Port Resolution Community Conservation Area:

Appendix 1 - management plan development and supporting information

Tanna Island, Vanuatu

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Contents

1. Introduction

The geographic location of Vanuatu means it is vulnerable to earthquakes, volcanic eruptions, subsequent tsunamis and tropical cyclones and has been described as the most disaster-prone country in the South Pacific due to its vulnerability to these hazards (Meheux and Parker, 2006). Tanna Island is located in the south of the archipelago of Vanuatu's 83 islands in the Pacific Ocean (Figure 1). It is one of the smaller inhabited islands of Vanuatu with a total area of 550 km^2. One of the key threats to marine species in Tanna is overexploitation for consumption to meet the demands of a large population, being the most densely populated island in Vanuatu (Government of Vanuatu 2016).

Port Resolution is the most easterly point on the island of Tanna and includes Resolution Bay, a shallow bay sheltered from the prevailing southeast trade winds that is a significant safe "port" for visiting yachts (Ceccarelli et al. 2018). The active volcano, Mount Yasur, lies a few kilometres inland from Port Resolution and has significant cultural importance for the people of Tanna Island as well as tourism values being one of the most accessible volcanoes in the world.

The Vanuatu Pacific Ecosystem-based Adaptation to Climate Change (PEBACC) project, a five-year initiative, funded by the German Federal Government and implemented by the Secretariat of the Pacific Regional Environment Programme (SPREP), focuses on strengthening and protecting the role of natural ecosystem services to enhance resilience to climate change. PEBACC completed a comprehensive ecosystem and socio-economic resilience analysis and mapping (ESRAM) activity as a basis for Ecosystem-based Adaptation (EbA) planning in Tanna. Port Resolution was identified as the site for the implementation of the Tanna EbA demonstration project. One of the key EbA options identified was the development a Marine Protected Area (MPA) at Port Resolution, and the registration of the MPA as a Community Conservation Area (CCA) under the provisions of the Environmental Protection and Conservation Act CAP 283 (Mackey et al. 2017). Further, under the National Biodiversity Strategy and Action Plan 2018-2030 (NBSAP), the Vanuatu Government identified parts of Port Resolution (Shark Bay) as a target for formal protection by 2030.

The community in Port Resolution recently formed a local CCA Committee comprised of representatives from the six different Nakamals in the area. Progress towards CCA registration was made possible under the PEBACC project and specialist consultants from C_2O Pacific facilitated the fulfilment of the requirements for registration in close consultation with the Port Resolution community through the CCA Committee.

To successfully develop a management plan that was relevant and appropriate to the Port Resolution community, and to fulfil the requirements of the DEPC CCA process, a structured process was followed guided by the DEPC CCA guidelines. This report supports the CCA management plan by summarising relevant background information and the processes followed. As such, the management plan is simplified to contain key information needed to successfully implement the CCA, with much of the technical detail in this report. This was done to help ensure the management plan itself was 'user-friendly' for communities to become familiar with and understand its content. This report therefore provides detailed context for the final management plan and can inform future reviews of the CCA. The content of this report:

- Documents the background information required under the DEPC CCA registration process and used to inform the development of the management plan.
- Outlines the process followed with the Port Resolution community during development of the CCA management plan and supporting material.

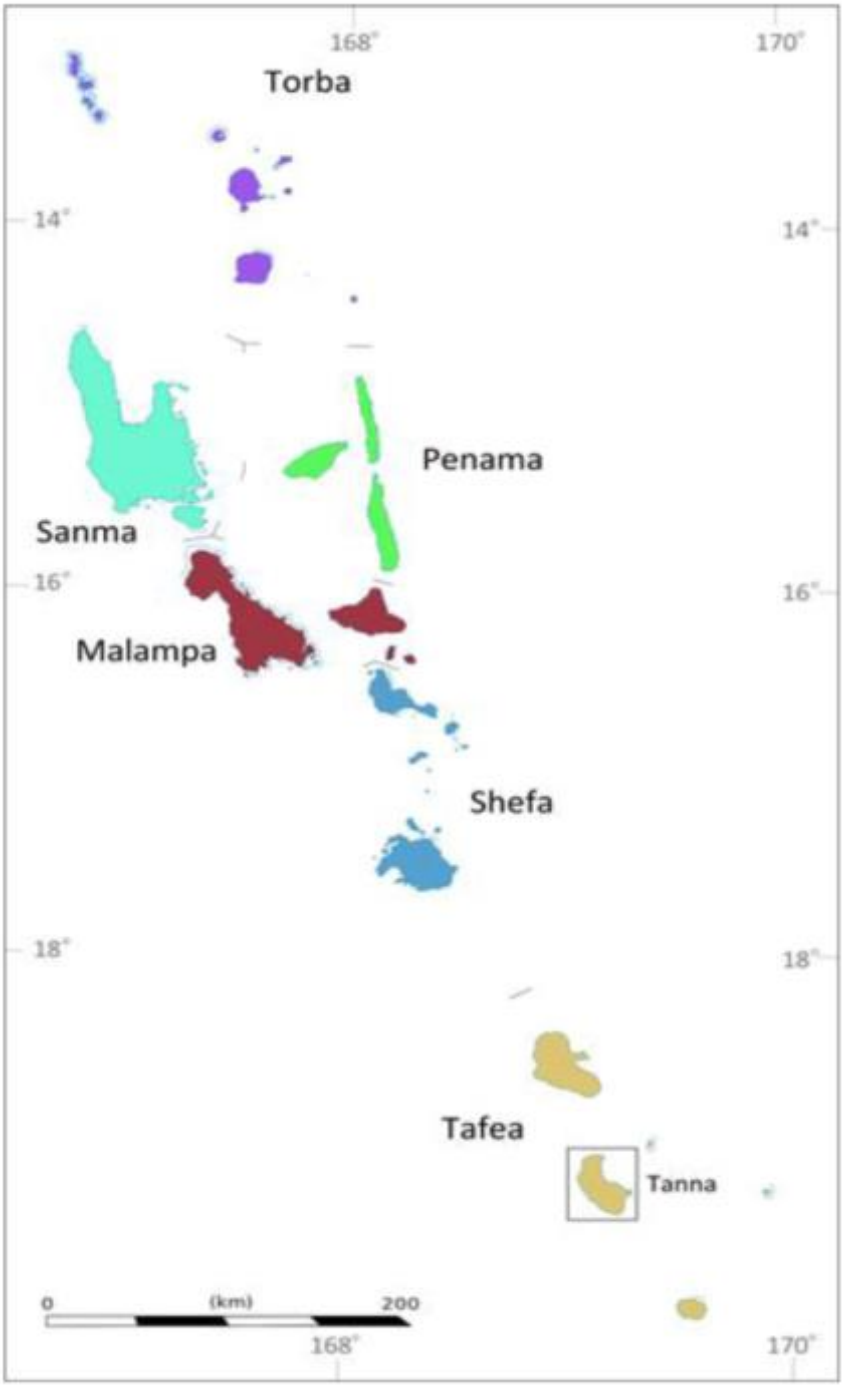

Figure 1. Map of the Vanuatu archipelago with islands colour coded by their official administrative provinces. Tanna is indicated in the south in the boxed area in Tafea Province. Source: Mackey et al. (2018).

2. Background knowledge

Background information for the area intended for CCA registration is critical to ensure that key issues and habitats are included as much as possible, and that the management plan is relevant and appropriate to the local context. The information documented was collated using three main approaches:

- published and/or publicly available information (e.g. reports, scientific journals, online),
- consultations with local communities and provincial and government departments, and
- field-based surveys and observations.

Socio-economic information

Population

In 2016, the population of Tanna Island was estimated to be 32,280 people, up from 28,734 in 2009 (Vanuatu National Statistics Office, 2016). This represents an annual population growth rate of 1.76 % for the period, lower than the national growth rate of 2.34 % for the same period. Across Vanuatu, non-communicable diseases are affecting the Ni-Vanuatu population with cardiovascular disease, diabetes, cancers and chronic respiratory diseases responsible for between 52 and 60% of premature deaths (Carter et al. 2016). Despite this, at the current population growth rate it is projected that by 2070 ecosystem services on Tanna will not be sufficient to support the population. For example, by 2070 the total estimated area of subsistence garden required to support the growing population would be greater than the total land area of Tanna Island (Mackey et al. 2017).

Local governance

The local governance system follows that typical of Vanuatu and authorised under the Vanuatu Constitution, and described in Mackey et al. (2017). On Tanna, governance occurs through two separate but connected network structures:

- Tafea provincial government network, and the
- *Malvatumauri* (National Council of Chiefs) network.

There are tribes made up of a number of different villages on Tanna. In each village decision-making is through the *Village Council*, also called the *Nakamal*, and is chaired by the village Chief. Within each tribe, one of the village *Nakamals* is called the *Supreme Nakamal*, which has the power to make decisions on behalf of the tribe. In Port Resolution there are seven villages and six Nakamals. The *Tribal Council* makes decisions at the tribal level and its members are made up of the Chiefs of each village. The Chief of the Supreme Nakamal chairs the Tribal Council. The *Area Council* functions within each of the two Networks. Within the *Malvatumauri* network the *Area Council* is comprised of the chairpersons of each *Tribal Council* and has an elected Chairperson. Within the Provincial Government Network the same Chiefs are members but it also includes the Provincial Area Secretary as well as pillar representatives (women, youth, etc.) and is chaired by one of the Chiefs. On Tanna, there are seven *Area Councils* and each usually has 12 members. In the *Malvatumauri* network, the *Area Council* takes direction from the *Island Council of Chiefs* (on Tanna this is called the *Nikoletan*). This has an elected Chairperson. In the Provincial

Government Network, the *Area Council* takes direction from the Tafea Provincial Government Committee (TPGC), of which the Area Secretary is a member.

Employment and economic opportunities

The level of economic development on Tanna Island is reported to be relatively low, despite the Mount Yasur volcano being well visited by tourists (Mackey et al. 2017). Currently, most of the population on Tanna depends on subsistence farming for their livelihoods and increasing commercial-scale agriculture is likely to be having an increasing input to the local economy (Malvatumauri 2012), and some rely on operating small shops or selling produce at roadside stalls. Tourism is relatively low with Mt Yasur the main attraction but visitation to Tanna by tourists tends to be short term possibly due to a lack of diversity in tourist attractions. There is a range of accommodation options from resort style to local bungalows with SCUBA diving at White Grass Resort one added attraction. Recent and ongoing road infrastructure projects may enhance the potential for tourism in the Port Resolution area. Currently there are a small number of bungalows, restaurants and eco-tourism businesses in Port Resolution, which appear to attract only periodic visitation. Tourism therefore supports only a small number of people through direct and indirect (service industry) jobs (Mackey et al. 2017). There is, however, the potential for cruise ships to include the White Sands/Port Resolution area as a future 'port' of visitation.

Migration from Tanna to Port Vila for economic reasons is common (Lidstrom, 2011) and individuals who manage to find work in Port Vila often support their relatives on Tanna by sending money back home. SPREP (2017) note the significant issues of rapid population growth, which is exerting increasing pressure on the environment in Tanna. A possible solution to this may require the identification and development of alternative cash income opportunities. In recent years the seasonal worker program in Australia and the Recognised Seasonal Employer Programme in New Zealand has created economic opportunities, particularly for males, with over 3,300 Ni-Vanuatu working in Australia in 2017-2018 (https://dfat.gov.au/geo/vanuatu/development-assistance/Pages/development-assistance-in-vanuatu.aspx). The downside of these programmes is the absence of men from communities for long periods however their work results in periodic injections of cash for community benefits such as business opportunities and house improvements.

Natural resource use

The people of Port Resolution, like all other areas of Vanuatu, have a heavy reliance on natural resources, particular coastal marine resources, for local consumption and household income (Bell et al. 2017). The recent SPREP ESRAM report estimated that 99 % of Tanna's ecosystem services value is generated by coastal coral reefs (81 %) and subsistence gardens (18 %).

Species of community importance

DEPC requirements for the registration of a CCA include documenting the plant and animal species present within the CCA that are important for community use. Through community consultations we identified 23 plant species (Table 1) and 21 animal species/species groups (Table 2) important to the local community for various reasons, including food, income, local *kastom*, medicine, building materials, soaps, materials for canoes and traditional hunting

weapons. These lists are not exhaustive and further consultation would likely identify more species. For example, fish catches are typically multi-species due to the large diversity of reef fish species available in coastal waters, however individuals only identified key species during interviews.

Table 1. Key plant species in the Port Resolution area identified as important for communities and main uses. Local name is given where possible and refers to Bislama and/or local language; English name is given in brackets. The list was compiled through local consultations (see Appendix 1).

Local name (English name)	**Scientific name**	**Main uses**
Kokonas; Napway (Coconut)	*Cocos nucifera*	Custom; Food; Income; Medicine; Timber
Nipikisi (Sandalwood)	*Santalum austrocaledonicum*	Custom; Income; Medicine
Napanga; Napek (Banyan tree)	*Ficus (microcarpa)?*	Treehouse; Medicine; Nakamal
Purao; Newou (Wild hibiscus)	*Hibiscus* spp.	Wind breaker
Nier/Niar (Oak tree)	*Quercus* spp.	Timber; Grass skirt; Medicine; Soap; Food
Nivara (Bandanas)		Timber
Niviangviang (Seagrass)	*Cymodocea rotundata*; *C. serrulata*; *Thalassia hemprichii*	Food; Income
Nemer/Nemar (Breadfruit)	*Artocarpus altilis*	Handicraft; Medicine; Canoe
Namariu	*Acasia simplex* or A. *spiropsis*	Bow and arrow
Nakongar		Medicine
Napina		Medicine
Nagambe (Tahitian chestnut)	*Inocarpus fagifer*	Food; Income
Niapar		Culture
Takraus		Culture
Nikawa (Kava)	*Piper methysticum*	Custom; Income; Drink
Manvara (Pandanus)	*Pandanus* spp.	Custom
Napar (Tamanu)	*Calophyllum inophyllum*	Wind break
Nakoutuve (Blue water tree/Rosewood)	*Dalbergia* spp.	Timber
Namele/Namar (Cycad)	Order Cycadales	Custom (tabu areas)
Nikariang (Poison fish tree)	*Barringtonia asiatica*	Medicine; Fish poison
Napkapi (Glue tree)		Medicine (during circumcision)
Nisei	*Evodia hortensis*	Custom (during circumcision); medicine; perfume
Nikavai (Wild vine)		Income; Food; Medicine

Table 2. Key animal species in the Port Resolution area identified as important for communities and main uses. Local name is given where possible and refers to Bislama and/or local language; English name is given in brackets. The list was compiled through local consultation (see Appendix 1).

Local name (English name)	**Scientific name**	**Use**
Iwea crab (Sand crab - red)	Order Decapoda	Food
Naura; Ieren (Lobster)	*Panulirus* spp.	Custom; Food; income
Pixeye; Kusan tonga (Green snail)	*Turbo marmoratus*	Custom; Food; income
Bubu; Kisep (Triton)	*Charonia tritonis*	Cultural – special occasion
Troca; Karikau (Trochus)	*Trochus niloticus*	Fishing bait; Food; Income
Sea snail	Gastropoda	Local medicine; Food for turtle
Nataiae (Giant clams)	*Tridacna* spp.	Food; Decoration
Kipori (Sea cucumber)	Holothuroidea	Medicine; Income; Food
Iapsis (Squid)	*Sepioteuthis lessoniana*	Fishing bait
Nawita (Octopus)	All species	Custom; Food; income
Blu fis (Parrotfish)	Family Scaridae	Food; income
Mustas fis; Iasu (Goat fish)	Family Mullidae	Food; Income; Attraction
Malet (Sea mullet)	Family Mugilidae	Food; Income
Nawita (Skipjack tuna)	*Katsuwonus pelamis*	Food; Income
Mangru; Peme/Pema; Mangoru (Scad)	*Selar* sp.	Custom; Food; income; Fishing bait
Nawaukuk (Mudskipper)	Family Oxudercidae	Custom belief (messenger fish)
Stingri; Waraku (Stingray)	All species	Custom; Food; income
Sak; Puengen (Shark)	All species	Custom; food
Totel; Iaku (Turtle)	Superfamily Chelonioidea	Custom; food
Cowfis; Kurmakao (Dugong)	*Dugong dugon*	Tourist attraction
Wapu (Gecko)	Family Gekkonidae	Traditional belief (protects food crops)

Physical information

Geology

It has been estimated that Tanna was formed approximately 2.5 million years ago by a combination of volcanic activity and reef growth (Carney and McFarlane 1979). Mt Yasur, located less than 5 km from Port Resolution, is currently one of the most active volcanoes in Vanuatu, erupting every few minutes with repeated strombolian and vulcanian-type eruptions (Merle et al. 2013). A large magma reservoir feeds these eruptions, which have been ongoing for the last 600 years (Firth et al. 2015). The Port Resolution area has experienced significant recent geological change such as a 12 metre uplift after two strong earthquakes in 1878 (Nairn et al. 1998) which formed the present day Lake Eweya (Clare et al. 2018).

Many of the cliffs surrounding the Port Resolution area are made up of geotechnically weak volcanic deposits and this, coupled with the fast rate of uplift in the area, makes them prone to land slips (Brothelande et al. 2016). Indeed there is evidence of this in the region and the low cliffs surrounding Resolution Bay show evidence of continual erosion. A recent study showed evidence that large boulders and debris were present on top of the carbonate coral structures in the coastal Port Resolution area and it has been suggested that the fallen boulders and sediment create linear gullies on the seabed as they mix with the seawater (Clare et al. 2018).

Climate

Vanuatu has a tropical climate, driven by El Nino Southern Oscillation (ENSO) cycles and moderated by southeast trade winds from May to October, and high rainfall from November to April. The climate is often affected by cyclones from December to April. It is one of the world's most vulnerable countries to natural disasters, experiencing droughts, floods, cyclones, volcanic eruptions, landslides, tsunamis and coastal inundation. Since 1939, Vanuatu has experienced 124 tropical cyclones, of which 45 were categorised as having hurricane force winds.

Assessments of vulnerability to climate change undertaken over the last two decades have identified Vanuatu as being highly exposed to climate variability and change, and at risk of impacts, with the country ranked 9th globally under the Climate Risk Index for 1998–2017 (German Watch 2019).

Ecological information

The Port Resolution area includes a range of plant and animal species as well as a variety of habitat types. Port Resolution was identified as a one of the highest priority biophysically Special, Unique Marine Area's (SUMA) in Vanuatu during the recent MACBIO national marine spatial planning process (Wendt et al 2018). This was partly due to the fact it is one of very few areas in Vanuatu that contains coral reef, seagrass and mangrove habitats, each of which are key habitats for a wide range of organisms and for different stages of their life cycles (Ceccarelli et al 2018). At the broad scale Port Resolution is dominated by tropical forest habitats (low, thickets and shrubs), coastal fringing coral reefs and land areas modified for subsistence gardening (Figure 2; Mackey et al. 2018). Data is generally limited however recent research has greatly advanced knowledge of the area, three notable studies being:

- the *Plants mo Pipo* project, a collaboration between the New York Botanical Garden, the Vanuatu Department of Forestry and the Tafea Kaljoral Senta, which formally documented plant species present in the Port Resolution area during 2018 (Figure 3),
- the Commonwealth Marine Economies (CME) Programme NOC Project which created marine habitat maps for Resolution Bay and the adjacent area using underwater imagery (Remotely Operated Vehicle - ROV) and aerial footage (drone) during 2017, and
- the PEBACC ESRAM report which documented and mapped threats and changes in local land use and habitats.

This section summarises these habitat types as well as animal and plant species identified as significant under the DEPC CCA guidelines. Where possible, the current status of important habitats is given based on observations, consultations and published literature.

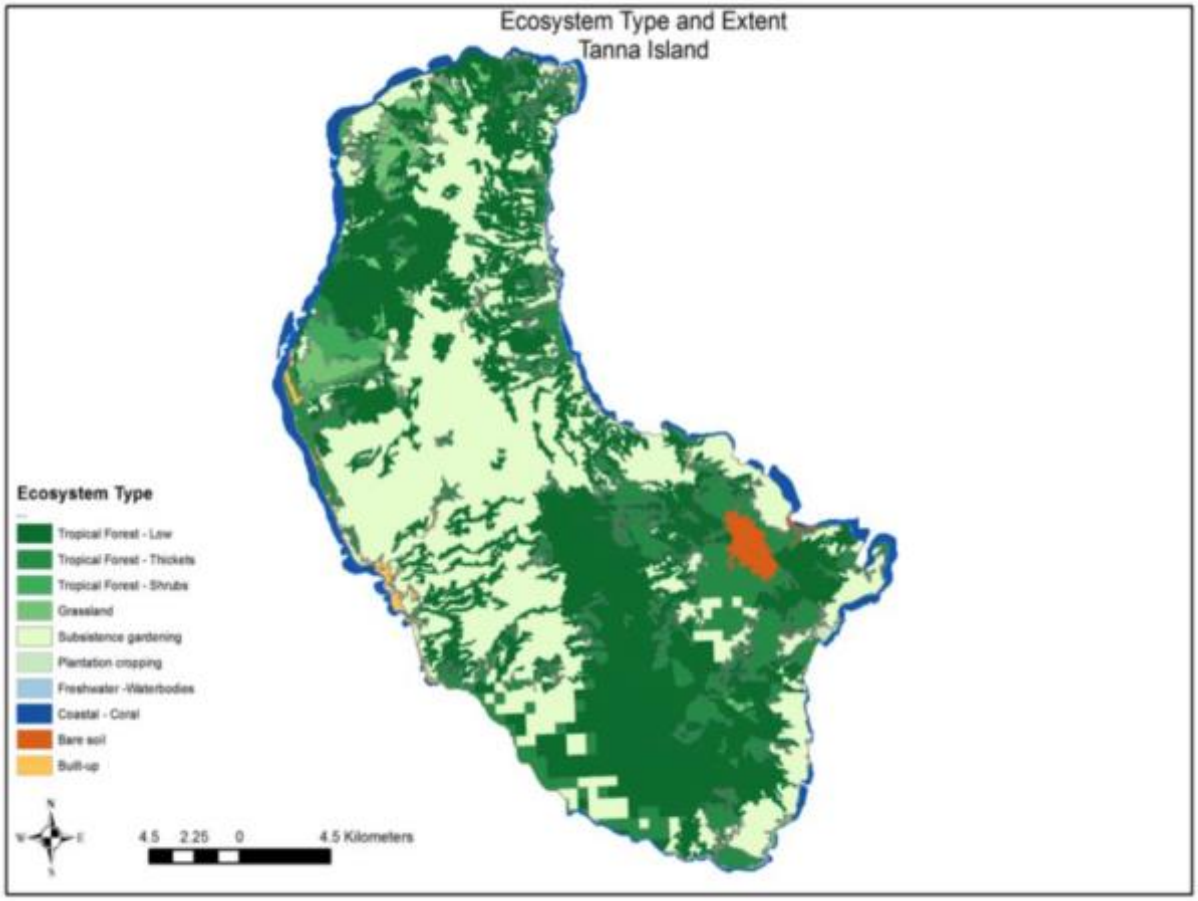

Figure 2. Ecosystem types for Tanna. The condition of most habitat types in the Port Resolution area has been assessed as 'transformed' with only a small proportion assessed as intact. Source: Mackey et al. (2017).

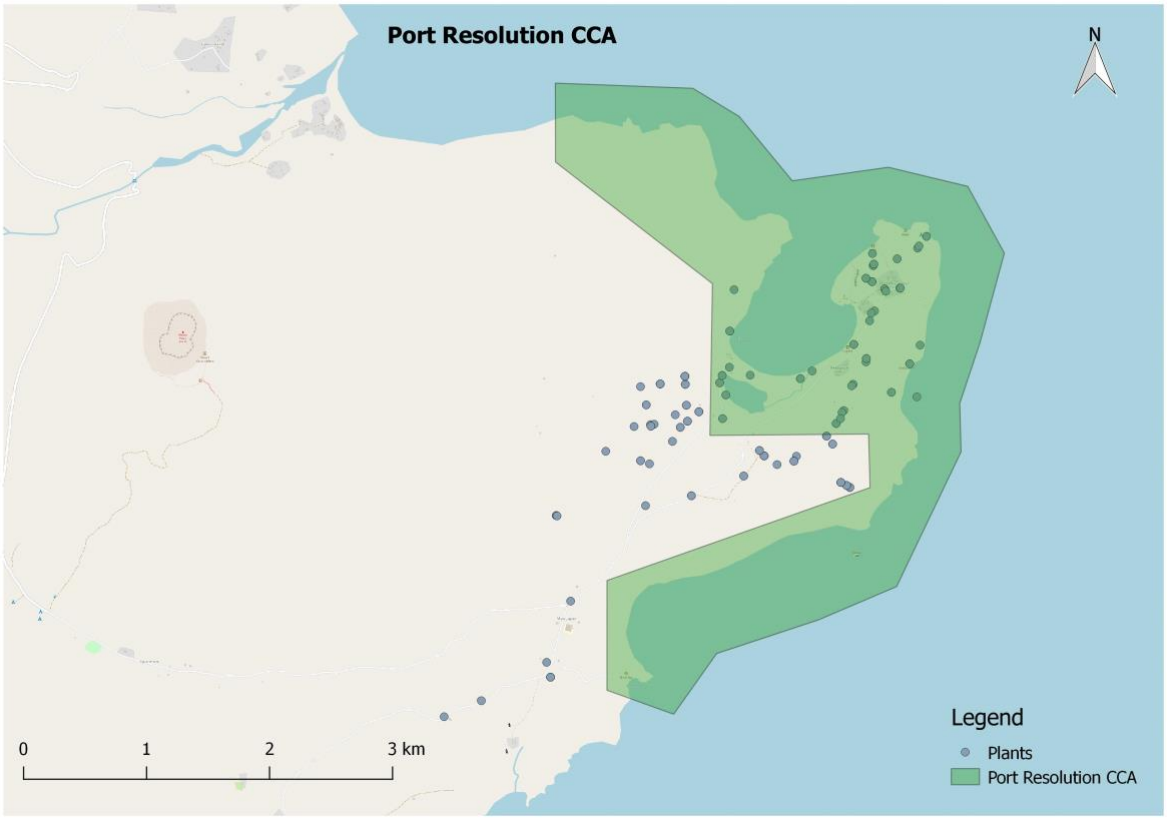

Figure 3. Map of the Port Resolution area showing the botanical plant survey locations of the recent *Plants mo Pipo* project in relation to the CCA boundaries.

Critical habitats

The Port Resolution area has a diverse range of habitat types that are recognised under this plan as significant habitats for the region.

Coral reefs

Fringing coral reefs occur along the entire eastern edge of the CCA and extend westwards into the eastern edge of Resolution Bay. Fragmented coral reef habitat also occurs in the north-western coastline of the CCA (Figure 2). This habitat supports significant populations of important marine resources harvested locally for income, trade and/or food security. The northern area of the CCA is influenced by turbid water flowing from the Siwi River into Sulphur Bay northwest of Port Resolution. Coral reef habitat structure varies throughout the Port Resolution CCA:

Eastern coastline – reef flat protected from high-energy wave action by a fringing reef edge with a gradually sloping low profile reef gradient of several hundred metres wide.

North-eastern coastline – reef flat protected from high-energy wave action by a fringing reef edge with a narrow reef slope comprised of high profile reef bommies dropping to sand within 100 m from the reef edge. Also a high current zone often with turbid water.

Eastern edge of Resolution Bay – numerous isolated small coral bommies interspersed with boulders and sand in sheltered but typically turbid water (Figure 4).

Coastline west of Resolution Bay – typically very turbid with mainly rocks, boulders and sandy substrate but also with isolated reef patches on a gradual slope (Figure 4).

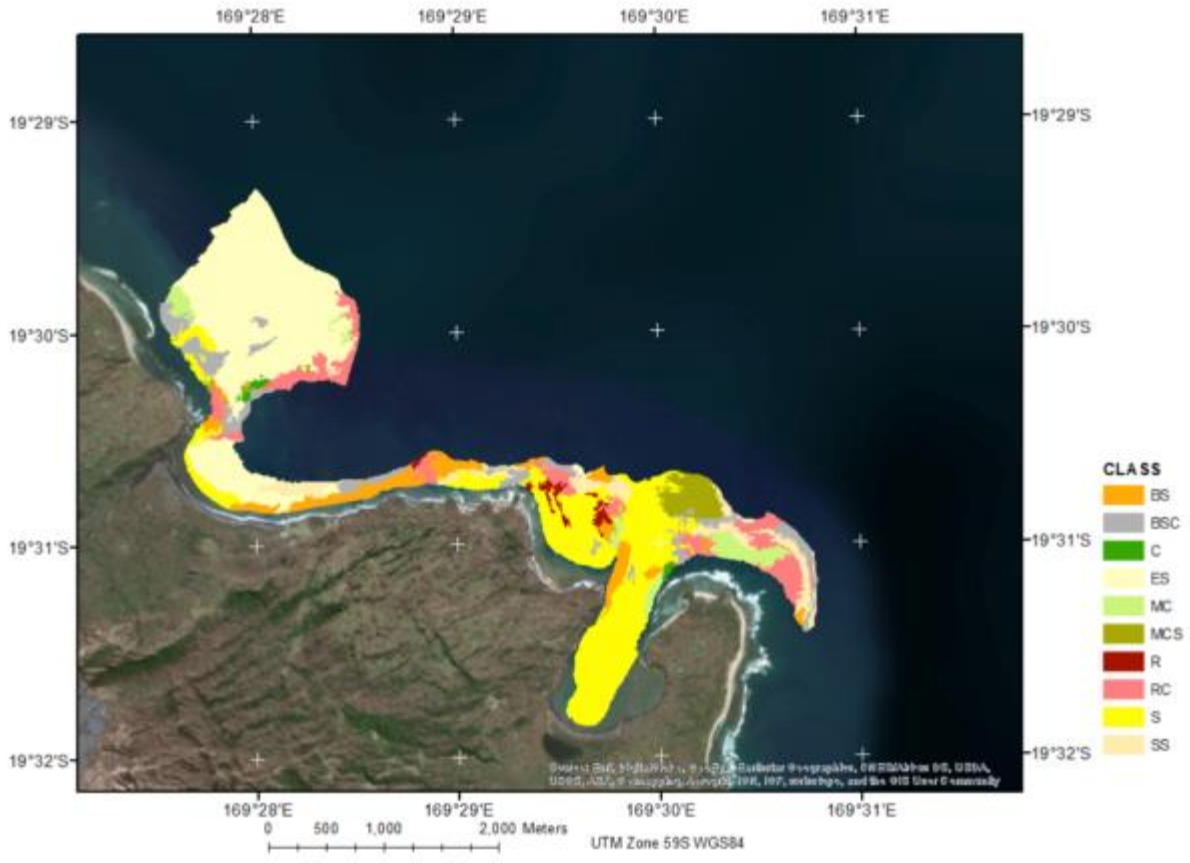

Figure 4. Marine benthic habitat as determined from underwater imagery (ROV) for some of the Port Resolution CCA area. BS – Boulders and Sand; BSC – Boulders, Sand and some coral; C – Reef; ES – Epibenthic Sand; MC – Reef and some Boulder; MCS – Reef and some Sand; R – Rock; RC – Rock and some Coral; S – Sediment; and SS – Sediment and some Stones. Source: Le Bas (2017).

The recent ESRAM report characterized the condition of coral reef habitat of Port Resolution as 'transformed', meaning it is considered degraded due to land-based pollution and the cascading trophic effects from the overharvest of fish, invertebrates and turtles (Mackey et al 2017). The condition was inferred using the human population density in the coastal area as a proxy. More detailed data on habitat condition were collected in early 2019 during the development of the management plan from direct observation using underwater visual survey methods (see Section 4 below).

Seagrass

Seagrass beds are found in some areas of Resolution Bay and support occasional dugong and turtle feeding visitations, although the presence and condition of this habitat appears to vary considerably over time, particularly in Resolution Bay. These habitats are naturally

ephemeral, however, there appears to have been significant diebacks of seagrass at different stages likely from local runoff events and/or from the Siwi River. Some narrow strips of seagrass beds are also found on the reef flats of the eastern and north-eastern CCA shoreline in the reef flat zone. The species of seagrass found in Port Resolution are *Cymodocea rotundata*, *C. serrulata* and *Thalassia hemprichii* and these have persisted since at least 1989 (Chambers et al. 1990). Seagrass meadows are known to be important nursery areas for a range of reef fish and invertebrate species, including the valuable sandfish (*Holothuria scabra*).

Mangroves

Port Resolution supports the only tracts of mangrove habitat found on Tanna Island (Ceccarelli et al. 2018) where there are 4 species present: *Rhizophora apiculata* (Black mangrove), *Avicennia marina* (Grey or White mangrove), *Excoecaria agallocha* (Back mangrove) and *Barringtonia racemosa* (Powder-puff tree). This habitat is found around the entire shoreline of Lake Eweya, although this has been modified and cleared around some parts for human access and possibly from grazing by cows. The densest mangrove growth occurs in the eastern section of the lake and continues along the banks of the short river connecting the lake to the sea in Resolution Bay (approx. 0.5 km in length) (Figure 5). This habitat supports a variety of crab species, including mud crabs (*Scylla* spp.), which are regularly harvested, sometimes illegally by villagers from other areas, and regular digging of crab holes is evident in the mangrove forests. The NBSAP reports that overfishing is occurring in the Port Resolution mangroves (Government of Vanuatu 2016). There is also evidence of cutting of mangrove trees as timber for building materials and/or firewood.

Figure 5. Map of Lake Eweya. Mangroves can be seen as the fine light green colour particularly in the eastern section of the lake edge. Source: Google Earth.

Lake Eweya

This small lake and wetland area connects to Resolution Bay (Figure 4). It comprises an area of floodplain that is also an area of significant subterranean thermal springs, which leads to at least one main tributary into the lake. The total habitat area, excluding the extensive floodplain currently used for grazing cattle, is approximately 0.28 km^2. The lake is also seasonally connected to the sea in Resolution Bay via a mangrove-lined river channel. The lake and its surrounds meet at least two criteria for listing as a site designated to be of international importance under the Ramsar Convention. As such the boundaries of the CCA were placed to explicitly include as much of this habitat as possible.

Lake Eweya is a significant nursery area for local reef fish species (e.g. snappers, trevallies, etc), as well as supporting the only mangrove stands on Tanna. There are two obvious local threats and impacts identified: i) overfishing, and ii) introduced species. Overfishing is due to local people (mainly women and pikinini) fishing daily in the lake using destructive fishing gears that targets smaller fish (e.g. small mesh gill nets and very small hook sizes) (Figure 6). Poaching is also reported to occur, mainly by individuals from adjacent (e.g inland) communities coming at night and targeting all resources but especially mud crabs. A concomitant decline has been reported in mud crabs. The other threat is the introduced species of Mozambique Tilapia (*Oreochromis mossambicus*) that are very common in the lake. Although a favourable aquaculture species in Vanuatu, when released into the environment they can quickly outcompete native species and cause significant environmental damage. They are reported to move between the lower and upper reaches of the lake depending on the level of saltwater ingress and salinity levels in the waterway. The Tilapia population size also varies markedly depending on saltwater ingress and when the lake is seasonally closed to the sea it is reported that tilapia populations "explode". Collectively these impacts have the potential to devastate juvenile reef fish and early life history stages of crabs. It was also noted that there were very few water birds present. Local reports are that hunting for water birds (e.g. ducks, herons) is common and may be responsible for the decline, and it used to occur more often, perhaps when they were more plentiful.

Figure 6. Two of the biggest threats identified in Lake Eweya is the use of fishing practices that harvest juvenile reef fish (e.g. very small hook sizes) (left; juvenile snapper, *Lutjanus* sp.) and the presence of the invasive pest species Tilapia (right). Photos: C_2O Pacific.

Sheltered bay

Resolution Bay is a shallow soft-bottom sheltered embayment subject to runoff and sedimentation, which is reported to be increasing. It supports an important and seasonal mangru (*Selar* sp.) fishery (June-December) and provides a safe anchorage for visiting vessels (mostly yachts) during the 'dry' season, which brings substantial economic benefit to the area. It also supports much of the areas seagrass habitat and is therefore an important habitat for dugong and turtle as well as providing nursery grounds for fish and invertebrates. Most of the bay is soft sediment but with significant areas of rock and coral (Figure 7).

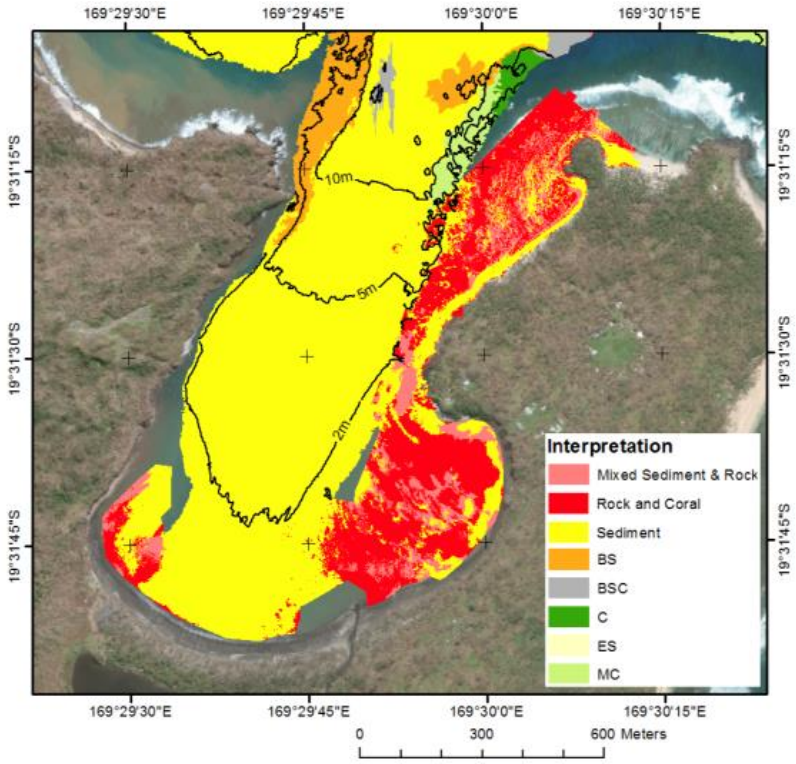

Figure 7. Habitats of Resolution Bay interpreted from both underwater imagery (ROV) and drone imagery. Source: Le Bas (2017).

Hot Springs

Subterranean thermal springs are present in the region, mainly in the area immediately to the south and west of Lake Eweya, but also in the southwestern corner of Resolution Bay on the shoreline. These springs represent a significant habitat that currently provides tourism opportunities, though limited. These thermal springs occur due to heat from the magma beneath Mt Yasur radiating through the bedrock and heating the spring water deep beneath the island, before it percolates upwards to ground level.

Sandy beaches

These habitats occur along much of the coastline within the CCA and include white fine sandy beaches as well as darker, coarser volcanic sandy beaches. White sandy beaches on the north-eastern tip of the CCA supports nesting sites for green and hawksbill turtles.

Rocky and cliff coastline

Cliffs line the southern and western coastline of Resolution Bay. On the southern coastline these cliff edges are prone to erosion and collapse, particularly during heavy rains. Several rocky headlands occur on both the northern and eastern coastlines of the CCA.

Lagoon reef flats

Reef lagoon habitat occurs mainly around the north-eastern and eastern coastline and acts as a nursery area for many reef fish species and also as primary habitat for several invertebrate species. Seagrass meadows are also found in these lagoon reef flat areas.

Mixed lowland rainforest

Most of this habitat has been cleared in the Port Resolution area for subsistence gardening with some as pasture for cattle grazing. The forest areas that remain are restricted to the coastal fringe area on the eastern edge of the CCA and around lake Eweya is classified as "Tropical forest – thickets", while a small area in the northwestern area of the CCA is classified as "Tropical forest – low" (Mackey et al 2017). Not surprisingly Mackey et al (2017) classified the condition of the Port Resolution CCA terrestrial area as "transformed" with some small areas classified as "removed". Forest habitats are very important in coastal and wetland fringes as they help prevent erosion and runoff and are also important for flying foxes, birds and coconut crabs.

Species of national significance

DEPC requirements for the registration of a CCA include documenting the plant and animal species present within the CCA that are of national significance. The DEPC defines species of national significance as endangered, vulnerable, threatened, rare or endemic. The status of these plants and animals is defined by the IUCN (International Union for the Conservation of Nature: www.iucnredlist.org). We were able to identify 10 endemic plant species (Table 3) and 4 endangered, vulnerable, threatened or rare plant species (Table 4). There were also 4 endemic animal species/species groups confirmed (Table 5) and 10 endangered, vulnerable, threatened or rare animal species (Table 6).

We have only included species that are confirmed in the Port Resolution area and there may be others that are yet to be officially recognised. Further, the dominance of marine animal species reflects the CCA boundaries, which currently include only a narrow terrestrial area adjacent to the coast (see below). Those species listed were identified based on published information, online data (e.g. https://www.inaturalist.org/observations), unpublished data and community consultations. Some of the plant species present were confirmed through recent surveys conducted under the *Plants mo Pipo* project, a collaboration between the New York Botanical Garden, the Vanuatu Department of Forestry and the Tafea Kaljoral Senta. Dugong have historically been sighted in Resolution Bay with one during the 1980's famous for its friendliness with swimmers (Chambers et al. 1989). This individual was reported to have died in the late 1980's and since then there have only been very occasional sightings.

Table 3. Plant species of national significance (endemic) confirmed in the Port Resolution area. Local name is given where possible and refers to Bislama and/or local language; English name is given in brackets. The list was compiled through local consultation and surveys (see Appendix 1).

Local name (English name)	**Scientific name**
(Santo Kauri)	*Agathis silbae*
(Snakeskin Fishtail Palm)	*Caryota ophiopellis*
(Carpoxylon Palm)	*Carpoxylon macrospermum*
(Palm)	*Cyphosperma voutmelense*
(Palm)	*Licuala cabalionii*
Nabanga (Vanuatu Wild Fig)	*Ficus granatum*
Yam	*Dioscorea hebridensis*
Navenue	*Macaranga megacarpa*
Tamanu	*Calophyllum neoebudicum*
(Palm)	*Veitchia spiralis*

Table 4. Plant species of national significance (endangered, vulnerable, threatened, rare) confirmed in the Port Resolution area. Local name is given where possible and refers to Bislama and/or local language; English name is given in brackets. The list was compiled through local consultation and surveys (see Appendix 1).

Local name (English name)	**Scientific name**	**IUCN redlist status**
Nipikisi (Sandalwood)	*Santalum austrocaledonicum*	Critically Endangered
(Carpoxylon Palm)	*Carpoxylon macrospermum*	Critically Endangered
(Palm)	*Cyphosperma voutmelense*	Endangered
Namele/Logologo (Queen Sago Palm)	*Cycas seemannii*	Vulnerable

Table 5. Animal species of national significance (endemic) confirmed in the Port Resolution area. The list was compiled through local consultation and surveys (see Appendix 1).

English name	Scientific name
Vanuatu Imperial Pigeon	*Ducula bakeri*
Yellow white-eye	*Zosterops flavifrons*
Vanuatu Kingfisher	*Halcyon farquhari*
White Flying Fox	*Pteropus anetianus*

Table 6. Animal species of national significance (endangered, vulnerable, threatened, rare) confirmed in the Port Resolution area. The list was compiled based on the DEPC CCA guidelines and through local consultation and surveys (see Appendix 1).

English name	Scientific name	IUCN redlist status
Green turtle	*Chelonia mydas*	Endangered
Hawksbill turtle	*Eretmochelys imbricata*	Critically Endangered
Leatherback turtle	*Dermochelys coriacea*	Critically Endangered
Dugong	*Dugong dugon*	Vulnerable
Humpback whale	*Megaptera novaeangliae*	Endangered
Humphead wrasse	*Cheilinus undulatus*	Endangered
Coconut crabs	*Birgus latro*	Data Deficient*
Giant Clam	*Tridacna gigas*	Vulnerable
Vanuatu Imperial Pigeon	*Ducula bakeri*	Vulnerable
Vanuatu Flying Fox	*Pteropus anetianus*	Vulnerable

* Coconut crab are listed as Data Deficient but are included here due to widespread reports of serious decline in Vanuatu (including Port Resolution) and the last IUCN red list assessment was conducted in 1996.

3. Key threats

Climate change

Vanuatu is exposed to the increasing impacts of climate-induced hazards such as tropical cyclones, flooding, drought and storm surge, and the effects of slow-onset events such as sea level rise, increasing air and sea temperatures and ocean acidification. Atolls, low-lying islands, and low-lying coastal areas of Vanuatu are particularly vulnerable to climate change. In Port Resolution, satellite images taken days after Cyclone Pam in March 2015 indicated large sediment plumes in the coastal areas due to terrestrial runoff (Clare et al. 2018). Climate change projections for Vanuatu are provided in Table 7.

Table 7. Average climate in Vanuatu, and future projections based on the IPCC AR5 RCP8.5 (high) emissions scenario or equivalent. Data sources: Knutson et al. (2010); Ganachaud et al. (2011); BoM and CSIRO (2014, 2015).

Climate/ocean feature	1980-1999 average	Projected change		
		2030–2035	2050	2090–2100
Air temperature (°C)	24.2 (Efate)	+0.5 to +1.0	+0.8 to +2.0	+1.9 to +4.0
Sea temperature (°C)	27.1[a]	+0.7 to +0.8	+1.2 to +1.6	+2.2 to +2.7
Rainfall (annual %)	2118 mm (Efate)	-6 to +8	-12 to +14	-15 to +34
Rainfall (monsoon %)	*n/a*	+1	+1	+5
Tropical cyclones (number per decade)	24[b]	+3 to +21% cyclone intensity; +2 to +11% maximum windspeed[c]		
Wave height (m) Dec-Mar/Jun-Sep	1.1/1.3	0/0	n/a	-0.1/0
Sea level (cm)	+6 since 1960	+8 to +18	+17 to +35	+42 to +89
Ocean pH (units)	8.08	-0.4	-0.8	-1.5
Ocean currents	Increase in South Pacific Gyre	SEC decreases at equator; EUC becomes shallower; SECC decreases and retracts west[d]		

a = average for Vanuatu EEZ derived from the HadISST dataset; b = between the 1969/70 and 2010/11 monsoon seasons; c = 2100 regional projections; d = SEC: South Equatorial Current, EUC: Equatorial Undercurrent, SECC: South Equatorial Counter-current.

The consequences of these climate related risks on Tanna Island and specifically for communities at Port Resolution include the following:

- Increases in daily air and sea temperatures with more heatwaves expected;
- Sea level rise will continue and accelerate, so risks of coastal inundation will be high when combined with storm surges and high seas;
- Ocean acidification may degrade 80% of coral reefs within 20 years;
- Extreme weather events, including cyclones and storms, will increase in intensity but not necessarily in frequency;
- Dry periods will last longer, potentially impacting water supplies and crop gardens; and
- Extreme rainfall will be more frequent and intense, so communities will be exposed to more erosion and flooding, and local reefs and seagrass habitats are likely to receive more sedimentation.

Thermal stress on Tanna: historic exposure and future projections

Downscaled analyses of sea surface temperatures, and in particular past (1985–2017) and projected future (2018–2100) impacts of thermal bleaching on the coral reefs of Vanuatu found high spatial variation (Maynard et al. 2018). Many reefs in Vanuatu have historically been refugia from thermal stress that causes coral bleaching, including Tanna, south Efate, Ambrym, north Pentecost and west Maewo islands. These historic refugia were less frequently exposed to severe thermal stress in the past 30 years and had relatively low rates of change in warm season temperatures. Climate model projections for Vanuatu (under high emissions RCP8.5) show that some of these historic refugia are also temporary refugia from

future thermal stress. That is, they are projected to experience annual severe bleaching conditions later than the average for Vanuatu of 2040. For the reefs of Tanna, annual severe bleaching is projected to occur between 2048 and 2050 (Figure 8).

Coral reefs with lower past and projected future exposure to thermal stress are expected to have lower relative vulnerability to climate change. Coral reefs with lower vulnerability to climate change are more likely to continue to provide ecosystem goods and services as the climate changes and should be conservation and management priorities. Reducing threats from human activities at locations with low climate vulnerability can give these reefs the best chance of remaining healthy and continuing to provide goods and services (e.g. food, income) for communities.

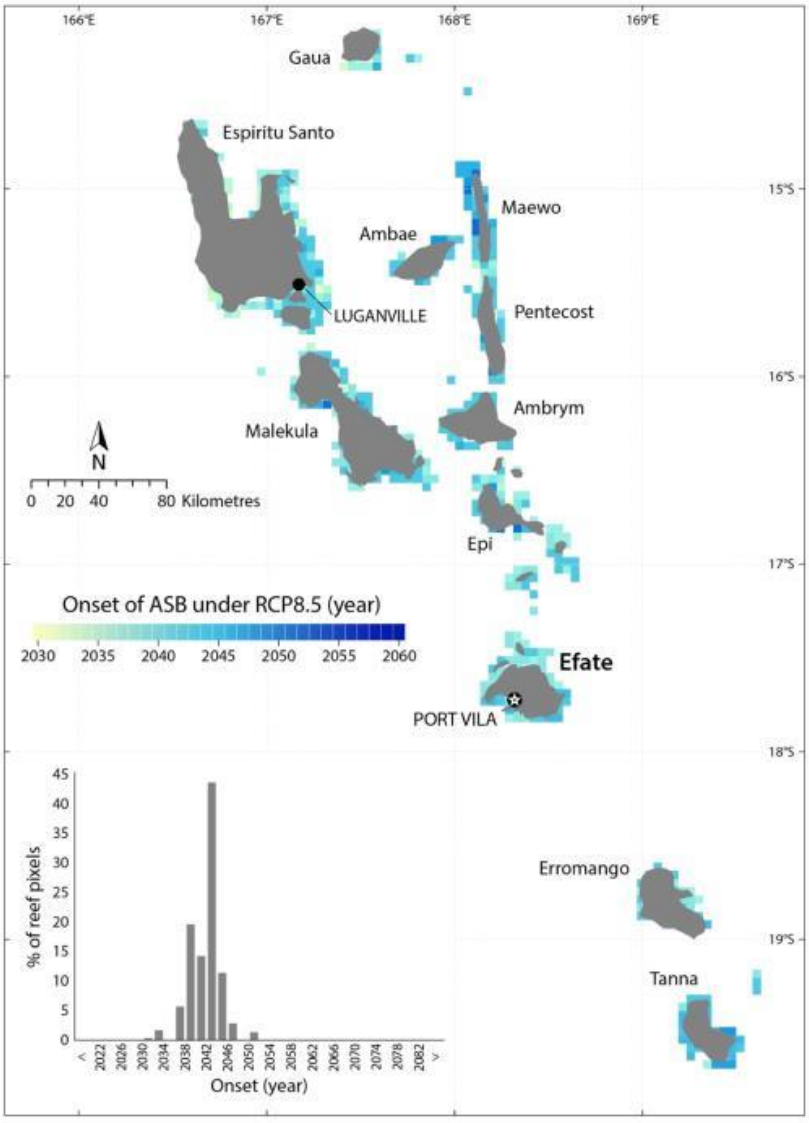

Figure 8. Timing of annual severe bleaching (ASB, ≥8 DHWs) under RCP8.5. 16% of reef pixels in Vanuatu (n=432) are temporary refugia under RCP8.5. At these refugia locations, ASB is projected to occur later than 2045. Refugia in Vanuatu are mostly in southern Epi, Tanna and western Maewo islands. Source: Maynard et al. (2018).

Local threats

Threats localised to the Port Resolution area documented here are sourced from the recent SPREP ESRAM report (Mackey et al. 2017) and community consultations, particularly with the CCA Committee. Mackey et al. (2018) assessed the risk to the coral reef socio-ecological system in Port Resolution of four main indicators: poor water quality, shoreline instability, reef harvest pressure and tourism development pressure. They determined that overall these risk factors present a high-extreme level of risk to ecosystem services in the future. Further, they assessed forest harvesting, measured as the area of forest per person, as an extreme risk factor to the *kastom* forest socio-ecological system. These risks are captured in key threats identified and described below.

Land clearing

The pressure of increasing population and the need for increasing area of gardening for the additional food requirements has resulted in significant clearing of land on Tanna between 2011 and 2016. It was estimated that during that period almost the entire area of the Port Resolution CCA was cleared for subsistence gardening. Most of the area cleared was tropical forest areas (Mackey et al. 2017). Further, decreasing fallow periods between crop rotations is reducing soil fertility (Hoffman 2013; Mackey et al. 2017). With projected increases in human populations this trend is considered unsustainable and there will not be enough arable land to sustain populations in the future.

Major developments

In the late 1990s a local area of land was cleared in Port Resolution with plans for a small airstrip, with several homes having to be relocated. The airstrip development did not proceed, and the cleared land is now used for subsistence gardening. Further, three land titles within the CCA have been sold (under leasehold) to foreign investors over time. One was sold in 1992 and is a very large area (encompassing Lake Eweya) and the investor had plans for a 5-star resort but the time condition placed on this development is thought to have expired. A second title on the eastern coastline that was sold in 1992 is still not developed but had plans for a hotel. The third title was recently 'resold' to a Chinese investor. It is less than a hectare in area and is located on the south-eastern coastline of the CCA. It is also undeveloped but there is thought to be plans for a bungalow business. The sale of these land titles remains a local source of tension due to the lack of community consultation during such land transactions (see management plan issues identification – Disputes; Section 5). Although no major developments have proceeded in Port Resolution, it remains an ongoing threat especially given other increasing pressures.

Overharvest of resources

Some traditional management measures that manage fishing pressure have been in place in Port Resolution for some time. Despite this, overharvesting of all local terrestrial and marine species is recognised by Port Resolution communities as an increasing issue. High levels of fishing effort occur daily in Lake Eweya using small mesh nets and very small hooks that selectively target juvenile reef and estuarine species. Fishing on reefs is also a daily activity, especially spearfishing during the day and night. Although compliance levels of the traditional management are unknown, there is evidence that banned fishing activities have

persisted. Mackey et al (2018) determined that reef harvest pressure represented a *medium* level of risk to local ecosystem services, although also reported the local community concern over declining reef fish stocks. In agreement with this latter statement, the CCA consultations and recent survey observations, reef harvest pressure should be more accurately described as a *high-extreme* risk factor. Scientific fish and habitat surveys conducted during the management plan development process provide further insight into this issue (see Section 4).

Poaching

Aside from the possibility that local management rules are not respected, harvest of local resources is reported to occur daily by people from outside the Port Resolution tribal area, without prior permission. This often occurs at night and targets all species, but mud crab harvest from Lake Eweya by outsiders was highlighted as a key issue.

Lack of respect for traditional ways

Also identified by Mackey et al (2018) as a threat, there is a local perception that traditional *Kastom* is slowly being eroded. In terms of CCA goals, two key associated issues are the reported poaching by outsiders (see above) as well as Port Resolution people reported to be increasingly disrespecting traditional management.

Poor fishing practices

Poor fishing practices are included as a separate threat to 'Overharvest' due to the selectiveness of particular fishing practices that impact fish populations. In particular, there are three local practices that appear to be impacting the ability of local fish populations to replenish: i) the use of small mesh gill nets (non-mangru fishing) that selectively catches smaller immature (juvenile) fish; ii) the use of very small hook sizes selectively catches smaller immature (juvenile) fish, and iii) spearfishing at night allows the easy capture of all species when they are vulnerable causing overfishing, particularly blu fis (parrotfish) and los (groupers).

Waste

Management of local waste was identified through CCA consultations as a key issue as there are no adequate waste disposal sites and debris frequently washes up on the exposed eastern shoreline.

Invasive species

Tilapia (*Oreochromis niloticus*) are present in Lake Eweya, which is a significant nursery habitat for reef fish species (see 'Critical habitats' in Section 2). Crown-of-Thorn Starfish (COTS; posen sta) are also present on other parts of Vanuatu and may recruit to Port Resolution reefs in the future. No COTS were seen during surveys of local reefs carried out during development of the management plan. Mynah birds are very common in Port Resolution. All these species have the potential to outcompete native and endemic species and/or cause significant habitat degradation.

Natural threats

Vanuatu has been identified as one of the most at-risk countries in the South Pacific due to natural disasters (Meheux and Parker, 2006). Locally these include cyclones, earthquakes and volcanic eruptions from Mount Yasur, tsunamis, heavy flooding and consequent coastal erosion particularly along the Resolution Bay coastline. The local community could better manage the issue of coastal erosion with preventative measures such as riparian and coastal zone planting and maintenance, by restricting areas where clearing and developments can occur.

4. Marine baseline surveys

As part of the data collection for the CCA registration process, C_2O Pacific conducted underwater visual surveys to inform the development of the Port Resolution CCA management plan. These data provide a baseline of the status and condition of benthic reef habitats and finfish populations within the CCA. Habitat and finfish surveys were conducted concurrently at the same sites although adverse weather conditions typical of the area restricted the number of sites surveyed and also resulted in some sites not being surveyed for habitats (Table 8; Figure 9). Surveys were conducted in March and April, 2019 using snorkel for the shallow sites (Sites 1-3), and SCUBA in 6-12 m depth on the reef slope (Sites 4 & 5). The choice of sites and the number of sites surveyed were impacted by adverse weather conditions, however the sites where surveys were conducted were spatially extensive and considered representative of the different fringing reefs in Port Resolution.

Table 8. Summary of field survey sites. Three transects were conducted at each site. GPS coordinates were taken in the middle of the site. Finfish survey sites – F; Habitat survey sites – H.

#	Site name	Date	Latitude	Longitude	Depth (m)
1	Yacht club shallow (F, H)	10/03/19	19° 31.251'S	169° 30.000'S	3-6
2	Cooks Rock (F)	12/03/19	19° 32.779'S	169° 29.865'S	5-6
3	Cliff edge (F)	12/03/19	19° 32.098'S	169° 30.365'S	5-6
4	Yacht club deep (F, H)	28/04/19	19° 31.194'S	169° 30.025'S	10
5	Cooks Rock South (F, H)	28/04/19	19° 32.963'S	169° 29.428'S	10-11

Habitat surveys

Introduction

Vanuatu has different reef types including fringing, platform and oceanic ribbon reefs, and atolls. The reefs contain significant biodiversity with records of 295 hard corals, 469 reef fishes, and 18 species of sea cucumbers. Total reef area is estimated at 4,110 km^2 (Johnson et al. 2018). Seismic events and cyclones periodically cause significant damage to Vanuatu's coral reefs. Vanuatu also lies within the tropical cyclone belt and is affected by an average of two cyclones per year. Crown-of-thorns starfish (COTS) outbreaks have also been recorded in Vanuatu reefs, and are known to cause significant coral reef declines (Johnson et al. 2016, 2018). Consistently, communities, government and NGOs report that the greatest threats to the reef environments of Vanuatu are tropical cyclones, overexploitation of fisheries, coral

predation, coral bleaching, land-based pollution, and coastal development for tourism (Raubani 2009; Pakoa 2007).

Methods

The benthic habitat surveys measured three components of the Port Resolution marine environment: (1) current reef condition, (2) coral bleaching impacts, and (3) other reef impacts, e.g. predation, physical damage or disease. The method used was a rapid reef health assessment (for full methods see Johnson et al. 2016).

Figure 9. Map of the field survey sites in relation to the CCA boundaries as indicated by the green markers. GPS coordinates were taken in the middle of the site. No sites were located in current or proposed no-take areas.

Reef health assessment

The rapid reef health assessment method was used to quantify benthic (substrate) composition, coral and macroalgae composition, incidence of threats or impacts including coral bleaching, disease, predation and physical damage, and key biota presence/absence. The coral bleaching assessment records the coral lifeforms most affected and the severity of bleaching. The assessments document the types of corals affected, the proportion of those coral that are bleached and the severity of bleaching on a 4-point scale (1=upper tips, 2=pale or fluorescent, 3=totally white, 4=recently dead). The coral bleaching assessment provides a snapshot of current bleaching conditions, and impact extent.

The observer swam the same three replicate transect lines (50 x 1 m) placed on the reef slope along the same depth contour. The distance between the three replicate transects was at least 10 m. The observer recorded the site details (depth, visibility, habitat type,

complexity, temperature), substrate composition, macroalgae and coral cover, coral lifeforms, and proportion of impacted coral.

Data analysis

The survey data from the three transects (50 x 1 m) was averaged for each site and analysed for substrate cover, hard coral cover, macroalgae cover, coral lifeforms, macroalgae lifeforms, percentage of each coral lifeform showing signs of impacts, such as bleaching, disease, predation by COTS or the Drupella snail (*Drupella cornus*) or physical damage. These data were used to provide fundamental reef health information for each site and assess the extent and severity of impacts.

Results

All three reef sites surveyed had average live hard coral cover of 24% to 32%, high macroalgae cover of 34% to 50% and moderate to high coral diversity. Other substrate cover, including sand and live rock (crustose coralline algae; CCA) were recorded in low to moderate levels, while coral rubble and recently dead coral were consistently low at all three sites (Figure 10 and Table 9). The virtually absent 'coral rubble' and 'recently dead coral' indicate that all three sites have not experienced any recent impacts on corals.

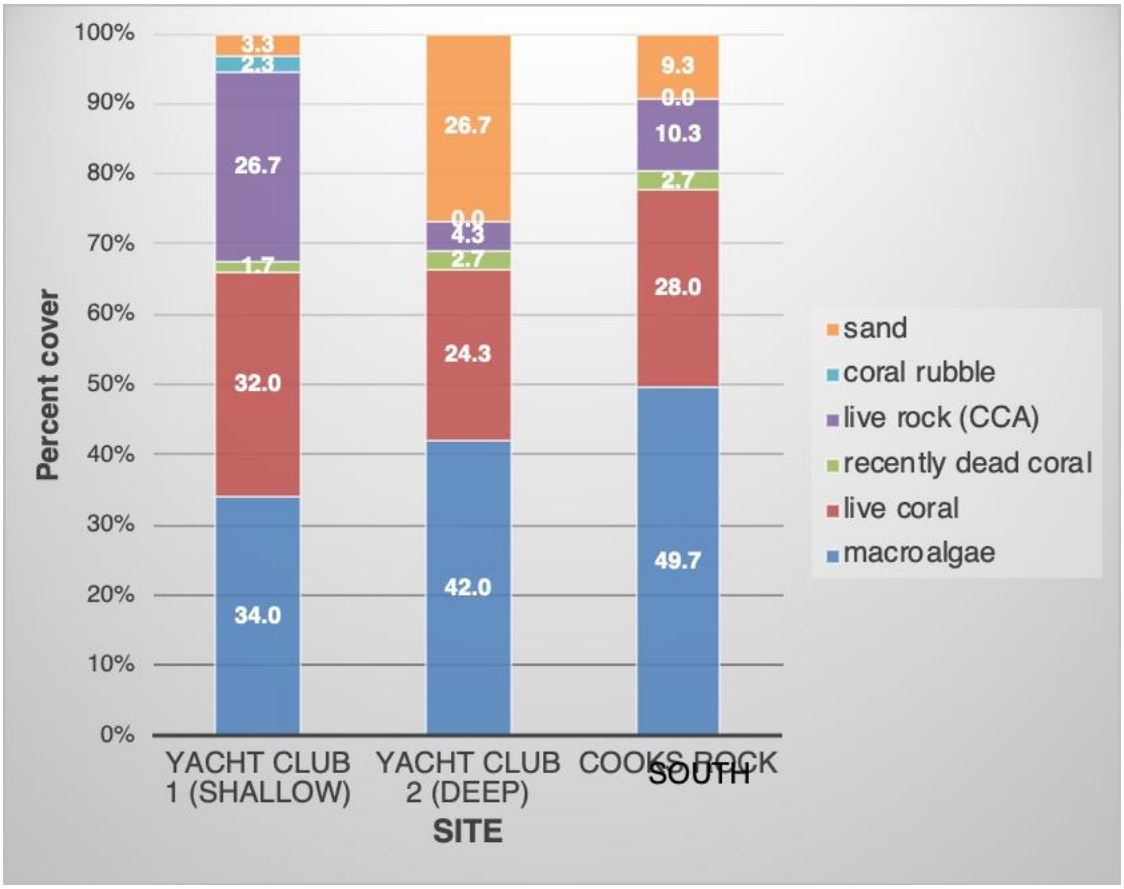

Figure 10. Results of substrate and benthos cover for the three survey sites.

Table 9. Summary of reef indicator results for all reef surveys in Port Resolution. Habitat complexity is measured on a 5-point scale, from smooth substrate (=1) to highly complex (=5).

Site	Site name	Habitat complexity	Coral diversity	Bleached corals (%)	Other impacts (%)
1	Yacht Club (shallow)	3	high	0.5	1
2	Yacht Club (deep)	4	moderate	3.67	0.84
3	Cooks Rock South	2	moderate	2	0

Dominant coral genera were *Galaxea* at the two Yacht club sites, a small 'massive' lifeform, and *Goniopora* (the "daytime coral") at the Cooks Rock South site. The macroalgae assemblage was dominated by calcareous genera, in particular, *Halimeda* spp. and an entangled lifeform of *Caulerpa* (probably *Caulerpa fergusonii*). All sites were high energy sites with persistent wave action and/or water movement.

Coral bleaching

Reef health surveys documented a low percentage of bleached corals at all three survey sites (Table 10) and no recent bleaching mortality. Most corals that were bleached were fully white and predominantly it was the encrusting, branching and foliose lifeforms. The low level of bleaching is not unusual, as corals can bleach in response to a range of stresses (e.g. elevated sea surface temperatures, freshwater, high sediment loads), and a review of the satellite temperature data indicated that it is unlikely to be a consequence of thermal stress (Figure 11).

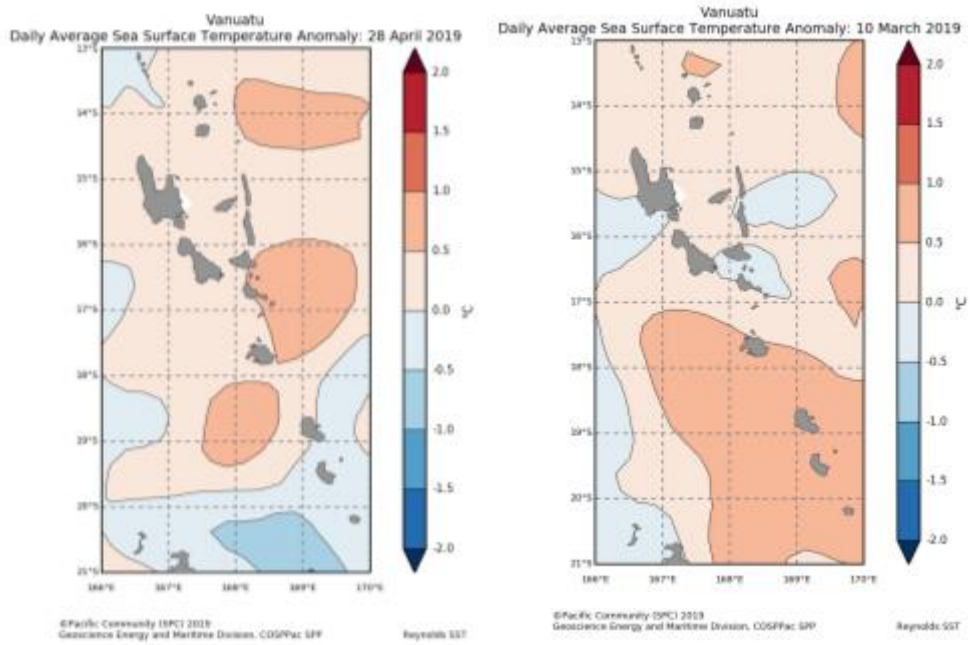

Figure 11. Daily average sea surface temperature anomaly for March and April 2019 (Source: SPC Ocean Portal).

Discussion

The reef health surveys have documented relatively healthy reefs in Port Resolution but with some systemic issues. The presence of low-level coral bleaching and other impacts are to be expected in any dynamic reef system.

The Global Coral Reef Monitoring Network (GCRMN) regional analysis of coral reef status and trends in the Pacific (Moritz et al. 2018) reported that percent coral cover and its variation were higher during the 1996-2006 decade than during the 2007-2016 decade, going from 29.8% (SD ±3.1%) to 25.4% (SD ±2.0%). The opposite observation was made for macroalgae with percent cover increasing from 8.5% (SD ±6.1%) to 14.2% (SD ±3.3%) between the two decades. The decrease in coral cover appears to have been fairly consistent over the study period, but the absence of data prior to 1989 prevents estimation of whether the starting point of this temporal assessment represents an already-altered state. In light of these regional data, the coral cover at Port Resolution is consistently at or higher than the regional average since 1996. However, macroalgae cover is consistently much higher than the regional average, with the Cooks Rock South site over 3x the regional average. While the reefs at Port Resolution appear to be sustaining healthy coral communities, the high macroalgae cover is of concern and may be a sign of low herbivore biomass and/or increasing nutrients from land-based runoff.

Reducing anthropogenic pressures on reefs, particularly overfishing, will be important to the future condition and resilience of these reefs. Ongoing monitoring and assessment of reef condition is important to inform effective management, using community-based and innovative techniques to measure coral reef status and trends, as well as fish populations.

Finfish surveys

Introduction

Coastal fisheries in Vanuatu support important finfish catches for local subsistence and income generation, representing a critical source of protein for ni-Vanuatu people (Friedman et al., 2008; Bell et al., 2011b). Recent projections identify Vanuatu as one of the PICTs at highest risk to future shortfalls in coastal marine resources to support food security, primarily due to increasing populations and the implications for increased levels of harvesting (Bell et al., 20011b). Although there has been occasional work done in Vanuatu to assess coastal marine resources, it is generally fragmented in time and space and therefore resource status remains undefined. Assessment of finfish stock status in the Port Resolution area will provide a critical baseline for the CCA and potentially inform communities and government of management needs to be considered under the CCA management plan actions.

Methods

We conducted underwater visual surveys (UVS) of coastal finfish on reef slopes around Port Resolution to provide preliminary baseline estimates of relative abundance and biomass of key species. We adopted the UVS method used by the Pacific Community (SPC). The technique involves the observer swimming a 50 m transect while recording the number and

estimated size (Total Length, TL; cm) of species within all the survey fish families within 5m of one side of the transect tape. Due to the difficulty in getting SCUBA gear to the Port Resolution area, 3 sites were surveyed on snorkel while 2 sites were done on SCUBA. Fish were recorded to species level where possible otherwise to Family level. The selection of key fish families was based on their fishery importance and as indicators of coral reef health (e.g. Chaetodontidae: Butterflyfishes) (Table 10).

Table 10. Key fish families and their common names recorded during underwater visual surveys based on their local fishery importance and as coral reef health indicators.

Fish Family	Bislama name	Common Name
Acanthuridae	Strong skin/Pocket-knife fis	Surgeonfish
Balistidae	Strong skin	Triggerfish
Caesionidae		Fusiliers
Chaetodontidae	Butterfly fis	Butterflyfish
Holocentridae	Red fis	Squirrelfish/Soldierfish
Labridae		Wrasses
Lethrinidae	Redmouth/Siko	Emperor
Lutjanidae	Siko	Snappers
Kyphosidae		Sea chubs/Drummer
Mullidae	Mustas fis	Goatfish
Scaridae	Blu fis	Parrotfish
Serranidae	Los	Groupers
Siganidae	Pico	Rabbitfish
Zanclidae	Talimuru	Moorish idol

Field sites

Finfish surveys were conducted in March and April, 2019. Survey sites were chosen randomly but based on accessibility, spatial spread across the area and representativeness; however sites were also influenced by the weather conditions. At each site observers randomly chose a transect direction perpendicular to the reef slope. Three replicate transects were conducted at each site with divers ensuring that there was at least 100 m between replicates to minimize the possibility of recounting fish.

Data analyses

Data from all sites were grouped for analyses. From the raw data collected during the surveys the main parameters generated for each family were: i) relative abundance using density estimates (number of fish per unit area; fish/1,000 m^2), and ii) where possible, size structure and mean fish size (cm, total length (TL)). Biomass estimates are possible to generate but would need access to the SPC database and their established species-based length-weight relationships, and this could not be done during the study period. Finfish data were analysed at the family level as not all observations could be consistently recorded to the species level and counts were generally low. Mean size data are only useful at the species-level and so analyses of this metric were limited to species with sufficient counts.

Results

Species composition

Species composition observed was dominated by surgeon fish (Strong skin, Family Acanthuridae). This species group was dominated by two species, which collectively made up 95 % of all surgeon fish observed: the Bristle-toothed surgeon fish (*Ctenochaetus striatus*; 64 %) and the Striped surgeon fish (*Acanthurus lineatus*; 31 %). The next most common were Fusiliers (Family Caesionidae) and Butterfly fish (Family Chaetodontidae), both not generally targeted by fishers (Figure 12). Of the survey species groups three were not observed at all: Lethrinidae, largely because they prefer sandy inter-reef or reef flat habitat; Holocentridae, a more cryptic species that prefers caves and overhangs; and Kyphosidae, seen in the area during non-survey periods and prefer high energy water areas.

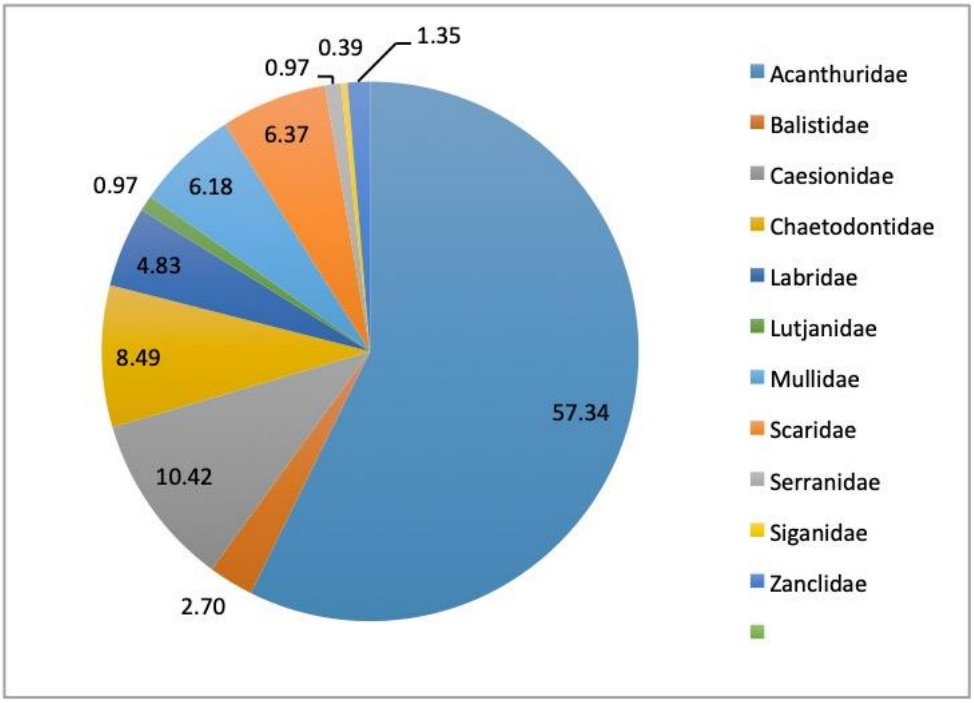

Figure 12. Key fish families observed and their percentage composition across all surveys.

Density

Abundance varied among the 5 surveyed sites although Surgeonfish were consistently the most common. Notably, both Yacht club sites had low species diversity with only 6 Families represented at each site and the Yacht club Deep site had particularly low fish abundance overall with only 67 fish/1,000 m^2. Across all sites the overall density of Surgeonfish was 79.2 fish per 1,000 m^2, significantly more common than the next most abundant species group, the Fusiliers with 14.4 fish/1,000 m^2 (Figure 13). Surgeonfish were also the most diverse species group with at least 9 species observed. Of particular note were the very low abundances of some key functional family groups, in particular the Scaridae (Parrotfish or Blu fis), Lutjanidae (Snappers or Siko) and Serranidae (Groupers or Los). The overall density of Parrotfish was only 8.8 fish/1,000 m^2 while for groupers a single species was observed

(Flagtail rockcod, *Cephalopholis urodeta*) with a density of 1.3 fish/1,000 m^2 (Figure 13). Snappers also had a density of only 1.3 fish/1,000 m^2.

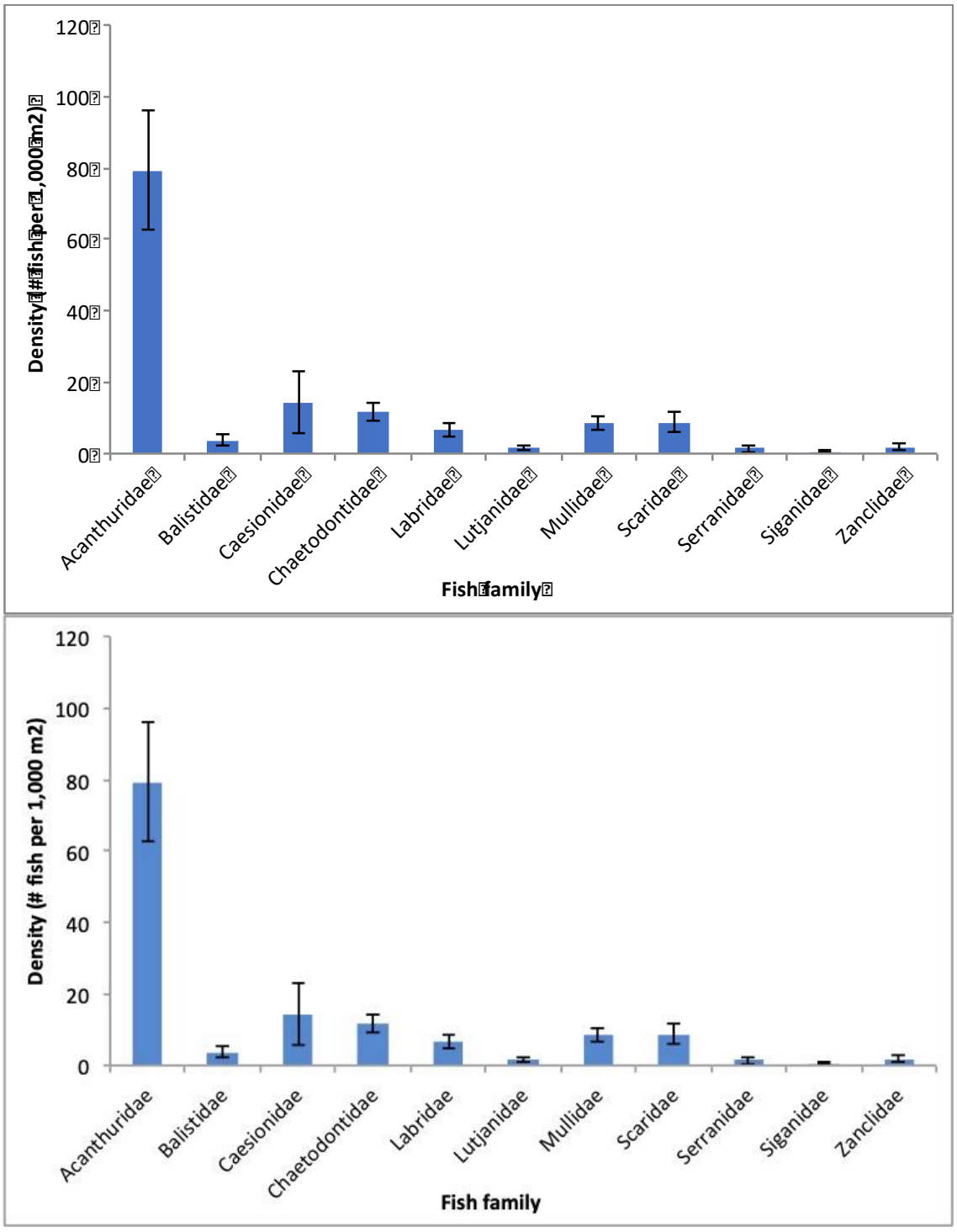

Figure 13. Densities (+/- SE) for the 11 finfish families observed during Port Resolution finfish surveys (density is number of fish/1,000 m^2).

Size distribution

There were only two species observed in sufficient numbers to examine size data. These were the two dominant Surgeonfish species the Bristle-toothed surgeonfish (*Ctenochaetus striatus*) which had a mean size of 14.83 cm and the Striped surgeonfish (*Acanthurus lineatus*) which had a mean size of 16.15 cm. A broad range of sizes was observed for the Bristle-toothed surgeonfish with many fish present that were larger then the size at maturity of 13.5 cm (Choat and Axe 1996; Longenecker et al 2017)(Figure 14). This contrasted with the Lined surgeonfish, which had few individuals larger then the size at maturity (Choat and Axe 1996; Craig et al 1997) (Figure 15).

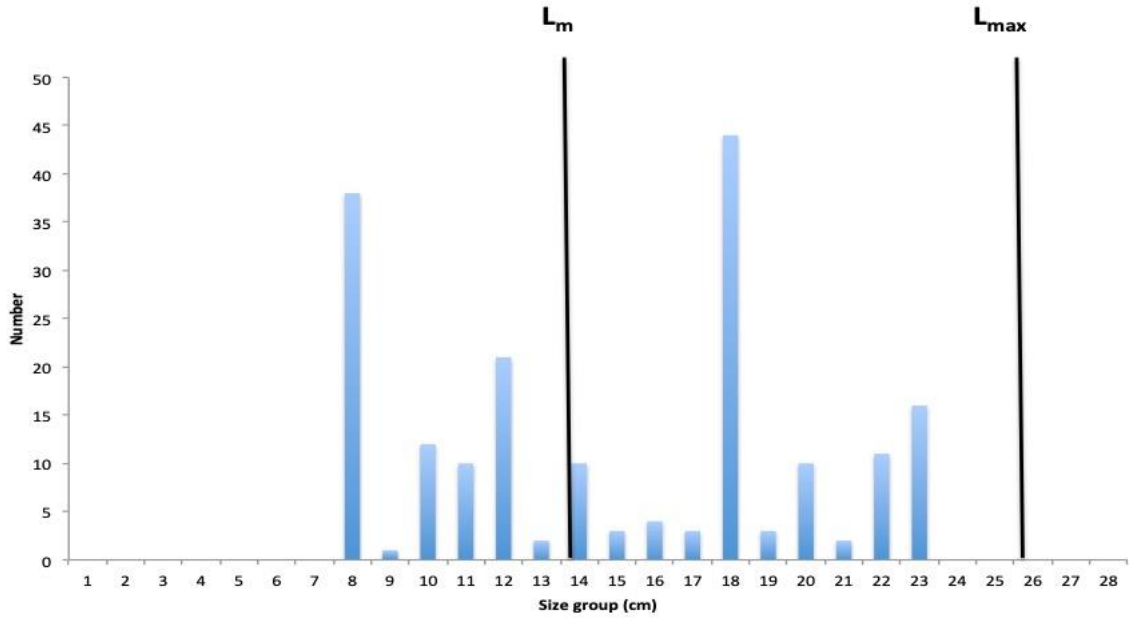

Figure 14. Size distribution of the Bristle-toothed Surgeonfish observed across all sites. Lm shows the size at maturity and Lmax shows the reported maximum size.

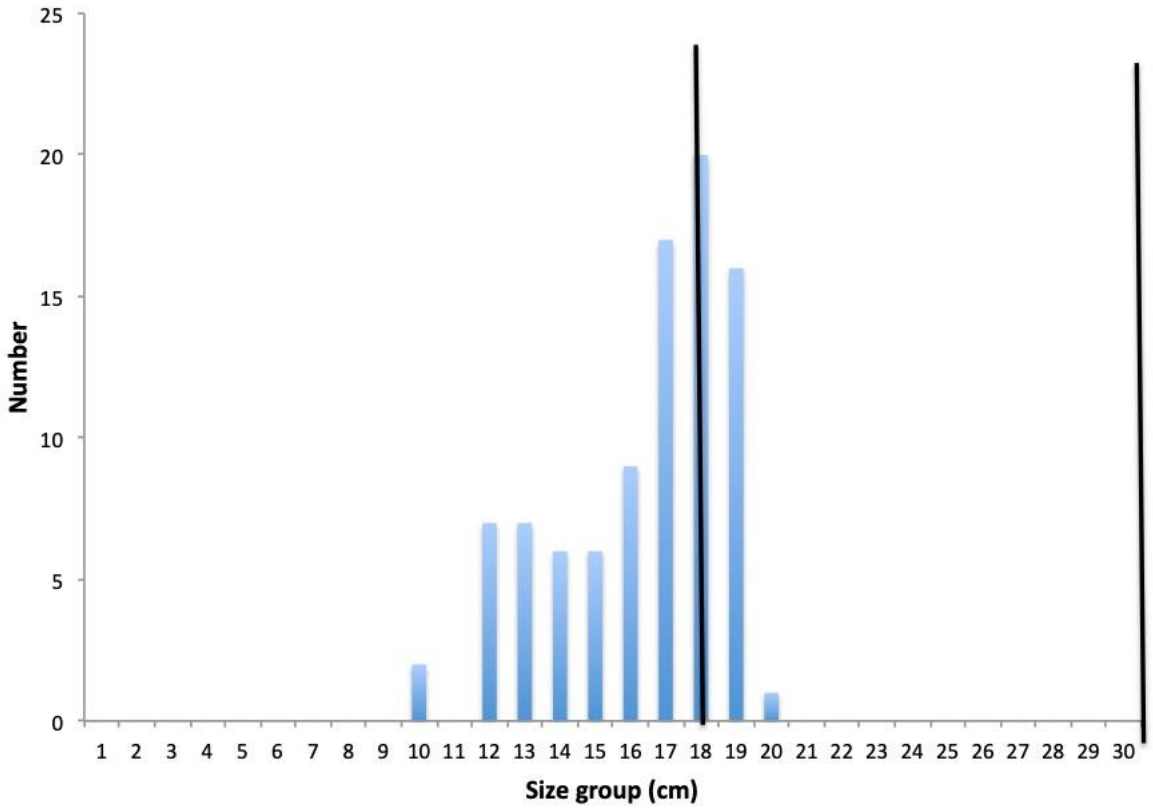

Figure 15. Size distribution of Striped surgeonfish observed across all sites. Lm shows the size at maturity and Lmax shows the reported maximum size.

Discussion

Fish of the Family Acanthuridae are often a dominant species group in tropical reef fish populations so their relative abundance in Port Resolution is not surprising. Bristle-toothed surgeonfish are also very common throughout Vanuatu with recent surveys in North Efate showing they comprised approximately 60 % of all surgeonfishes observed (Welch 2016) and so their dominance in the surveys was also not a surprise. Despite this, their overall relative abundance in Port Resolution is very low compared to other studies around the Pacific region with densities in unfished populations of surgeonfish in similar habitats up to ~300 fish/1,000 m^2 (Welch 2016). Densities of surgeonfish in other heavily fished areas of Vanuatu have generally been above 100 fish/1,000 m^2 but can be over 300 fish/1,000 m^2 in some places.

The abundance and low species diversity of Parrotfish was quite concerning. Like surgeonfishes, parrotfish are an important functional group on coral reefs and the density of Parrotfish in Port Resolution was only 8.8 fish/1,000 m^2. This is the lowest relative abundance compared to other similar studies in the Pacific region with very low densities of 28 fish/1,000 m^2 observed in some parts of North Efate in 2016 (Welch 2016). Parrotfish abundance in other parts of the Pacific, including Vanuatu, have generally been around 100 fish/1,000 m^2 or more (Welch 2016).

Bristle-toothed surgeonfish are likely taken in local catches given their high relative abundance. Although a relatively long-lived species with a maximum reported age of 35 years, they have very rapid growth in their first two years, achieving 90 % of their adult size in the first year, and reach maturity between 1 and 2 years of age (Choat and Axe 1996; Trip et al 2014). Therefore, despite their longevity this suggests they are relatively robust to fishing pressure, which is reflected by their abundance and wide range of sizes with many fish larger than the size at maturity. However, research on the size at maturity for *C. striatus* across different regions globally has been variable with the length at which 50 % of the population are mature ranging from ~13-17 cm TL (e.g. Montgomery and Galzin 1993; Choat and Axe 1996; Longenecker et al 2017) emphasising the need for local research to estimate the size of maturity of this species in Port Resolution.

It is unclear if Lined surgeonfish are targeted by fishers in Port Resolution, however the size distribution observed suggests they are with larger individuals lacking and few fish larger than the size at maturity (Figure 14). They are a long-lived species attaining a maximum age of 46 years and the age at which approximately half the population are mature is 4 years (Choat and Axe 1996; Craig et al 1997). These life history traits make them moderately vulnerable to overharvest and there are warning signs that this is already occurring based on these surveys.

The maintenance of healthy populations of the different trophic fish group populations on coral reefs are critical to healthy ecosystems and in particular herbivores are critical for reef resilience (Hughes et al 2007). Monitoring of reefs open and closed to fishing on the Great Barrier Reef, where fishing of herbivore species (comprised almost entirely of Surgeonfish, Parrotfish and Rabbitfish) is virtually non-existent, found that total herbivore density was in the range of approximately 150 and 600 fish per 1,000 m^2 with an average close to 400 fish per 1,000 m^2 (Sweatman et al., 2015). A recent study in North Efate found that densities of the three main herbivore family groups, although variable among sites, was ~100 fish per to 1,000 m^2 (Welch 2016). In Port Resolution herbivore density was estimated to be 88 fish per 1,000 m^2. Density of piscivore species (fish eaters; primarily Snappers and Groupers) was also found to be low in North Efate at 7.3 fish per 1,000 m^2 however in Port Resolution the piscivore density was only 2.7 fish per 1,000 m^2. These results suggest that overfishing is occurring across all species groups in Port Resolution

Conclusions and Recommendations

There is clear evidence of habitat impacts and depleted finfish stocks on Port Resolution coastal reefs. Very low counts of important functional groups of fishes is likely to reduce the resilience of coral reefs in Port Resolution. Habitat surveys showed some of the highest algal cover seen on coral reefs in the Pacific. This is consistent with the low herbivore numbers, which are important fish that feed on and control algal growth to allow corals to thrive. Collectively this represents strong evidence that overfishing is reducing the resilience of Port Resolution coastal reefs and puts at risk sustainability of the ecosystem services that coastal reefs provide, including resources for food and income as well as healthy reefs to support local bungalows and eco-tourism.

It is recommended that controls on coastal fishing are put in place that limit overall harvest of all species. In particular, controls on fishing for parrotfish are urgently needed. Simple and effective solutions are needed such as implementing size limits and/or limiting or banning spearfishing at night.

5. Development of the CCA management plan

Background information

This section describes the processes followed in close association with the Port Resolution CCA Committee and consultations with the local community, in developing the management plan for the CCA. The process incorporated the relevant baseline information documented above, while also drawing on other local community knowledge and feedback. Results from coastal reef habitat and finfish surveys conducted during the Port Resolution consultation period was also incorporated into development processes however was limited to the final stages due to the timing of the surveys being conducted. Nevertheless, issues identified and for which management actions were identified in the management plan are consistent with the results of the surveys.

Late in the process to prepare the Port Resolution CCA for formal registration, conflicting information from different government departments created community confusion about the legal implications of CCA registration particularly in regard to land ownership and control. Subsequently the community decided to proceed with implementation of the local CCA management plan but not with the formal registration through the DEPC. The community also determined that they may proceed in the future to register the CCA.

CCA area

The Port Resolution community is in agreement for a single shared CCA to be jointly managed among the 6 local Nakamals. The initial scope of the CCA was to include an area from the western outer tip of Resolution Bay and approximately to the current defined southern coastal limit, with a terrestrial boundary that included only the coastal fringing area. During the workshop to develop the plan, the CCA committee agreed that they wanted the area to extend further west to the edge of Sulphur Bay and to include a much larger land area with boundaries that coincided with the tribal boundaries (Figure 16).

After considerable discussion the community agreed to develop a CC in line with the original intent, and in later reviews of the CCA consider extending the boundaries to those proposed in Figure 16. An expansion would require considerable liaison with the DEPC and the Forestry Department. The recent surveys of flora of Port Resolution would be a valuable resource if the CCA is later expanded. Further, the recent SPREP ESRAM report identified increasing forest clearing for subsistence gardens as an increasing and significant threat (Mackey et al 2017) and an expanded CCA area with a much larger terrestrial component will be better able to manage this threat.

Figure 16. Port Resolution map with the potential boundaries identified for a possible future expanded CCA (white line) compared to the current CCA boundaries (yellow line).

Therefore the current proposed CCA extends from the Sulphur Bay area at its northwestern edge, eastwards to include all of Resolution Bay, and further east to include the eastern coastline with a southern boundary near Shark Bay (Figure 17; see management plan for a larger map). The total area covered by the CCA is approximately 10,173 km^2, of which 5,306 km^2 is marine (52 %) and 4,868 km^2 is terrestrial (48 %). The outer marine seaward boundary is approximately 9.36 km in total length and is located **300 metres seaward from the reef crest (edge) or shoreline where there is no reef flat.** The terrestrial boundary is approximately 8.32 km in length giving the CCA a total boundary length of approximately 17.68 km. Full boundary coordinates are provided in the Table 11.

Figure 17. Map of the Port Resolution area showing the proposed boundaries. Numbered points on the map correspond to coordinates provided in Table X below. The seaward boundary is 300 metres from the reef crest (edge) or shoreline where there is no reef flat.

Table 11. Landward boundary coordinates for the Port Resolution Community Conservation Area. The CCA extends 300 metres seaward from the reef edge. Coordinates are given in degrees decimal minutes.

Label	Description	Latitude	Longitude
1	North-western seaward corner	19° 30.612’ S	169° 28.634’ E
2	North-western landward corner	19° 30.957’ S	169° 28.632’ E
3		19° 31.491’ S	169° 29.363’ E
4	Lake Eweya	19° 32.156’ S	169° 29.351’ E
5		19° 32.153’ S	169° 30.090’ E
6		19° 32.389’ S	169° 30.089’ E
7	Manuepen	19° 32.789’ S	169° 28.872’ E
8	Southern landward corner	19° 33.270’ S	169° 28.872’ E
9	Southern seaward corner	19° 33.376’ S	169° 29.182’ E

Consultation and development process

Consultation timeline

Development of the management plan and associated information gathering took place between December 2018 and May 2019. During this period the consultant team conducted four field visits to Port Resolution and followed a structured process using a combination of: formal and informal meetings with the CCA committee, workshops with the CCA committee, training, community engagement through meetings and interviews, community education and awareness, field surveys, and meetings with relevant government department officials

(Table 12). Key to this process was the CCA Committee and its members, who represented the 7 villages in the Port Resolution area. The committee was the central point of contact for all major activities in the development process, for engaging with other members of the community, and for local logistical support and advice (Figure 18).

Table 12. Overview of the schedule and activities to progress the development of the CCA management plan and associated activities, as well as training of local 'Champions'.

Trip #	Dates	Activities
1	9-12 December 2018	Meet CCA committee & local community
		Discuss CCA boundaries and planning process
		Ensure clear understanding of CCA obligations
		Establish working guidelines and schedule
		Assess CCA area
		Meet with Provincial Government
2	10-15 February 2019	DEPC presentation to CCA committee
		Management plan workshop with CCA committee
		Community interviews & engagement
		Community meeting – management plan consultation
		Field surveys of Lake Eweya and wetlands
		Educational community awareness evening
		Meet with Provincial Government
3	7-15 March 2019	Review management plan with CCA committee
		Conduct underwater field surveys
		Community engagement
		Develop livelihood plan with CCA committee
		Meet with Fisheries Department
4	25 April - 3 May 2019	Champion and monitoring toolkit training
		Review & finalise management plan with CCA committee
		Conduct underwater field surveys
		Community Nakamal meeting
		Review livelihood plan with CCA committee
		Community engagement
		Meet with Provincial Government
		Meet with Fisheries Department

Approach

The management plan was developed during a 2-day participatory workshop with the project team and the CCA Committee and adopted an approach similar to that used in fisheries management plan development around the world. Other community members participated in the workshop on different days. In particular we closely followed the approach of *A community-based ecosystem approach to fisheries management: guidelines for Pacific Island Countries* the Pacific (SPC 2010). This approach was used to: i) ensure management activities focused on the biggest issues first; ii) limited resources were put to

good use; and iii) ensure the management was as simplified as possible. These steps ensure the CCA has the best chance of success.

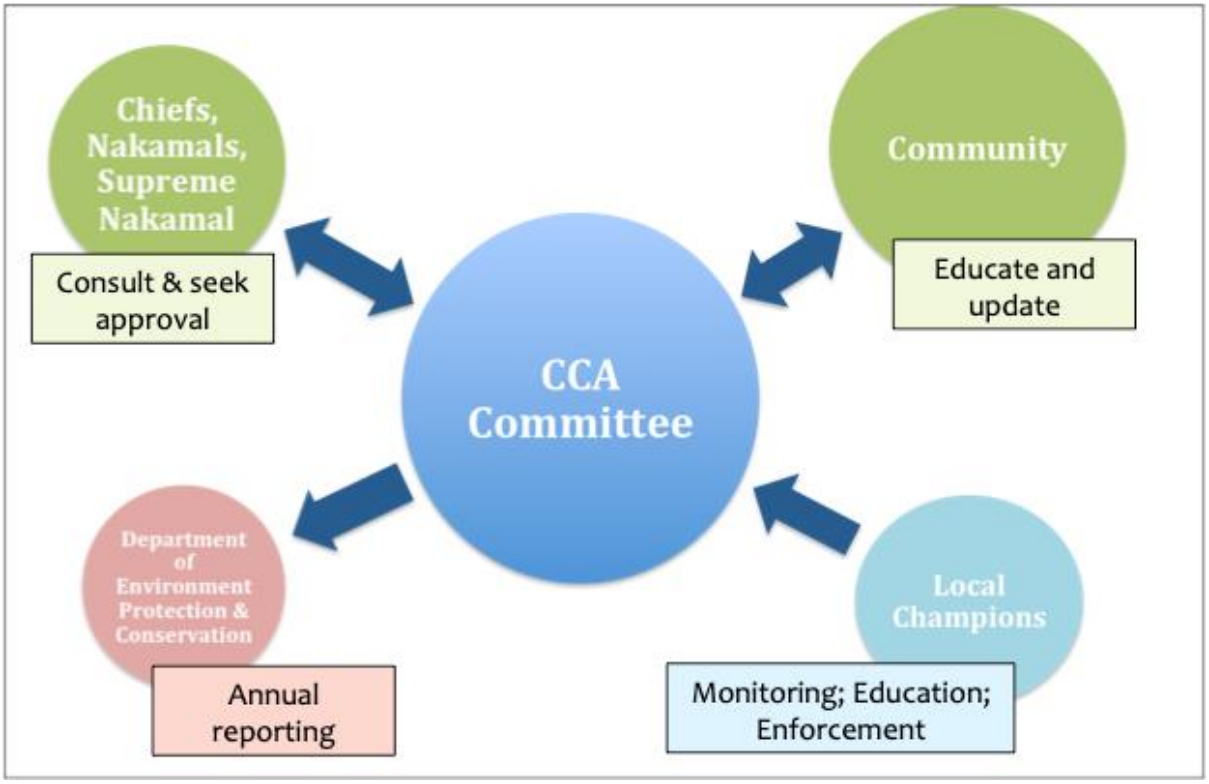

Figure 18. Diagram representing the central role of the local CCA committee in the facilitation of the CCA development process and the on-going implementation of the management plan. This reflects the role of governance played by the CCA Committee and its members and included in the management plan.

Once the top issues were identified and agreed, detailed *operational objectives* of the management plan were identified that directly link to each issue. The operational objectives collectively help to achieve the overall goal of the CCA, and it is these objectives that are assessed during review periods to determine if the CCA and associated management activities are effective. Following this, a range of management activities were identified that *could* address the issue and therefore achieve the identified objectives. The final management activities were further decided by considering a range of factors, in particular how well they address the issue and the feasibility and ease of implementation taking into account local custom. The final management activities inform what rules need to be established to enforce the management plan.

Following is a summary of the process followed with the CCA Committee in developing the CCA management plan. Some of these elements will require further development.

1. Define the scope of the plan – this included establishing the area to be included in the CCA and the boundaries, the resources that lie within that area and use of resources by the community, significant species, habitats and sites.

2. Define the main objective of the CCA
3. Identify local issues and prioritise
4. Agree on management (operational) objectives
5. Identify management actions to address issues (and achieve objectives)
6. Determine rules and penalties
7. Identify the implementation governance structure
8. Develop an action plan for implementation
9. Establish a monitoring program
10. Design a compliance/enforcement program
11. Define the "review and management adaptation" process

Management activities & objectives

Key issues within the CCA

It is not feasible for the CCA management plan to address *all* the local issues perceived as important by the community. Too many issues to address would overcomplicate management resulting in poor use of limited resourcing and less likelihood that the management will be respected. Workshop participants were therefore asked to identify anything they thought was a local issue with negative consequences, particularly where there were environmental impacts. Fifteen key issues were identified overall and the committee decided 6 issues could be dropped as least important (Table 13). These issues were then prioritised with the biggest issues at the top of the list. This was done by breaking the workshop into 3 groups who independently created a prioritised order of the issues, ranked from highest to lowest priority. The average ranking across the groups was used for the final prioritised order. Through further discussion the CCA committee agreed to initially focus management on **the top four issues**, with the option to include other issues if thought to be feasible. This was critical to focus limited resources on the biggest issues first, and to create a more manageable CCA by reducing complexity. One of the key considerations in deciding on the top issues to focus on was that most management actions addressed multiple issues. In identifying management actions that address the top four issues, in effect all of the top nine issues were addressed to some extent. Details the main issues are given in Table 13.

Table 13. List of all the local issues identified by participants during the management plan workshop and a brief description of each issue. The top nine are listed in their prioritised order and the top four, which were the focus of management, are in bold. See text for a description of the process.

Rank	Local issue	Issue description
1	**Catching too many small fish**	Participants agreed that local fishing catches are indiscriminate in terms of the size of the fish caught, with very small fish making up a large component of all catches and that small fish are often targeted using very small hook sizes, small mesh nets and indiscriminate spearfishing. There was an acknowledgement that this was bad for fish populations.
2	**Overharvest of marine resources**	Participants agreed that they had noticed a decline in marine resource populations, even in only recent times, and that the community was catching too much of everything with all gears. It was acknowledged that a key reason for this was the increasing local human population and the desire for cash from selling catches. It was also acknowledged that fish were becoming harder to catch and were getting smaller on average.
3	**Disputes**	This issue related to the historical 'sale' of land to foreign leaseholders with intentions for developments. The key issue for community members was the lack of consultation by the community member responsible for the sale. Three prominent local examples were noted two of which go back to the early 1990s and no developments have resulted. A third lease was recently 'resold' to a Chinese investor who apparently has plans for developing bungalows on the southeastern CCA coast just south of Cooks Rock. Despite reports of frequent offers, new lease agreements appear to be infrequent. However, leasing local land to foreigners is an ongoing concern of locals.
4	**Waste management**	There are no local facilities or dumping sites for proper disposal and treatment of household and commercial rubbish, which is often just dumped in the bush and/or burned on site. Participants mentioned the issue of plastic and discarded nets as a big problem. There is also some concern that local septic systems may affect the local water table or seep into the marine environment.
5	Lack of respect for customary laws	Port Resolution people are very proud of their local custom with many local stories and traditions still passed on to younger generations, and local customary laws in place. Despite this, participants acknowledged and were concerned that local community members increasingly did not respect local rules and traditions, and that adjacent communities also did not respect local tradition. For example, night time poaching from other communities are reported to occur frequently in Lake Eweya, where as in the past the tradition was for an open trade of products (e.g. garden vegetables for local fish/crabs)
6	Excess land clearing	Participants acknowledged the increasing clearing of forest areas for gardens in particular, and also buildings, and that often this was done by fires. This concurs from findings in the

		recent SPREP ESRAM report (Mackey et al 2017).
7	Damage to coral reefs	Participants thought that reef health was declining with increasing damage from runoff, cyclones, coral bleaching, reef walking, yacht anchoring in Resolution Bay and by youth being careless. They also acknowledged the use of poison by pikininis to target small fish on shallow reef flats
8	Runoff	Participants noted increasing turbidity in local waters and acknowledged the role of the Siwi River contributing to this by local currents, but also localised runoff from: increased land clearing and logging, and erosion of the cliffs in Resolution Bay.
9	Natural disasters	Participants were generally concerned about being vulnerable to the range of potential natural disasters, particularly earthquakes, tsunamis and cyclones.
X	Poaching	Concern over the lack of respect of existing rules and also non-local community members actively accessing Port Resolution resources without seeking permission. It was felt that this was driven by financial incentives.
X	Too many Chiefs	Concern that some people become Chiefs through non-traditional ways (non-family lines)
X	Salt affecting fruit trees	Thought to be increasing but causes unknown
X	Increasing human population	Acknowledged as an underlying cause of all the issues identified
X	Livestock roaming everywhere	Concern over damage caused to the environment by large roaming livestock
X	Western culture in schools	Concern that this is contributing to the erosion of local tradition

CCA operational objectives

Operational objectives are linked to issues and provide a simple goal that when achieved will help to resolve the relevant issue. Having clearly articulated operational objectives under the CCA management plan also provide a means to assess how well the management is working, and in doing so, help guide ongoing management of the CCA as well as fulfilling DEPC reporting obligations. During the workshop, although it was greed to focus on the top four issues for initial management, participants identified operational objectives and potential management options for the top eight issues. This was done by combining issues #6 and #8 for a total of seven issues with operational objectives and potential management options for each. Although the management plan focuses on the top four issues, future reviews and amendments by the CCA committee to the management plan already has potential solutions to key issues to work with. Therefore the seven operational objectives developed were:

1. To minimize the catch of small (juvenile) fish

2. To limit catches to avoid overharvesting

3. To reduce conflict and disputes in the community

4. To improve waste management practices

5. To improve respect for traditional laws and values

6. To reduce land clearing and runoff

7. To minimize damage to coral reefs

Management activities

Management activities are agreed actions that help to address the relevant issue (and achieve the relevant goal). The best management actions are ones that effectively address the issue, and are relatively simple to implement and enforce. Below lists operational objectives and potential management actions identified by participants during the workshop for each of the top seven issues. The final list of agreed management actions to be included in the management plan are summarised in Table 14 below. Note that the management action to "Introduce more tabu areas (no-take zone)" was addressed by the community identifying several existing and new no-take areas which are detailed with maps and coordinates in the management plan.

Key issue #1: Catching too many small fish

Objective: To minimise the catch of small (juvenile) fish

Proposed management options:

- Introduce a minimum net mesh size
- Introduce a minimum hook size
- No poisenem fish
- Introduce more tabu areas (no-take zone)
- Education and awareness
- Ban fishing in Lake Eweya except for tilapia

Key issue #2: Overharvest of marine resources

Objective: To limit catches to avoid overharvesting

Proposed management options:

- Education and awareness
- Better enforce the traditional harvesting calendar (Yam harvest April-June)
- Increase and respect no-take zoning area

- Encourage improved enforcement
- Ban fishing in Lake Eweya except for tilapia

Key issue #3: Disputes

Objective: To reduce conflict and disputes in the community

Proposed management options:

- Education and awareness in Nakamals
- Mutual agreement through governing structure

Key issue #4: Waste management

Objective: To improve waste management practices

Proposed management options:

- Education and awareness
- Create proper dumping sites
- Promote greater use of composting toilets

Key issue #5: Lack of respect for customary laws

Objective: To improve respect for traditional laws and values

Proposed management options:

- Education and awareness of customary ways in schools, Nakamals, church, etc.
- More resource monitors in individual communities

Key issue #6: Excess land clearing & runoff

Objective: To reduce land clearing and runoff

Proposed management options:

- Create a community plant nursery
- Replant trees:
    - to replace harvested trees (reforestation)
    - to rehabilitate erosion sites (river banks, lake bank, road edge)
- Maintain control of fires

Key issue #7: Damage to coral reefs

Objective: To minimise damage to coral reefs

Proposed management options:

- Install more moorings in Port Resolution Bay

- Raise awareness in the community of damaging practices

- (Ban damaging gears)

Table 14. Summary of agreed management actions to be included in the management plan and the issues each action addresses.

Management activities	Issues addressed
1. Nets used for reef and lake fishing must have a mesh size of 3 inches or larger.	1, 2
2. Nets used for mangru fishing must have a mesh size of 2.5 inches or larger.	1, 2
3. All hooks must be size #1 or larger.	1, 2
4. August 1 –March 31 (Yam growing season): Only hook and line (with size #1 hook), and traditional bow & arrow allowed for fishing. Nets can be used for mangru fishing. During Yam harvest all other permitted fishing methods can be used.	1, 2, 5
5. Parachute nets are not allowed.	1, 2, 7
6. Poisenem fis is not allowed.	1, 7
7. Introduce more no-take areas.	1, 2, 7, 9
8. Education and awareness.	All issues
9. Only tilapia and malet can be caught from Lake Eweya.	1, 2
10. Create proper dumping sites.	4
11. Promote greater use of composting toilets.	4

Implementation and review

An implementation plan and a monitoring schedule was also developed and is attached to the management plan along with this report as Appendices. As part of the management plan is an explicit annual review phase. This is an important step to ensure the effectiveness of the CCA management plan can be assessed and any issues can be identified and solutions identified. This may include strategies that are not working or are problematic in some way, possible reasons explored, and changes made to management if necessary. This adaptive approach to management if followed will help ensure success of the port Resolution CCA.

Sustainability

With the introduction of the CCA and the associated rules that restricts activities, there is the potential that local people will be negatively impacted in their capacity to maintain current livelihoods. This is particularly relevant due to the strong historical reliance on natural resources by the people of Port Resolution. In order to maximise the likelihood that the CCA will be sustainable, a *Livelihood Plan* was developed to provide "high-level" guidance for the development of potential funding and livelihood alternatives. Further, there will be initial and ongoing financial costs to support the implementation of the CCA and its Management Plan. The *Livelihood Plan* serves to:

i) Provide background information on current resource use and livelihoods,

ii) Recommend the alternative livelihoods most likely to be feasible, and

iii) Provide a preliminary appraisal of funding mechanisms to support the implementation of the CCA

The *Livelihood Plan* report is provided separately and will require further support through the PEBACC or other projects to develop options.

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