	Least Concern
Muraenidae	*Echidna nebulosa*	Snowflake moray	Not evaluated
Muraenidae	*Gymnothorax cf. chilospilus*		Least Concern
Muraenidae	*Gymnothorax* elegans		Not evaluated
Muraenidae	*Gymnothorax favagineus*	Blackspotted Moray	Not evaluated
Muraenidae	*Gymnothorax fimbriatus*		Not evaluated
Muraenidae	*Gymnothorax flavimarginatus*	Yellow edged Moray	Not evaluated
Muraenidae	*Gymnothorax herrei*		Not evaluated
Muraenidae	*Gymnothorax javanicus*	Giant Moray Eel	Not evaluated
Muraenidae	*Gymnothorax richardsoni*		Not evaluated
Muraenidae	*Gymnothorax thyrsoidea*		Not evaluated
Muraenidae	*Gymnothorax undulatus*		Not evaluated
Muraenidae	*Gymnothorax zonipectis*		Not evaluated
Muraenidae	*Moringua* sp.		
Muraenidae	*Pseudoechidna brummeri*		Not evaluated
Muraenidae	*Rhinomuraena quaesita*	Ribbon Moray	Least Concern
Myliobatidae	*Aetobatis narinari*		Near Threatened
Nemipteridae	*Pentapodus trivittatus*	Three-striped whiptail	Least Concern
Nemipteridae	*Scolopsis bilineata*	Two-lined monocle bream	Least Concern
Nemipteridae	*Scolopsis ciliatus*	Whitestreak monocle bream	Least Concern
Nemipteridae	*Scolopsis lineata*		Least Concern
Nemipteridae	*Scolopsis margaritifera*	Pearly monocle bream	Least Concern
Nemipteridae	*Scolopsis monogramma*	Monocle bream	Least Concern
Ophichthidae	*Callechelys marmorata*	Marbled Snake Eel	Not evaluated
Ophichthidae	*Kaupichthys* sp.		
Ophichthidae	*Ophichthus bonaparti*	Napolean snake eel	Not evaluated
Orectolobidae	*Eucrossorhinus dasypogon*	Tasselled wobbegong	Least Concern
Ostraciidae	*Lactoria cornuta*	Longhorned cowfish	Not evaluated

Family	Scientific Name	Common Name	IUCN Status
Ostraciidae	*Ostracion cubicus*		Not evaluated
Ostraciidae	*Ostracion meleagris*	White-spotted boxfish	Not evaluated
Ostraciidae	*Ostracion solorensis*	Reticulate boxfish	Not evaluated
Pegasidae	*Eurypegasus draconis*	Short dragonfish	Least Concern
Pempheridae	*Parapriacanthus ransonneti*	Yellow sweeper	Not evaluated
Pinguipedidae	*Parapercis clathrata*	Latticed grubfish	Not evaluated
Pinguipedidae	*Parapercis hexophtalma*		Not evaluated
Pinguipedidae	*Parapercis lineopunctata*	Nose stripe grubfish	Not evaluated
Pinguipedidae	*Parapercis millepunctata*	Blackdotted grubfish	Not evaluated
Pinguipedidae	*Parapercis xanthozona*	Java grubfish	Least Concern
Platycephalidae	*Cymbacephalus beauforti*	Crocodile fish	Least Concern
Plesiopidae	*Calloplesiops altivelis*	Comet	Not evaluated
Plesiopidae	*Plesiops caeruleolineatus*		Not evaluated
Plotosidae	*Plotosus lineatus*	Striped catfish	Not evaluated
Pomacanthidae	*Apolemichthys trimaculatus*	Three spot angelfish	Least Concern
Pomacanthidae	*Centropyge bicolor*	Bicolor angelfish	Least Concern
Pomacanthidae	*Centropyge bispinosa*	Twospined angelfish	Least Concern
Pomacanthidae	*Centropyge vrolikii*		Least Concern
Pomacanthidae	*Genicanthus melanospilos*	Blackspot angelfish	Least Concern
Pomacanthidae	*Pomacanthus imperator*	Emperor angelfish	Least Concern
Pomacanthidae	*Pomacanthus sexstriatus*	Sixbar angelfish	Least Concern
Pomacanthidae	*Pomacanthus xanthometopon*	Yellowface angelfish	Least Concern
Pomacanthidae	*Pygoplites diacanthus*	Royal angelfish	Least Concern
Pomacentridae	*Abudefduf lorenzi*		Least Concern
Pomacentridae	*Abudefduf sexfasciatus*		Least Concern
Pomacentridae	*Abudefduf vaigiensis*		Least Concern
Pomacentridae	*Amblyglyphidodon aureus*	Golden damselfish	Least Concern
Pomacentridae	*Amblyglyphidodon curacao*	Staghorn damselfish	Least Concern
Pomacentridae	*Amblyglyphidodon leucogaster*	Yellowbelly damselfish	Least Concern
Pomacentridae	*Amphiprion clarkii*	Clark's anemonefish	Not evaluated
Pomacentridae	*Amphiprion melanopus*	Fire anemonefish	Least Concern
Pomacentridae	*Amphiprion percula*	Clown anemonefish	Least Concern
Pomacentridae	*Amphiprion perideraion*	Pink anemonefish	Least Concern
Pomacentridae	*Amphiprion polymnus*	Saddleback anemonefish	Least Concern
Pomacentridae	*Chromis amboinensis*	Ambon chromis	Not evaluated
Pomacentridae	*Chromis atripectoralis*		Not evaluated

Family	Scientific Name	Common Name	IUCN Status
Pomacentridae	*Chromis atripes*	Darkfin chromis	Least Concern
Pomacentridae	*Chromis margaritifer*		Not evaluated
Pomacentridae	*Chromis retrofasciata*	Blackbar chromis	Not evaluated
Pomacentridae	*Chromis ternatensis*		Not evaluated
Pomacentridae	*Chromis viridis*	Blue green damselfish	Not evaluated
Pomacentridae	*Chromis weberi*		Not evaluated
Pomacentridae	*Chrysiptera rollandi*	Rolland's demoiselle	Not evaluated
Pomacentridae	*Chrysiptera talboti*	Talbot's demoiselle	Not evaluated
Pomacentridae	*Dascyllus aruanus*	Humbug dascyllus	Not evaluated
Pomacentridae	*Dascyllus melanurus*		Not evaluated
Pomacentridae	*Dascyllus reticulatus*		Not evaluated
Pomacentridae	*Dascyllus trimaculatus*		Not evaluated
Pomacentridae	*Dischistodus chrysopoecilus*		Not evaluated
Pomacentridae	*Dischistodus prosopotaenia*	Honey-head damsel	Not evaluated
Pomacentridae	*Neoglyphidodon melas*		Not evaluated
Pomacentridae	*Neoglyphidodon nigroris*	Black and gold chromis	Not evaluated
Pomacentridae	*Neoglyphidodon oxyodon*		Not evaluated
Pomacentridae	*Neopomacentrus azysron*	Yellowtail demoiselle	Not evaluated
Pomacentridae	*Neopomacentrus taeniurus*		Data Deficient
Pomacentridae	*Plectroglyphidodon lacrymatus*	Jewel damsel	Not evaluated
Pomacentridae	*Pomacentrus amboinensis*	Ambon damsel	Not evaluated
Pomacentridae	*Pomacentrus armillatus*		Not evaluated
Pomacentridae	*Pomacentrus bankanensis*	Speckled damselfish	Not evaluated
Pomacentridae	*Pomacentrus cf. amboinensis*		Not evaluated
Pomacentridae	*Pomacentrus cf. wardi*		Not evaluated
Pomacentridae	*Pomacentrus colini*	Colin's damselfish	Not evaluated
Pomacentridae	*Pomacentrus grammorhynchus*	Bluespot damsel	Not evaluated
Pomacentridae	*Pomacentrus moluccensis*		Not evaluated
Pomacentridae	*Pomacentrus nagasakiensis*	Nagasaki damsel	Not evaluated
Pomacentridae	*Pomacentrus nigromanus*	Goldback damsel	Not evaluated
Pomacentridae	*Pomacentrus pavo*		Not evaluated
Pomacentridae	*Pomacentrus reidi*		Not evaluated
Pomacentridae	*Premnas biaculeatus*	Spinecheek anemonefish	Not evaluated
Pomacentridae	*Stegastes albifasciatus*		Not evaluated
Pomacentridae	*Stegastes fasciolatus*		Not evaluated
Pomacentridae	*Stegastes nigricans*	Dusky gregory	Not evaluated

Family	Scientific Name	Common Name	IUCN Status
Priacanthidae	*Priacanthus hamrur*	Crescent tail bigeye	Least Concern
Pseudogrammidae	*Pseudogramma polyacantha*		Least Concern
Pseudogrammidae	*Suttonia lineata*		Least Concern
Psuedochromidae	*Pictichromis aurifrons*	Yellow-headed dottyback	Not evaluated
Psuedochromidae	*Pseudochromis fuscus*		Least Concern
Psuedochromidae	*Pseudochromis marshallensis*		Least Concern
Psuedochromidae	*Pseudochromis sp.*		
Pterelotridae	*Nemateleotris decora*	Purple fire goby	Least Concern
Pterelotridae	*Nemateleotris magnifica*	Fire goby	Least Concern
Pterelotridae	*Ptereleotris evides*	Arrow goby	Least Concern
Scaridae	*Calotomus carolinus*		Least Concern
Scaridae	*Calotomus spinidens*		Least Concern
Scaridae	*Cetoscarus bicolor*	Bicolor parrotfish	Least Concern
Scaridae	*Chlorurus bleekeri*	Bleeker's parrotfish	Least Concern
Scaridae	*Chlorurus microrhinos*		Least Concern
Scaridae	Chlorurus *sordidus*	Bullethead parrotfish	Least Concern
Scaridae	*Hipposcarus longiceps*		Least Concern
Scaridae	*Leptoscarus vaigiensis*		Least Concern
Scaridae	*Scarus chameleon*		Least Concern
Scaridae	*Scarus flavipectoralis*		Least Concern
Scaridae	*Scarus frenatus*		Least Concern
Scaridae	*Scarus ghobban*		Least Concern
Scaridae	*Scarus niger*	Swarthy parrotfish	Least Concern
Scaridae	*Scarus quoyi*		Least Concern
Scaridae	*Scarus rivulatus*		Least Concern
Scaridae	*Scarus schlegeli*		Least Concern
Scaridae	*Scarus spinus*		Least Concern
Sciaenidae	*Sciaenops* sp.		
Scombridae	*Euthynnus affinis*		Least Concern
Scombridae	*Katsuwonus pelamis*		Least Concern
Scombridae	*Rastrelliger kanagurta*		Data Deficient
Scombridae	*Scomberoides lysan*		Least Concern
Scombridae	*Scomberoides tol*		Least Concern
Scorpaenidae	*Ablabys taenianotus*		Not evaluated
Scorpaenidae	*Dendrochirus brachypterus*	Shortfin lionfish	Least Concern
Scorpaenidae	*Dendrochirus zebra*	Zebra lionfish	Least Concern

Family	Scientific Name	Common Name	IUCN Status
Scorpaenidae	*Pterois antennata*	Spotfin lionfish	Least Concern
Scorpaenidae	*Pterois volitans*	Common lionfish	Least Concern
Scorpaenidae	*Rhinopias aphanes*	Lacy scorpionfish	Least Concern
Scorpaenidae	*Scorpaenodes albaiensis*		Least Concern
Scorpaenidae	*Scorpaenodes guamensis*		Least Concern
Scorpaenidae	*Scorpaenodes hirsutus*		Least Concern
Scorpaenidae	*Scorpaenodes parvipinnis*		Least Concern
Scorpaenidae	*Scorpaenodes* sp. 1		
Scorpaenidae	*Scorpaenodes* sp. 2		
Scorpaenidae	*Scorpaenopsis diabolus*	Devil scorpionfish	Least Concern
Scorpaenidae	*Scorpaenopsis macrochir*	Flasher scorpionfish	Least Concern
Scorpaenidae	*Scorpaenopsis oxycephala*	Tasselled scorpionfish	Least Concern
Scorpaenidae	*Scorpaenopsis possi*	Poss's scorpionfish	Least Concern
Scorpaenidae	*Scorpaenopsis venosa*	Raggy scorpionfish	Least Concern
Scorpaenidae	*Sebastapistes* sp.		
Scorpaenidae	*Sunagocia* sp.	Fringe lip flathead	
Scorpaenidae	*Taenianotus triacanthus*	Leaf Scorpionfish	Least Concern
Serranidae	*Anyperodon leucogrammicus*	White-lined rockcod	Least Concern
Serranidae	*Cephalopholis argus*		Least Concern
Serranidae	*Cephalopholis boenak*		Least Concern
Serranidae	*Cephalopholis leopardus*		Least Concern
Serranidae	*Cephalopholis miniata*	Coral rockcod	Least Concern
Serranidae	*Cephalopholis urodeta*	Flagtail rockcod	Least Concern
Serranidae	*Cromileptes altivelis*	Barramundi cod	Vulnerable
Serranidae	*Diploprion bifasciatum*	Barred soapfish	Least Concern
Serranidae	*Epinephelus fasciatus*	Black-tip rockcod	Least Concern
Serranidae	*Epinephelus fuscoguttatus*	Flowery cod	Near Threatened
Serranidae	*Epinephelus maculatus*	Marbeled rockcod	Least Concern
Serranidae	*Epinephelus merra*	Honeycomb cod	Least Concern
Serranidae	*Epinephelus polyphekadion*	Camouflage cod	Near Threatened
Serranidae	*Grammistes sexlineatus*	Lined soapfish	Least Concern
Serranidae	*Plectropomus laevis*	Blacksaddle coral trout	Vulnerable
Serranidae	*Plectropomus leopardus*		Near Threatened
Serranidae	*Pseudanthias fasciatus*	One-stripe anthias	Not evaluated
Serranidae	*Pseudanthias hypselosoma*	Stocky anthias	Least Concern
Serranidae	*Pseudanthias luzonensis*		Least Concern

Family	Scientific Name	Common Name	IUCN Status
Serranidae	*Pseudanthias pleurotaenia*	Square-spot anthias	Least Concern
Serranidae	*Pseudanthias squamipinnis*	Scalefin anthias	Least Concern
Serranidae	*Pseudanthias tuka*	Purple anthias	Least Concern
Siganidae	*Siganus argenteus*		Least Concern
Siganidae	*Siganus javus*	Java rabbitfish	Least Concern
Siganidae	*Siganus puellus*		Least Concern
Siganidae	*Siganus spinus*		Least Concern
Siganidae	*Siganus vulpinus*		Least Concern
Soleidae	*Pardachirus pavoninu*		Least Concern
Soleidae	*Pardachirus* sp.		
Solenostomidae	*Solenostomus cyanopterus*	Robust ghost pipefish	Least Concern
Solenostomidae	*Solenostomus halimeda*	Halimeda ghost pipefish	Data Deficient
Solenostomidae	*Solenostomus paegnius*	Rough snout ghost pipefish	Not evaluated
Solenostomidae	*Solenostomus paradoxus*	Ornate ghost pipefish	Least Concern
Sphyraenidae	*Sphyraena flavicauda*	Yellowtail barracuda	Not evaluated
Sphyraenidae	*Sphyraena qenie*	Blackfin barracuda	Not evaluated
Stegostomatidae	*Stegostoma fasciatum*	Leopard shark	Endangered
Synanceia	*Synanceia verrucosa*		Not evaluated
Syngnathidae	*Corythoichthys amplexus*	Brown-banded pipefish	Least Concern
Syngnathidae	*Corythoichthys haematopterus*	Messmate pipefish	Least Concern
Syngnathidae	*Corythoichthys intestinalis*	Scribbled pipefish	Least Concern
Syngnathidae	*Corythoichthys ocellatus*	Ocellated pipefish	Least Concern
Syngnathidae	*Corythoichthys polynotatus*	Many spotted pipefish	Least Concern
Syngnathidae	*Corythoichthys schultzi*	Schultz's pipefish	Least Concern
Syngnathidae	*Doryrhamphus dactyliophorus*	Ringed pipefish	Data Deficient
Syngnathidae	*Hippocampus* sp.	Seahorse	
Syngnathidae	*Syngnathoides biaculeatus*	Alligator pipehorse	Least Concern
Syngnathidae	*Trachyrhamphus bicoarctatus*	Bend stick pipefish	Least Concern
Synodontidae	*Saurida gracilis*	Gracile lizardfish	Least Concern
Synodontidae	*Synodus dermatogenys*		Least Concern
Synodontidae	*Synodus rubromarmoratus*	Redmarbled lizardfish	Least Concern
Synodontidae	*Synodus variegatus*	Variegated lizardfish	Least Concern
Tetradontidae	*Arothron caeruleopunctatus*		Least Concern
Tetradontidae	*Arothron hispidus*	White spotted pufferfish	Least Concern
Tetradontidae	*Arothron manilensis*	Narrow-lined pufferfish	Least Concern
Tetradontidae	*Arothron mappa*	Map pufferfish	Least Concern

Family	Scientific Name	Common Name	IUCN Status
Tetradontidae	*Arothron nigropunctatus*	Black spotted pufferfish	Least Concern
Tetradontidae	*Arothron stellatus*	Starry pufferfish	Least Concern
Tetradontidae	*Canthigaster compressa*	Compressed Toby	Least Concern
Tetradontidae	*Canthigaster janthinoptera*	Honeycomb toby	Least Concern
Tetradontidae	*Canthigaster papua*	Papuan toby	Least Concern
Tetradontidae	*Canthigaster valentini*	Valentini's sharpnose toby	Least Concern
Trichonotidae	*Trichonotus setiger*	Spotted sand diver	Least Concern
Tripterygiidae	*Enneapterygius* sp.		
Tripterygiidae	*Helcogramma* sp. 1		
Tripterygiidae	*Helcogramma* sp. 2		
Tripterygiidae	*Helcogramma striatum*	Striped triplefin	Least Concern
Xenisthmidae	*Xenisthmus cf. polyzonatus*		Least Concern
Zanclidae	*Zanclus cornutus*	Moorish idol	Least Concern

Appendix 10: Marine Mammals of Bootless Bay

Family	Scientific Name	Common Name	IUCN Status	PNG Status
Delphinidae	*Delphinus delphis*	Common dolphin	Not evaluated	Protected
Delphinidae	*Stenella longirostris*	Spinner dolphin	Not evaluated	Protected
Delphinidae	*Tursiops truncates*	Bottle-nosed dolphin	Not evaluated	Protected
Dugongidae	*Dugong dugong*	Dugong	Not evaluated	Protected

Appendix 11: Marine Reptiles of Bootless Bay

Family	Scientific Name	Common Name	IUCN Status	PNG Status
	Crocodylus porosus	Saltwater crocodile	Least concern	Protected
Chelonidae	*Chelonia mydas*	Green turtle	Endangered	Protected
	Eretomochelys imbricatus	Hawksbill turtle	Critically endangered	Protected
	Caretta caretta	Loggerhead turtle	Endangered	Protected
Hydrophidae	*Aipysurus leavis*	Olive sea snake	Data deficient	Not evaluated
Laticaudidae	*Laticauda* sp	Banded sea snake	Not assessed	