WAGINA ISLAND

Ecosystem and Socio-economic Resilience Analysis and Mapping

SPREP
Secretariat of the Pacific Regional Environment Programme

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

This report produced by BMT WBM for the Secretariat of the Pacific Regional Environment Programme (SPREP) presents Volume 2 (of three volumes) prepared as part of the Solomon Islands Ecosystems and Socio-economic Resilience Analysis and Mapping (ESRAM) to assess and prioritise climate change-related ecosystem-based adaptation options for selected locations in Solomon Islands. Volume 2 is the ESRAM report for Wagina Island in Choiseul Province.

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All photographs are credited to Beth Toki unless stated otherwise.

Key project partners

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List of Abbreviations

ACMCA	Anarvon Community Marine Conservation Area
AR5	Fifth Assessment Report of the IPCC
CHICHAP	Choiseul Integrated Climate Change Programme
CROP	Council of Regional Organisations in the Pacific
EbA	ecosystem-based adaptation
ESRAM	Ecosystem and Socio-economic Resilience Analysis and Mapping
GIS	Global Information Systems
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IPCC	International Panel on Climate Change
IUCN	International Union for Conservation of Nature
LLCTC	Lauru Land Conference of Tribal Communities
LMMAs	locally managed marine areas
MAR	mean annual rainfall
MECDM	Ministry of Environment, Climate Change, Disaster Management and Meteorology
PEBACC	Pacific Ecosystem-based Adaptation to Climate Change
R2R	ridge-to-reef
SPC	The Pacific Community
SOPAC	Pacific Islands Applied Geoscience Commission (part of SPC, now the Geoscience, Energy and Maritime Division of SPC).
SPREP	Secretariat of the Pacific Regional Environment Programme
TEV	total economic valuation
TNC	The Nature Conservancy
V&A	vulnerability and adaptation

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The personnel who travelled to Wagina Island and were responsible for the trip's logistics and transport, facilitation of meetings and consultation, field work and information acquisition, namely:

- Dr Tammy Tabe, David Boseto (Ecological Solutions Solomon Islands (ESSI)), Fred Tabepuda (SPREP/ LLCTC), Fredrick Chöbuna and Dr Beth Toki (BMT WBM).

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From left to right: Fredrick Chöbuna, Fred Tabepuda, David Boseto and Dr Tammy Tabe at Wagina

Executive summary

Project overview

This report, *Solomon Islands ESRAM: Volume 2 Wagina Island (Choiseul Province),* presents the second in a series of three Solomon Islands reports on ecosystem services, resilience and analysis mapping (ESRAM), prepared simultaneously for the Secretariat of the Pacific Regional Environment Programme (SPREP). It serves as the ESRAM study for one of three locations/scales selected as the focus for SPREP's Pacific Ecosystem-based Adaptation to Climate Change (PEBACC) project in Solomon Islands, namely Wagina Island in Choiseul Province. This ESRAM study (and its counterparts in Vanuatu and Fiji) represents the first time such an extensive assessment has been undertaken to guide ecosystem-based adaptation (EbA) implementation in the Pacific region.

Aims and objectives

The aim of the ESRAM study was to provide a baseline overview of ecosystems and ecosystem services, to inform subsequent EbA phases of the PEBACC project involving the identification of EbA options for strengthening the resilience of Solomon Islands to the impacts of climate change.

The objectives of the ESRAM study are listed below.

1. Identify ecosystem types, ecosystem services and threats in the context of: ecosystem types present; the present condition or health of the ecosystems; key ecosystem services in terms of direct community dependencies; the role of ecosystem services in providing socio-ecological resilience; critical ecosystem linkages or dependencies; and the main existing threats to an ecosystem and/or ecosystem service.
2. Map key ecosystems and related ecosystem services (where possible), including high-use areas and/or major threats based on existing spatial data.
3. Identify the current state of ecosystems, trends and drivers of change with root causes, scenarios and governance factors.
4. Undertake a total economic valuation to define the economic value of key ecosystem services relevant to ESRAM.
5. Assess the vulnerability of ecosystem services to the effects of climate change based on climate change projections and in the context of other existing threats.
6. Provide broad recommendations regarding strategic EbA options.

It is intended that this report (Volume 2) be read in conjunction with Volume 1 (BMT WBM 2017a), which provides background about the broader ESRAM study and PEBACC project, along with a detailed description and justification of the approach and methodology employed for the Solomon Islands ESRAM study. The third volume (Volume 3, BMT WBM 2017c presents the ESRAM assessment for the location/scale, Honiara City, the nation's capital.

Wagina Island ESRAM outcomes

Wagina's ecosystems are critical to the long-term resilience and prosperity of local communities, and even more so to building community resilience to climate change. However, current anthropogenic pressures, in addition to the existing and future effects of climate change, are threatening the services these ecosystems provide to the local community. Unsustainable practices such as over-harvesting of marine resources, ignoring protected area policies, and pollution, all combined with population increase, are adversely affecting the health of Wagina's ecosystem values and potentially the health of the local community.

Freshwater ecosystem services

Freshwater ecosystems provide essential services to Wagina Island, particularly during times when food and water supplies are limited. The key non-climatic threats to Wagina Island's freshwater ecosystem services are destruction of lowland swamps by wild pigs, modified river and creek banks and altered riparian vegetation from stream-side gardens, and pollution of groundwater wells and streams from sanitary uses, domestic animal waste, waste disposal, and fuel spills (outboard motor spills). The key climate threat to freshwater ecosystem services is salt water intrusion into groundwater wells and lowland swamps from sea-level rise. The key ecosystem services most vulnerable and in need of protection, restoration and enhancement to ensure resilience under future climate conditions are:

- provision of drinking water provided by groundwater wells;
- provision of food provided by lowland swamps (swamp taro and sago);
- supporting habitat and biodiversity by lowland swamps; and
- raw material provision by lowland swamps (sago leaves).

The provision of food and water by lowland swamps and groundwater wells are typically utilised during times of food shortages and prolonged dry periods when rainwater tanks have become dry. These 'back-up' services are critical in current climatic conditions and will need to be adequately managed to sustain their functionality during future climate change scenarios, particularly increases in temperature, extended dry periods, and overall frequency of natural disasters, which may affect food and water supply. Forward planning is needed to accommodate the lengthy yield times of swamp taro (approximately ten years) and an increasing population, while the protection of groundwater wells that are likely to be less vulnerable to saltwater intrusion must be protected from pollution and vegetation clearing. Protecting the ecosystems that provide the back-up services of today will strengthen the resilience of local residents to future effects of climate change.

The expected high vulnerability of lowland swamp biodiversity and raw material provision (sago leaves for building materials) to saltwater intrusion is likely to be difficult to mitigate and may require residents to adapt to alternative house-building materials.

Coastal and marine ecosystems and services

Marine and coastal ecosystem services are vital to the livelihoods and well-being of Wagina Island residents. They provide daily protein and nutrients, generate income, provide building materials, protect communities and the coastline from natural disasters and extreme weather events, and provide medicinal services. The key anthropogenic threats to marine and coastal ecosystem services are poor sanitary and waste disposal practices, unsustainable harvesting of marine resources, and the physical destruction of coral reefs from anchorage and the collection of coral products. The increasing population will intensify these threats. In terms of climate change, sea-level rise and an increase in sea temperature and associated ocean acidification and coral bleaching are projected to have the greatest effect on coastal and marine ecosystem services.

The key ecosystem services most vulnerable and in need of protection, restoration and enhancement to ensure Wagina's resilience under future climate conditions are:

- provision of food, trade and income-generation from local fisheries (turtle, shark, fish, molluscs, crustaceans, etc.) provided by reefs, marine lagoons, marine waters, mangroves and beaches;
- provision of habitat and biodiversity provided by reefs, marine lagoons, marine waters, mangroves and beaches;
- provision of income-generation (seaweed farming) provided by marine lagoons;
- provision of raw materials (coral rock and lime production) provided by reefs and marine lagoons; and
- coastal hazard protection by the attenuation and buffering of wave and storm energy by reefs.

The depletion of local marine resources, and the corresponding decrease in the provision of food and income generation will have severe implications for the health and livelihoods of Wagina Island residents. The full extent of the effects of climate change on marine resources is complex and potentially unavoidable. However, without appropriate measures in place to adequately manage existing ecosystem services provided by marine and coastal ecosystems, resilience to future climate and non-climate threats, coupled with a growing population, will be challenged. Observations of marine resource harvesting rates at Wagina, backed by reports from residents that the abundance of some species has declined, suggest that sustainable fisheries management and environmental education are urgently needed on Wagina Island.

A balance between meeting the subsistence food needs of residents and maximising benefits through the sale and trade of marine products is needed to build both social and economic resilience. To achieve this, however, marine ecosystem resilience needs to be enhanced by promoting environmental awareness (including the importance of protected and conservation areas), managing marine resources sustainably, improving sanitation and waste management, and sustaining mangrove forest health and abundance. Wagina's seaweed farming is an environmentally sustainable industry that provides a viable source of income for Wagina households and reduces pressure placed on harvesting other marine resources, such as sharks, turtles, fish and beche-de-mer. While various factors influence the viability of seaweed production, a multi-sectoral and multi-partner approach is needed to strengthen the long-term socio-economic stability of production and export.

Terrestrial ecosystem services

Wagina's terrestrial forests appear to be in good health and provide important ecosystem services for the local community, including the provision of food, fibre, timber and fuelwood. Gardens and plantations are essential for food provision and also contribute to building and medicinal provisions. The key threats to terrestrial forest ecosystem services are land clearing and over-harvesting for timber, while gardens and plantations are threatened by unsustainable harvesting, destruction by feral animals, pests and diseases, encroachment from expanding villages, excessive weed growth and theft of garden produce. Without appropriate measures in place, the growing population is likely to place further stress on both terrestrial forests and gardens by an increase in clearing, harvesting and food supply needs.

The climate change projections likely to have the greatest effect on Wagina's terrestrial ecosystem services are an increase in air temperature and an increase in extreme rainfall events. The key ecosystem services most vulnerable and in need of protection, restoration and enhancement to ensure resilience under future climate conditions are:

- the provision of food provided by terrestrial forests, gardens and plantations; and
- the provision of raw materials (timber, fuelwood and building materials) provided by terrestrial forests and plantations.

To strengthen the resilience of gardens and plantations to increasing temperatures and extreme rainfall events and sustain a growing population, new plant species with tolerance to climate fluctuations and a potential increase in pests and diseases may need to be explored to strengthen Wagina's food security.

Terrestrial forests in their current state are likely to be resilient to an increase in extreme rainfall events and an increase in air temperatures due to their intactness, which sustains cooler temperatures within forest ecosystems, and stable soils that reduce the potential for soil erosion. To maintain the resilience of forest ecosystem services to future climate and non-climate effects, management measures will need to be implemented for the island (e.g. replanting programmes, allocation of protected areas, and sustainable clearing, harvesting and cultivation practices). Sustaining the high level of resilience by terrestrial forests will have positive flow-on effects to other ecosystem services, such as supporting terrestrial fauna and biodiversity and therefore strengthening Wagina's food security, and providing regulating services, such as climate regulation, prevention of soil erosion, primary productivity and maintaining stream water quality (which in turn enhances water supply for Wagina Island residents).

While Wagina Island is highly vulnerable to a changing climate, and is already experiencing several effects of climate change, human-induced threats may present a greater risk to the livelihoods of local communities and ecosystem health. A change in the current mindset and behaviour of Wagina residents towards sustainable harvesting and fishing, sanitation, water supply and coastal erosion is needed to reduce the rate of environmental damage to the local and surrounding area.

Ecosystem-based adaptation options

Ecosystem-based adaptation (EbA) aims to increase the ability of local communities and ecosystems to adapt to the effects of climate change. Well managed and healthy ecosystems are critical for the provision of essential services to sustain the health, well-being and livelihood of Wagina Island residents.

The ESRAM process has identified the vulnerabilities of social ecological systems to climate and non-climate change threats and effects. Based on the vulnerable ecosystem services identified, EbA options have been proposed to protect, restore and strengthen ecosystems to increase the resilience of Wagina Island communities. Building environmental resilience to give Wagina's ecosystems the best chance to restore and adapt will, in turn, increase the likelihood of human adaptation to the adverse effects of climate change.

1 Introduction

1.1 Background

This report, *Solomon Islands ESRAM: Volume 2 Wagina Island (Choiseul Province),* presents the second in a series of three Solomon Islands reports on ecosystem and socio-economic resilience and analysis mapping (ESRAM) prepared simultaneously for the Secretariat of the Pacific Regional Environment Programme (SPREP). It serves as the ESRAM study for one of two locations/scales selected as the focus for SPREP's present Pacific Ecosystem-based Adaptation to Climate Change (PEBACC) project in Solomon Islands, namely Wagina Island in Choiseul Province (Figure 1-1).

1.2 Aims and objectives

The aim of the ESRAM study was to provide a baseline overview of ecosystems and ecosystem services, to inform subsequent EbA phases of the PEBACC project involving the identification of ecosystem-based adaptation options for strengthening the resilience of Solomon Islands to the impacts of climate change.

The objectives of the ESRAM study are listed below.

1. Identify ecosystem types, ecosystem services and threats in the context of:
    - ecosystem types present, in the context of the relevant ecosystem services;
    - present condition or health of the ecosystems present, based on existing information if available and/or recent observations (qualitative or opportunistic) throughout the course of the assessment;
    - key ecosystem services in terms of direct community dependencies;
    - the role of ecosystem services in providing socio-ecological resilience;
    - critical ecosystem linkages or dependencies; and
    - main existing threats to an ecosystem and/or ecosystem service.
2. Map key ecosystems and related ecosystem services, including high-use areas and/or major threats based on existing spatial data.
3. Identify the current state of ecosystems, trends and drivers of change with root causes, scenarios and governance factors.
4. Undertake a total economic valuation to define the economic value of key ecosystems services relevant to the ESRAM.
5. Assess the vulnerability of ecosystems services to the effects of climate change based on climate change projections and other existing threats.
6. Provide broad recommendations regarding strategic EbA options.

This ESRAM study (and its respective counterparts in Vanuatu and Fiji) represent the first time that such an extensive and broad scale assessment has been undertaken to guide EbA implementation in the Pacific region. An additional objective of the ESRAM studies is therefore to provide case studies for future knowledge sharing and developments in the application of EbA elsewhere.

1.3 Volume 2 report scope

The ESRAM study considers three geographic locations/scales. This Volume 2 report is the Wagina Island scale assessment. The Wagina scale ESRAM assessment (along with the Honiara assessment) is a more detailed exercise than the national scale (higher-level) assessment.

It is intended that this report (Volume 2) be read in conjunction with Volume 1 (BMT WBM 2017a), which provides background about the broader ESRAM and PEBACC projects, along with a detailed description and justification of the approach and methodology employed for the Solomon Islands ESRAM studies. The third and final volume (Volume 3, BMT WBM 2017c) presents the ESRAM assessment for the second focal location/scale, the national capital, Honiara City.

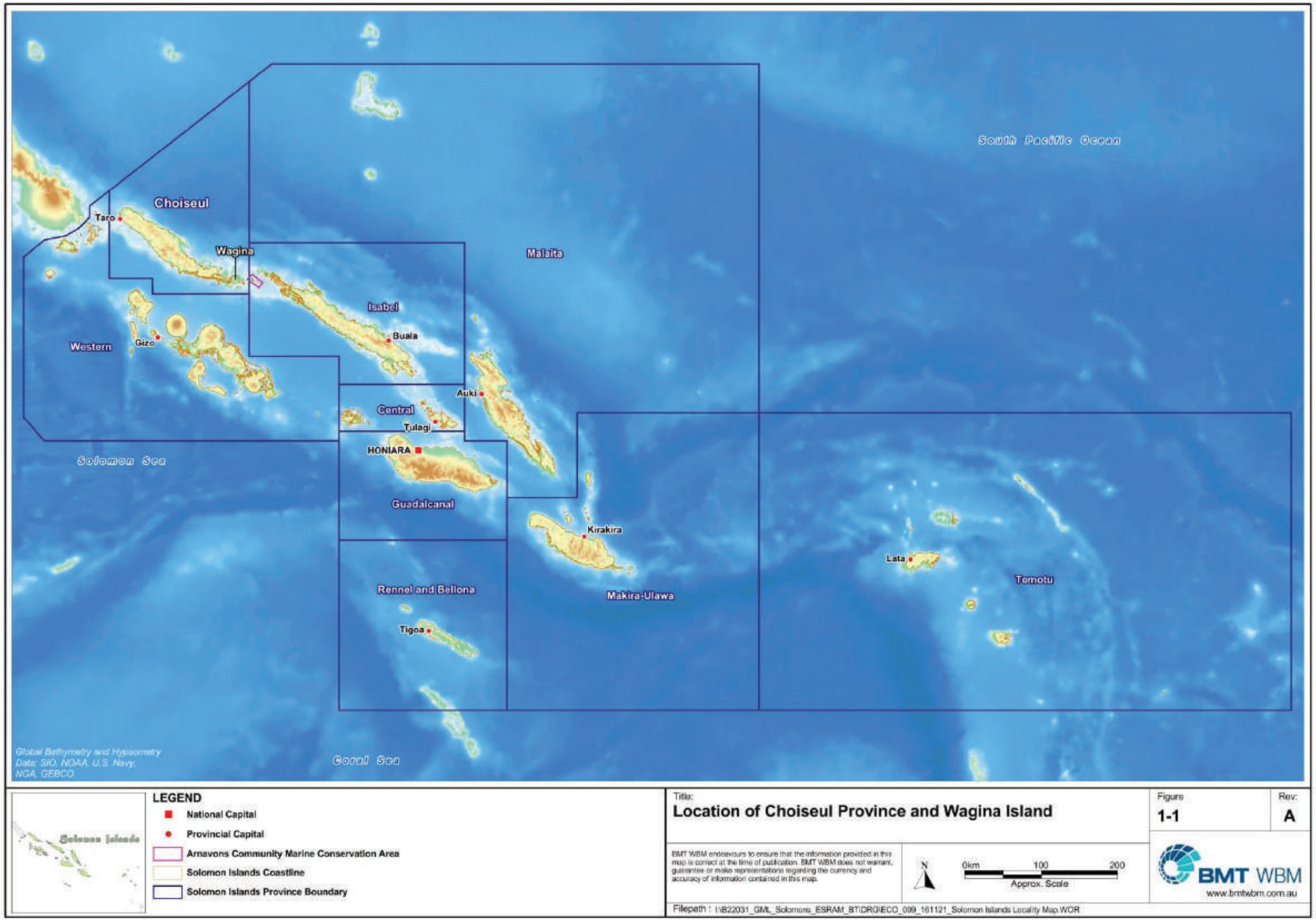


Figure 1-1 Location of Choiseul Province and Wagina Island

2 Wagina specific methodology

2.1 Study approach

The three Solomon Islands ESRAM studies (national, local and city) follow the conceptual framework presented in Figure 2-1. This generic methodology has been adapted for each of the different spatial scale/location contexts, depending on factors such as geographic extent, stakeholder engagement requirements and community/population size. Additional and/or specific methods relevant to the Wagina approach are detailed below.

The detailed ESRAM assessment for Wagina Island was largely informed by local knowledge sourced directly from the resident community, primarily through detailed consultation workshops with each of the four villages, as described below.

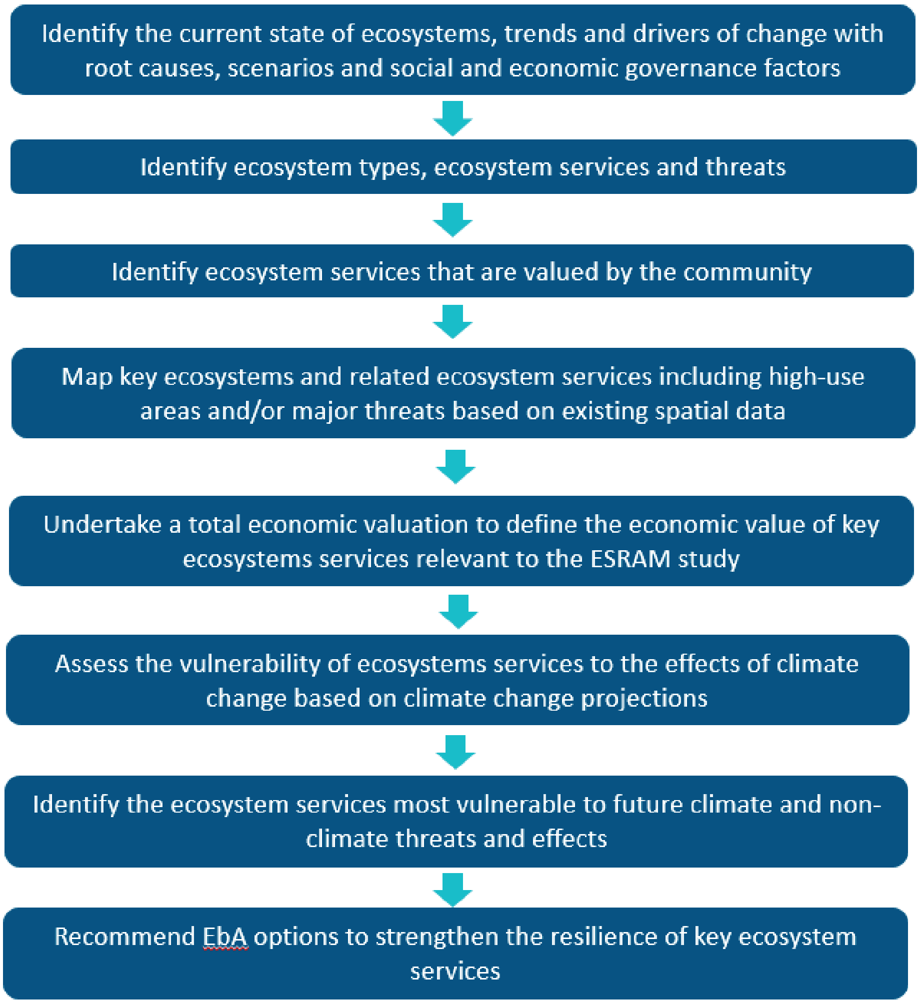


Figure 2-1 Conceptual framework

There were several reasons behind the decision to focus the provincial scale ESRAM on Wagina Island. Both the environment and community of Wagina are considered to be highly vulnerable to future threats, including both climate and non-climate related pressures. The island faces challenges from the effects of climate change, which are exacerbated by: an increasing population; fluctuating prices for the primary industry, seaweed farming; and a major mining proposal. Further, while Choiseul Province as a whole (particularly Choiseul Island and the Taro Island / Choiseul Bay area) have been the focus of a significant body of climate change work, there has been comparatively little climate change work focused on Wagina Island. Wagina Island presents a notable gap with respect to existing, and locally-specific, climate change adaptation recommendations.

2.2 Review of existing information and validation

Key information sources and existing programmes with respect to climate change vulnerability and adaptation in Choiseul Province that were reviewed in this project are *listed below.*

- *Choiseul Province Climate Change Vulnerability and Adaptation (V&A) Assessment Report (Mataki et al. 2013)*
- *Ecosystem-based Adaptation and Climate Change Vulnerability for Choiseul Province, Solomon Islands Synthesis Report* (Iacovino *et al.* 2013)
- *Integrated Climate Change Risk and Adaptation Assessment to Inform Settlement Planning in Choiseul Bay – Hazards Assessment* (BMT WBM 2014)
- Initiatives of the Choiseul Integrated Climate Change Programme (CHICHAP)
- Existing EbA works already implemented in Choiseul Province through SPREP and USAID.

The Choiseul V&A assessment presents a similar climate change assessment at the broader provincial-wide scale, with a strong emphasis on ecosystems due to the recognition that: *'The future of Choiseul Province is inextricably linked to its terrestrial and coastal biodiversity and ecosystems. Therefore, the AC [adaptive capacity] of Choiseul Province is closely linked to its ability to continue to use ecosystem services provided by these ecosystems… '* (Mataki *et al.* 2013; p 35). The outcomes of the Choiseul V&A reports classify the communities and coastal and marine environments of Wagina Island as being extremely vulnerable to climate change. This is largely associated with the community's high dependence on marine and coastal resources (e.g. for land, food, water and income), together with the vulnerability of these resources to both existing and climate change threats (Mataki *et al*. 2013; Iacovino *et al*. 2013).

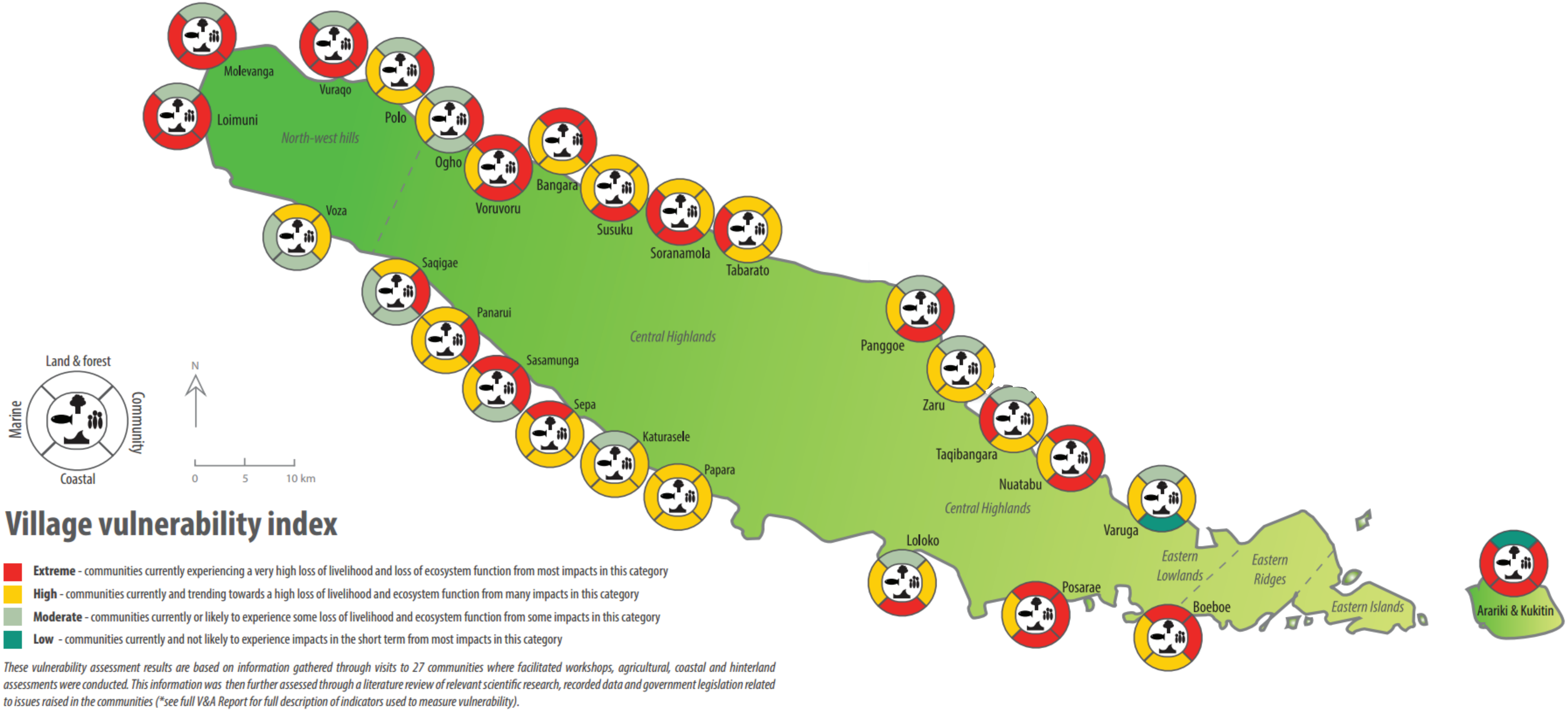


Figure 2-2 Summary of key climate change vulnerabilities identified for Choiseul Province (source: Iacovino *et al.* 2013). Note: Wagina Island is not pictured on the map, due to its exclusion from the Iacovino *et al.* (2013) vulnerability study. Wagina Island is located further east of Arariki and Kukitin.

a)

b)

Figure 2-3 Young onlookers watch measuring of water quality at village wells in Tekaranga (a) and Arariki (b)

2.3 Workshop methodology

Community consultations were undertaken on Wagina Island during September 2016, with each of the four villages consulted on separate days. Objectives of the consultation workshops were:

- to provide follow-up and further community consultation after SPREP's initial PEBACC meeting on Wagina in August 2016 (i.e. more locally relevant information on the ESRAM study and to a broader audience);
- advise community representatives from each village about the ESRAM study, its part in the PEBACC project, and the community's role in informing the ESRAM study;
- provide some awareness on ecosystems, ecosystem services and climate change in both the local (Wagina Island) context and that of the ESRAM/PEBACC projects;
- utilise and document the knowledge of the local community for informing the ESRAM study, with a particular focus on:
    - identifying local ecosystems as perceived by the community;
    - documenting ecosystem services in terms of the community's direct dependence on their local land and sea resources, including ascertaining the relative value of resources to the community (i.e. which resources are essential and/or valued most); and
    - undertaking interactive mapping exercises to spatially document ecosystem services, with a particular focus on high-use areas;
- identify existing threats to the ecosystems and/or ecosystem services, noting that there is often a strong overlap between ecosystem services and existing threats to ecosystems (e.g. in terms of over-exploitation of a particular land or sea resource).

Each consultation workshop was held in the village *maneaba* (meeting house) and was attended by approximately 20 active participants (

Table 2-1). Higher numbers were in attendance at Nikumaroro village as a result of the workshop occurring on a Sunday, immediately after the local church service and associated luncheon. An effort was made to encourage some diversity among participants, particularly in terms of encouraging women to attend and contribute. In this respect, women represented almost half (42–45%) of active participants at Tengangea and Tekaranga villages, and approximately one quarter (25–28%) of participants at Arariki and Nikumaroro villages.

During the interactive exercises to identify ecosystems, ecosystem services and threats and to undertake mapping, the participants for each workshop were divided into four groups: two concentrating on ecosystem services in close proximity to their village; and two advising on ecosystem services across the full geographic extent of Wagina Island and its immediate surrounds. In total, 88 community representatives were actively involved in the consultation workshops, together with the local village organiser (VO), the ESRAM study team and additional non-active observers/listeners. Photographs of example groups participating in these exercises are shown in Figure 2-4, while photographs of all participating groups are provided in Appendix A.

Table 2-1 Summary of 2016 workshop attendees for each village

	Nikumaroro	Arariki	Tekaranga	Tengeagea
Workshop date	18 Sept.	19 Sept.	20 Sept.	21 Sept.
Total number of actively involved local participants	29	20	20	19
Male proportion	72% (21)	75% (15)	55% (11)	58% (11)
Female proportion	28% (8)	25% (5)	45% (9)	42% (8)
Additional local observers	19	3	0	2
Project team	6 (incl. VO)	6 (incl. VO)	6 (incl. VO)	5

a) b)

c) d)

Figure 2-4 Examples of groups participating at community workshops: a) Nikumaroro, b) women at Arariki, c) youth at Tekaranga, d) Tengangea

The information sourced from workshops was then validated through a combination of complementary information gathering methods, including:

- site inspections and guided tours at each village, together with informal/opportunistic discussions with interested local residents;
- field surveys to map critical locations (e.g. in relation to the ecosystems and ecosystem services on which the community is directly dependent) and qualitatively assess the current condition of key ecosystems, particularly at high-use areas; and
- mapping and water quality testing (electrical conductivity and pH) at actively used water sources in each village (See Section 5.13.2.1).

3 Provincial context

3.1 Choiseul Province setting

3.1.1 Geographic and socio-economic setting

Choiseul Province is situated in the north-west of Solomon Islands. Choiseul (Lauru) Island is the sixth largest island (3,106 sq km) in Solomon Islands. Located between 6.5°S-7.5°S and 156.5°E-157.5°E, it is approximately 185 km long with a typical width of around 30 km. Choiseul Island is rugged, mountainous and has many rivers, the largest of which is the Kolombangara River in the south-central region (Boseto *et al.* 2007; Morrison *et al.* 2007). Topography is varied (Pikacha 2008). To the south-east the sharp volcanic peak of Komboro is at an elevation of 600 m and ridges of basalt occur to varying altitudes up to 800 m. Mt Maetambe (1600 m) dominates the central mountains. To the northwest are moderately gently sloping hills, to the east there are low-lying islands, remote reefs, rocky outcrops and shallow shelf seas (Ridgway and Coulson 1987). The province also includes two small islands, Wagina (82 sq km) and Rob Roy (67 sq km), and over 300 small islets, each less than 1 sq km (Menazza and Balasinorwala 2012).

The 2009 census (described in Choiseul Province Medium Term Development Plan (MTDP) 2012–2014) records the population of Choiseul Province as 26,372, up from 20,008 people in 1999. This represents an increase of 2.8% per annum and is the second highest provincial population growth rate behind Guadalcanal Province.

There are 28 major rural communities in Choiseul Province, with the highest population densities occurring in coastal villages on the north-west, south-central and southern regions (Morrison *et al.* 2007) (Figure 3-1). These communities are heavily dependent on natural resources, with around 80%–90% of people conducting subsistence activities such as fishing and gardening (Menazza and Balasinorwala 2012).

In this rural, isolated setting that lacks transportation and communication infrastructure, income for Choiseul's communities is mostly generated through small-scale copra production, harvesting of non-perishable marine products (trochus, shark fin, sea cucumbers), logging royalties, small-scale logging and associated timber milling (Menazza and Balasinorwala 2012). Logging is the only major commercial industry, with Choiseul Island generating the third highest log exports by province during 1995 to 2005 in Solomon Islands (see Table 3-1).

Table 3-1 Natural forest round log exports by province 1995–2005 (m^3) (Pauku 2009)

Central	Choiseul	Guadalcanal	Isabel	Makira	Malaita	Western	Total
32,450	94,800	9,800	118,950	56,350	35,100	675,500	1,018,100

Figure 3-1 Choiseul Province

3.1.2 Current climate

The climate of Choiseul is equatorial and influenced by maritime weather patterns, especially the El Niño Southern Oscillation (ENSO), the South Pacific Convergence Zone and the West Pacific Monsoon. South-east trade winds blow between May and October, and July is often wet, unlike most islands in the country, where July is generally dry (Pikacha 2008).

Data for the provincial capital, Taro Island, indicate that mean annual rainfall (MAR) at Taro Island is 3300 mm and is reasonably consistent throughout the year. The driest month is December and the wettest month is July (Figure 3-2). There are notable variations in MAR over the available data record; rainfall in excess of 5,000 mm occurred in 1993 and 2000, while rainfall was less than 2,500 mm in 1996 and 1999. Note that 1997 was regarded as a significant drought event regionally. Evaporation rates are of the order of 5 mm/day.[1]

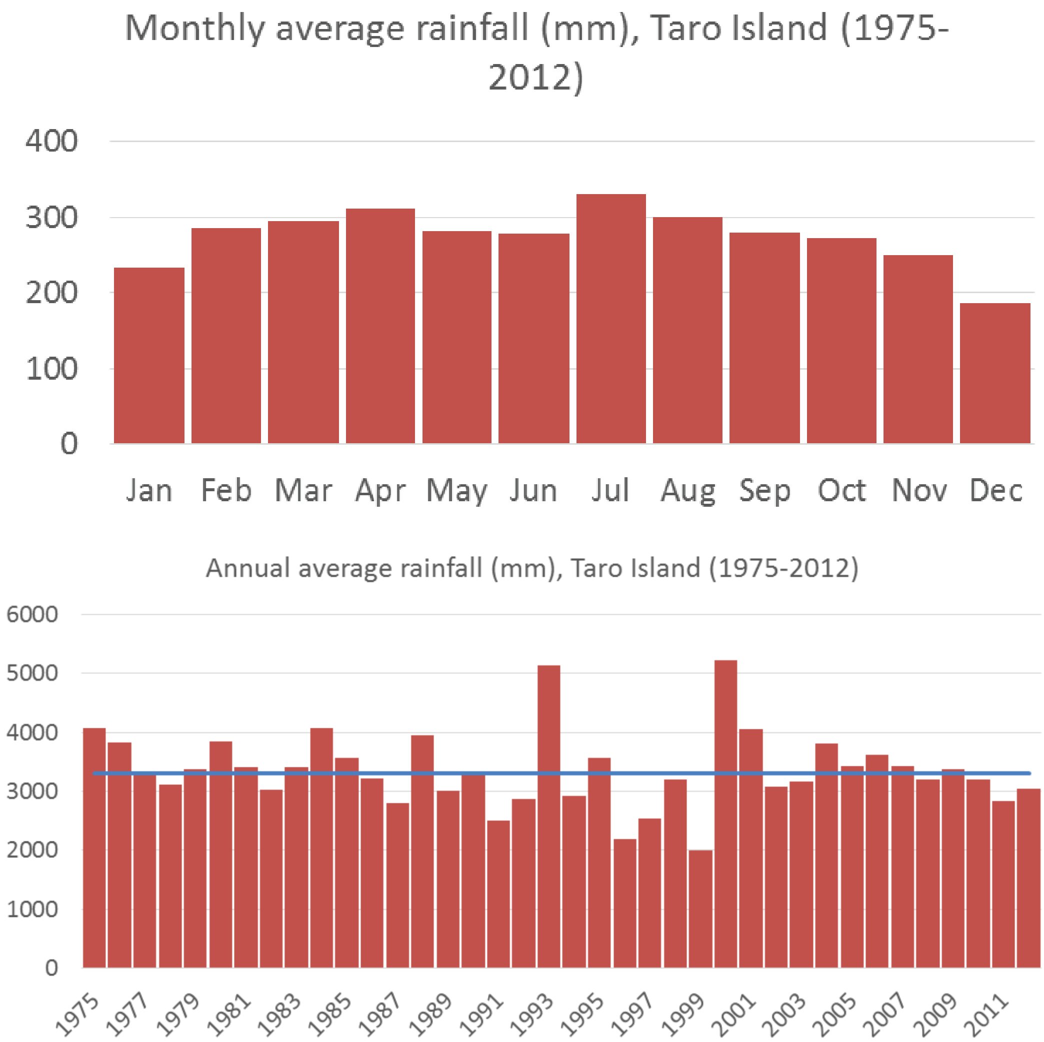


Figure 3-2 Monthly average (top) and annual average (bottom) rainfall, Taro Island, 1075–2012. For annual rainfall, the blue line shows the average over all years.

[1] Source: www.fao.org/ag/AGP/AGPC/doc/Counprof/southpacific/Solomon.htm

3.1.3 Climate change governance

The *Solomon Islands National Climate Change Policy 2012–2017* (Wickham *et al.* 2012) was issued by the Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM). The policy, launched in June 2012, was developed by several Solomon Island government ministries and supporting organisations. It provides a framework for a national approach to addressing climate change effects and adaptation, and achieving sustainable development.

The nation's holistic ridge-to-reef (R2R) approach to climate change adaptation is consistent with international, national and provincial commitments and planning policies, including the *Solomon Islands National Development Strategy 2016–2035; Solomon Islands National Climate Change Policy 2012–2017; Solomon Islands National Biodiversity Strategy and Action Plan* (Pauku and Lapo 2009); *Choiseul Province Medium Term Development Plan 2009–2011*, and the *Ridges to Reef Conservation Plan for Choiseul Province* (Lipsett-Moore 2010).

As alluded to in Chapter 1, there is a series of other projects in Choiseul Province focussing on climate change. These are led by organisations such as the *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ), The Nature Conservancy (TNC), the Pacific Community and SPREP. To ensure that such projects are complementary, national and provincial government ministries, the Council of Regional Organisations in the Pacific (CROP) agencies, development partners, and non-governmental and civil society organisations agreed to collaborate province-wide and across sectors using the ridge to reef approach. This collaborative partnership is the Choiseul Integrated Climate Change Programme (CHICHAP). CHICHAP aims to support the Solomon Islands Government and the Provincial Government of Choiseul in their efforts to strengthen the resilience of the *Lauru* (local name for Choiseul) people and communities against the effects of climate change and natural disasters; as well as to enhance their food security and strengthen the resilience of natural ecosystems in Choiseul Province. The Choiseul Province Climate Change Vulnerability and Adaptation Assessment Report (Mataki *et al.* 2013) provides the most recent province-wide climate change guidance for Choiseul Province.

Governance in rural communities is driven by tribal/cultural leadership and the church. Tribal leadership dominates land tenure issues, while daily affairs are generally the responsibility of church leaders. There are three main churches in Choiseul Province, the United Church (56.2% of the population), Roman Catholic Church (21.9%) and Seventh-day Adventist Church (16%). There are also several smaller evangelical churches (Iacovino *et al.* 2013).

3.2 Biodiversity values, ecosystem threats and conservation

3.2.1 Biodiversity values

Consistent with the high biodiversity values highlighted for Solomon Islands in *Volume 1* (BMT WBM 2016), Choiseul Province is also recognised for its high biodiversity values. In fact, much of the existing environmental literature for Choiseul Province is associated with its unique and/or endemic biodiversity features.

The inventory collated by Boseto and Pikacha (2016) provides a recent example of the unique and high biodiversity on part of Chosieul Island, namely the corridor from Mount Maetambe to Kolobangara River. It has been suggested that Choiseul Island is one of, if not the, most biodiverse islands in the country (Mayr and Diamond 2001; McClatchey *et al.* 2005; Boseto *et al.*. 2007; Morrison *et al.* 2007; Keppel *et al*. 2010; Game *et al*. 2010; Menazza and Balasinorwala 2012). Most of the unique biodiversity values of Choiseul Province are associated with its terrestrial ecosystems. However, the Solomon Islands Rapid Marine Assessment (Green *et al.* 2006) also highlighted the marine biodiversity values, with some of the study's highest coral and marine fish biodiversity scores recorded in Choiseul Province. Additionally, Choiseul Province is notable in a national context for containing the critical habitat for saltwater crocodile (*Crocodylus porosus*) and nesting beaches for sea turtles, especially hawksbill turtles (*Eretmochelys imbricata*) (Filardi *et al.* 2007). Note that barrier and fringing reefs are a notable marine habitat feature around Choiseul Province, particularly along the north eastern coastline (Figure 3-3), and that patch reefs are prominent around the eastern islands.

From a terrestrial perspective, Choiseul Province is acknowledged as having some of the largest remaining stands of lowland forest in the Pacific region (Mayr and Diamond 2001; McClatchey *et al.* 2005) and for having among the highest biodiversity in the country for a number of terrestrial groups (Boseto *et al*. 2007). These include birds (McClatchey *et al.* 2005), plants (McClatchey *et al.* 2005), reptiles (McCoy 2006) and frogs (Morrison *et al.* 2007). McClatchey *et al.* (2005) attribute the remarkable biodiversity of Choiseul Province with its relatively large land size, diversity of habitats and relatively low levels of forest degradation compared to other large islands in the country.

By way of introduction to the key features of terrestrial ecosystems and the unique biodiversity values of Choiseul Province, the following facts are noted.

Terrestrial vegetation

- Choiseul Island is primarily characterised by tropical, hilly, jungle vegetation of medium height with a closed canopy. It also features a plateau in the centre of the island, where cloud forests occur (Pikacha 2008).
- Figure 3-3 presents a vegetation classification map for Choiseul Island (noting that this mapping does not extend to Rob Roy or Wagina Islands). Most of the interior of Choiseul Island is classified as mixed rainforest on hills that is in good (i.e. not degraded) condition, the exception being the extensive Casuarina dominated hill forest that characterises the eastern lowlands and ridges. The coastal fringe of Choiseul Island supports a greater diversity of forest types (e.g. various swamp forest types and lowland rainforest). However, a greater proportion of the forests around the coastal fringe are in a degraded condition, including significant encroachment into adjacent rainforest on hills.
- For the dominant lowland forest vegetation type, Pikacha (2008) lists typical common tree species as including *Terminalia* spp., *Terminalia brassii*, *Dillenia* spp., rosewood (*Pterocarpus indicus*), pencil cedar, sago palms (*Metroxylon* spp.) and ngali nut trees (*Canarium indicum*). Ferns of the species *Diplazium esculentum*, *Cyclosorus magnificus* and *Dennstaedia samoensis* are prominent near the river edges and sporadically extend into the forest undergrowth (Pikacha 2008).
- Pikacha and Sirikolo (2009) provide an overview of dominant vegetation species (trees, palms, freshwater swamp flora and other plant groups) at key locations of biodiversity significance.

Terrestrial fauna

- Choiseul Province has the highest number of native mammal species recorded in Solomon Islands (Flannery 1995), primarily comprising a high diversity of native bats and native giant rats (Pikacha and Sirikolo 2009). Poncelet's giant rat *Solomys ponceleti* (Critically Endangered, IUCN) and Bougainville giant rat *S. salebrosus* (Endangered, IUCN) are endemic to Choiseul and Bougainville Islands. These species are widely distributed throughout Choiseul but in very low numbers and are becoming extremely rare (Pikacha 2008). Targeted surveys by Pikacha (2008) suggest they are slightly more common near Olivetti Village, in the interior of northwest Choiseul.
- Choiseul has the highest frog diversity in Solomon Islands – of the 21 known frog species in the country, 19 are found on Choiseul Island (Pikacha 2008). This includes the palm frog (*Palmatorappia solomonis*), listed as Vulnerable (IUCN) (Pikacha and Sirikolo 2009).
- Morrison *et al*. (2007) recorded endemic frogs and reptiles during surveys in Choiseul Island. Based on frog diversity and abundance, they identified the most critical habitats as being: mid-altitude rainforest (500 m–600 m); primary lowland rainforest; and lowland coastal forest.

Avifauna

- Choiseul Province is a key contributor to the high endemicity of bird fauna in Solomon Islands. The province supports 28 restricted range species (noting 25 of these are shared with Isabel Province), although the one species endemic to Choiseul, *Microgoura meeki*, is now presumed extinct (Filardi *et al.* 2007).
- Choiseul Province, particularly the Mount Maetambae and south-east Choiseul/Arnavon Island areas, host several birds of international conservation significance. These species are listed in Table 3-2 (as per Filardi *et al*. 2007).

Aquatic fauna

- The first freshwater fish surveys in Choiseul Province were undertaken in 2005 (Boseto *et al.* 2007) and subsequently by Boseto and Sirikolo (2009). Together, they identified 41 species from 15 families, and indicate intact and diverse aquatic ecosystems.
- Species richness was greatest in Lumutu and Kolombangara Rivers, and tended to be attributable to: (i) substrate type, whereby species richness was higher at gravel sites as opposed to muddy substrata; and (ii) distance from the coast, whereby the number of fish species was typically greater at sites near the coast compared to inland. Kolombangara River is a notable exception, where fish communities maintain high species richness and abundance inland (Boseto *et al.* 2007; Boseto and Sirikolo 2009).

Table 3-2 Key bird species of conservation significance in Choiseul Province (source: Filardi *et al.* 2007, Pikacha and Sirikolo 2009)

Common name	Scientific name	Conservation status (IUCN)
Choiseul pigeon	*Microgoura meeki*	Presumed Extinct
White-eyed starling	*Aplonis brunneicapillus*	Endangered
Yellow-legged pigeon	*Columba pallidiceps*	Vulnerable
Imitator goshawk	*Accipiter imitator*	Vulnerable
Fearful owl	*Nesasio solomonensis*	Vulnerable
Sanford's sea eagle	*Haliaeetus sanfordi*	Vulnerable
Black-faced pitta	*Pitta anerythra*	Vulnerable
Woodford's rail	*Nesoclopeus woodfordi*	Near Threatened
Solomons frogmouth	*Rigidipenna inexpetatus*	Near Threatened
Nicobar pigeon	*Caloenas nicobarica*	Near Threatened
Black and white monarch	*Monarcha b. barbatus*	Near Threatened
Crested cuckoo dove	*Reinwardtoena crassirostris*	Near Threatened

Biodiversity underpins all ecosystem services, but it can also be a service in itself (e.g. the existence value of a species under cultural services). Biodiversity is also considered to have insurance value by providing resilience in the face of current or future shocks to ecosystems and the services they provide (DEFRA 2007).

Highly functioning ecosystems provide natural solutions and barriers that build resilience and help society adapt to the adverse effects of climate change. For example, buffering and protecting communities from extreme weather events and natural hazards such as tropical cyclones, tsunamis and floods; reducing erosion and trapping sediment, thereby sustaining water quality; increasing natural resources for diversifying local livelihoods; and providing food, water and raw materials for well-being and shelter. Well-functioning ecosystems provide habitats for animals and plants, which, in turn, provide food security for communities during times of adversity such as drought and after natural disasters. Biodiversity maintains the stability and resilience of ecosystems in enabling them to maintain functionality over a range of environmental conditions, and thus providing humans resilience to a changing climate.

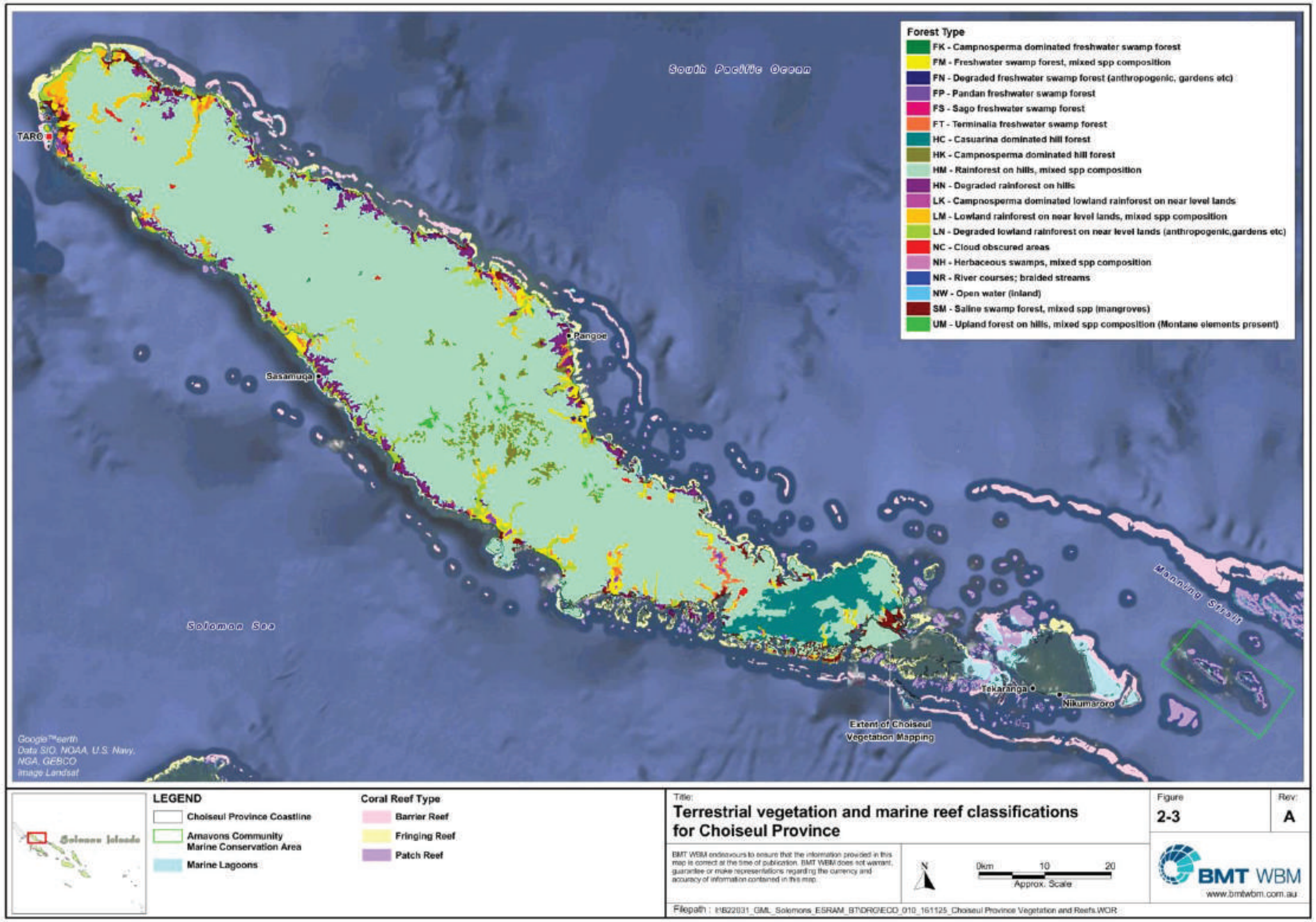


Figure 3-3 Terrestrial vegetation and marine reef classifications for Choiseul Province

3.2.2 Existing ecosystem threats

In addition to the above-mentioned biodiversity values, the socio-economic values of Choiseul's ecosystems are also critical to the long-term resilience and prosperity of Choiseul's communities, particularly in terms of building community resilience to climate change (Menazza and Balasinorwala 2012). As mentioned in Section 3.1.1, the local economy and community livelihoods are dependent on natural resources. However, unsustainable harvesting, together with large-scale commercial logging, currently present significant existing threats to the persistence of high-quality natural ecosystems, and well-functioning ecosystem services in Choiseul Province.

As stated by Morrison *et al.* (2007), logging is the major environmental threat on Choiseul Island. Commercial logging operations extracting hardwood from native forests are concentrated in the north and south-east side of the island. The environmental effects include large scale deforestation, soil erosion, sedimentation, soil compaction, extensive erosion and sediment run-off, increased suspended solids in waterways, and the resultant degradation of estuarine and marine environments through sedimentation (Boseto *et al.* 2007; Morrison *et al*. 2007; Menazza and Balasinorwala 2012). These effects are detrimental to ecosystem functioning and biodiversity. For example, the populations of the rare endemic giant rats (refer to Section 3.2.1) are declining further due to logging (Pikacha 2008).

Over-exploitation and/or unsustainable harvesting practices are the other major existing threats to local ecosystems. In Choiseul Province, over-harvesting has specifically been recognised as a key threat in aquatic ecosystems, especially to freshwater fish communities (Boseto *et al.* 2007; Boseto and Sirikolo 2009). This relates in particular to: (i) overharvesting freshwater mullet *Cestraeus plicatilis* during the spawning season; (ii) the mass harvesting of juvenile fish during migration from ocean to freshwater; and (iii) the use of derris root (a strong insecticide commonly used to poison fish) to harvest fish by pig hunters (Boseto *et al.* 2007).

Feral animals, or introduced pests such as rats, cats, cane toads and dogs, are an additional threat that cause habitat degradation and directly impact native fauna (Pikacha 2008). This is true for terrestrial ecosystems but is also considered a high risk for aquatic ecosystems if farmed tilapia were to escape from local aquaculture ventures (Boseto and Sirikolo 2009).

Proposed mining activities present a major threat that the province has not previously been exposed to. There are mining proposals being developed for southern Choiseul Island (nickel mining) and Wagina Island (bauxite mining).

3.2.3 Conservation

Formal conservation and environmental management approaches for Choiseul Province's cosystems remain largely in preliminary stages of development, with the exception of marine conservation areas which are more advanced. Overall, less than 1% of Choiseul's land and sea area is under protection, noting that virtually all land and shallow waters are under traditional ownership or customary tenure (Menazza and Balasinorwala 2012). Conservation efforts with the establishment of protected areas is presently largely facilitated by the Lauru Land Conference of Tribal Communities (LLCTC), in partnership with The Nature Conservancy, which has established a network of locally implemented and managed protected areas (Game *et al*. 2010).

Anarvon Community Marine Conservation Area (ACMCA) is arguably the most significant protected area as it was the first one recognised under national law. Declared in 1995 and encompassing 15,800 hectares (Figure 3-1), ACMCA borders both Choiseul and Isabel Provinces and is jointly managed by three communities: Katupika, Kia and Wagina. A primary driver for the establishment of the ACMCA was that it supports one of the largest remaining rookeries of hawksbill turtles (*Eretmochelys imbricata*) in the world and, prior to the establishment of ACMCA, turtle numbers were in severe decline due to over-harvesting (Menazza and Balasinorwala 2012; TNC 2016).

Locally managed marine areas established on traditional reefs around Choiseul Island have been successful with tangible results (Menazza and Balasinorwala 2012). The community-based protected areas (localities shown in Figure 3-1) are strict no-take areas, with harvest prohibition managed entirely by the customary owners of the sites (Game *et al*. 2010). This protected area network has a protection target of 10% of the total area of each feature to be protected (in line with Solomon Islands' commitment under the Convention of Biological Diversity 2006). For important food resources, such as fish spawning aggregation areas, and threatened species, such as marine/sea turtle nesting colonies, communities chose to increase this protection target area to 50% of the feature to be conserved (Game *et al.* 2010).

Formal protected areas for terrestrial ecosystems in Choiseul Island are generally yet to be established, with the exception of some small-scale locally managed areas (Figure 3-1), including a protected area at Boeboe village at the south-eastern part of the island. A conservation area is also being established, using the ridge-to-reef approach, covering the area of the Kolobangara River corridor to Mount Maetambe. Villages are engaged in mapping their territories and managing resources, with assistance from SPREP, ESSI, LLCTC and the Provincial Government (Boseto and Pikacha 2016). In addition, several authors have emphasised land-based protection priorities for Choiseul Province, most notably:

- the National Biodiversity Strategic Action Plan (Pauku and Lapo 2009) provides an overview of biodiversity and identifies priority areas for conservation;
- Filardi *et al*. (2007) propose important bird areas for the province, including: (i) Mount Maetambae and (ii) South Choiseul / Anarvon Islands; and
- biodiversity conservation initiatives on Choiseul Island proposed by WWF, with local landowners and communities, include the Sirebe Rainforest and Biodiversity Conservation Area, Vuri Rainforest and Biodiversity Conservation Area, Kubongava Forest Biodiversity Conservation Area, and Baukolo Forest Biodiversity Conservation Area (Pikacha and Sirikolo 2009; Boseto and Sirikolo 2009).

Figure 3-4 Choiseul managed areas

4 Wagina Island context

4.1 Wagina Island setting

4.1.1 Geographic

Wagina Island (also known as Vaghena) lies off the south-eastern coast of Choiseul Island,beyond Rob Roy Island, approximately 166 km from the provincial capital of Taro in the north (See

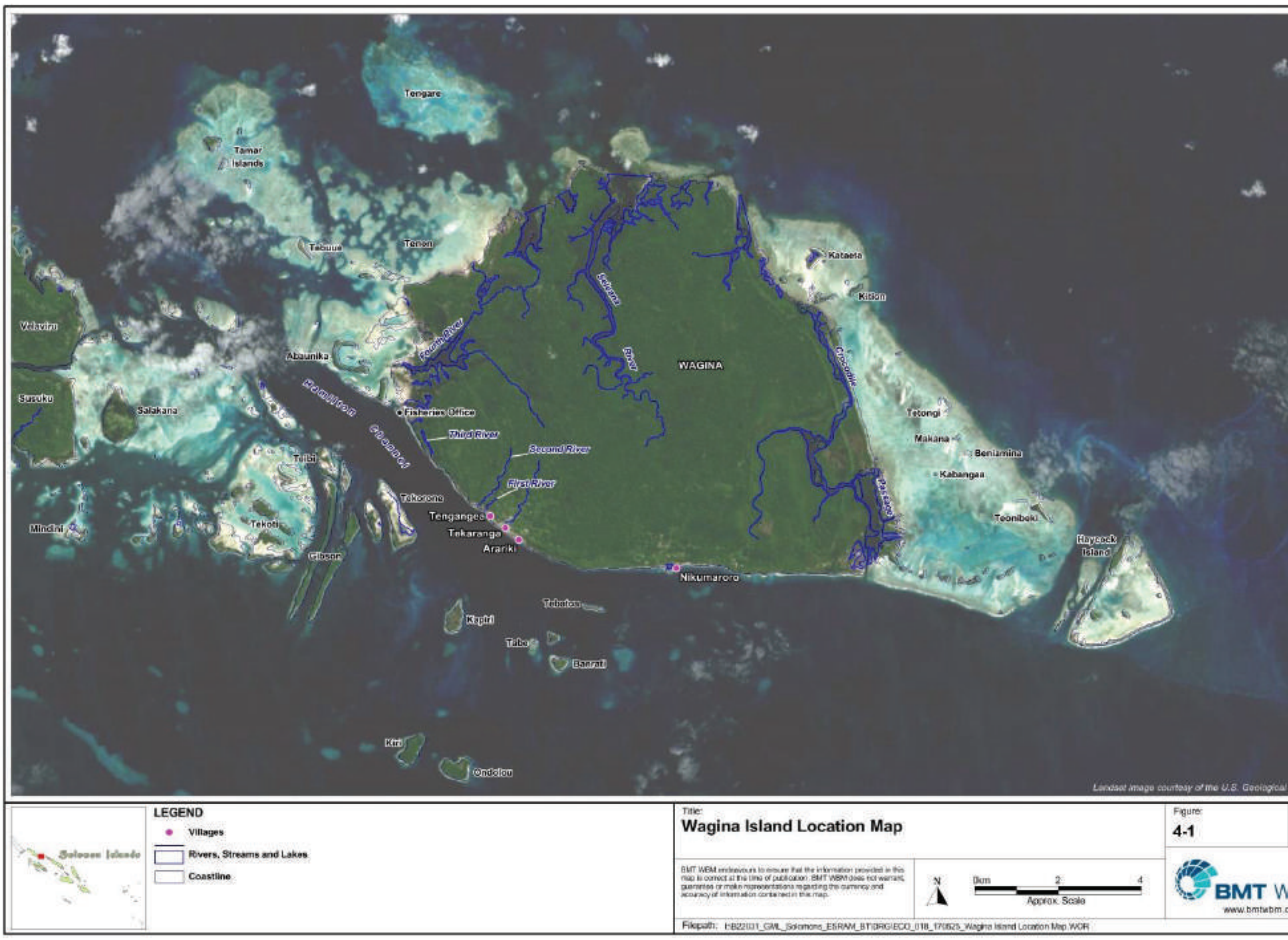


Figure **4-1**).

Measuring around 13 km in length and 9 km in width, Wagina Island has an approximate area of 82 square kilometres. It is predominantly a limestone island (i.e. emerged atoll / raised reef with karst features). It is also surrounded by several shallow marine lagoons and smaller islands/islets (>80 islands of limestone or sand geology) that are located within 6 km of Wagina Island proper.

The resident population (estimated ~2000) live in four villages situated on the southern coast of the island. They are:

- Nikumaroro
- Arariki
- Tekaranga

- Tengangea.

Note that the latter three are directly adjacent to one another and were originally a single village, Cookson (or Kukutin), which was later divided into separate villages as the population grew.

4.1.2 Cultural context

In a Solomon Islands context, Wagina is somewhat unique (together with Titiana on Ghizo Island), in that the community is primarily comprised of descendants of people who were resettled on Wagina under the Gilbertese re-settlement scheme of the 1950s and 1960s (Tabe 2011). The Gilbertese scheme was undertaken to provide new homes for the people of Hull and Gardner Islands in the Phoenix Group (now part of Kiribati), where poor soil and low rainfall had caused famines. The scheme was possible because both the Gilbert Islands and Solomon Islands were administered by Britain's Western Pacific High Commission (Solomon Islands Historical Encyclopaedia 2013).

The present day population of Wagina represents an ethnic (i-Kiribati) minority at both the provincial and national scales. They continue to use their i-Kiribati dialect as their dominant language among the community and maintain i-Kiribati culture and practices, albeit these practices have evolved over time as would be expected with exposure to external influences through:

- the different physical environment to which the original settlers were moved to;
- interactions with other Solomon Island communities; and
- modern day global influences (Tabe 2011).

Consistent with their Gilbertese roots, the people of Wagina are essentially a sea-dependent community, with the sea providing vital subsistence, economic and cultural values.

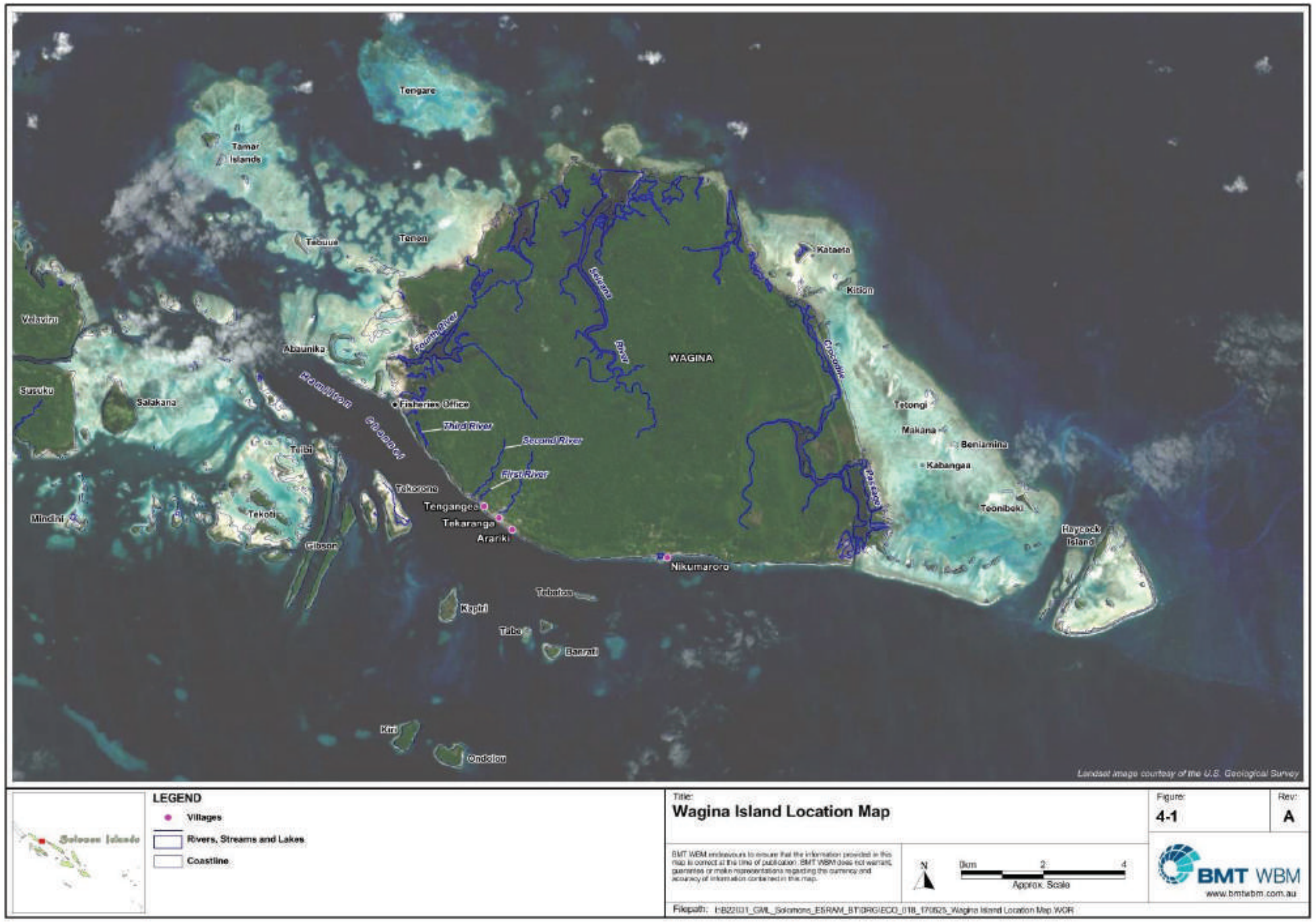


Figure 4-1 Wagina Island location map

Note that any assessment of Wagina Island needs to give due consideration to the underlying land tenure/rights for the island, and associated issues or conflicts. In the context of this ESRAM project, this will be most critical during the Ecosystem-based Adaptation (EbA) Options Assessment and subsequent implementation works. By way of brief background, the original resettlement scheme was justified on the assumption (and governmental classification) that the island was 'alienated land' since it was uninhabited at the time. Today, tenure of the island is officially split between the Wagina community and the government. However, the customary owners from southern Choiseul also claim rights to the island, as traditional owners who have maintained a connection with the land. There is further confusion among the Wagina community about the proportion of land allocated to the settlers – at the time they had thought it was the whole island, not realising a large proportion was retained as government-controlled alienated land. As of May 2017, the tenure of both the island and nearshore areas were under dispute in the Solomon Islands court (and therefore will not be discussed further).

Key socio-cultural issues for the people of Wagina are described in detail by Tabe (2011), and are generally associated with:

- changes in traditional practices, culture and moral behaviours;
- economic changes, particularly the shift to a cash economy and semi-subsistence (as opposed to a subsistence) way of life;
- land disputes, civil order and identity issues; and
- economic issues, such as access to opportunities, benefits and government assistance.

Refer to Tabe (2011) for further socio-cultural background in relation to the present-day community. Wagina Island also retains socio-cultural values for its traditional customary owners from southern Choiseul. These may have been highlighted in recent claims associated with potential mining royalties, but they are also evident through the existence of ancient shrine sites and ongoing access to the island to harvest natural resources (e.g. canoe trees).

4.1.3 Socio-economic profile

According to the 2009 census data and Kronen *et al.* 2010, the population of Wagina Island was approximately 1,500 people. There are anecdotal suggestions that the population has increased significantly since then, due to high birth rates and no birth control. Envi-Green Pacific Consultancy (2012) suggests there may be more than 2,000 residents on the island, which also indicates an increasing population.[2] While the average household size for Choiseul Province reflects the national average at 5.5, there is some evidence that this may be higher for Wagina Island (at six to eight persons per household) (Kronen *et al.* 2010 and 2009 census data).

Tribal leadership is based on a patrilineal system, where males of successive generations become the tribal head and elders of the community. Today, Wagina's community management and decision-making involves a mix of village elders and government representatives (Tabe 2011). Although both parties collectively manage the welfare and development of villages on Wagina, many elders are

[2] For the purpose of trends and drivers of change, a population of 2,000 people has been used as for Wagina Island's population until further data are available.

now deceased, resulting in an increased need for government representatives to provide management support (Tabe 2011).

The income sources for Wagina Island residents are largely limited to fishing (usually for export to Honiara) and seaweed farming. Other local income sources include small shops, salaries from government and church services, and selling handicrafts (mats), garden produce or pigs (Kronen 2010). Seaweed production has been a useful source of income for local residents and in 2005 there were approximately 300 seaweed farmers/workers on Wagina Island. However, seaweed is a low-value product and sensitive to international market developments and production costs, particularly transport costs. Furthermore, fluctuations in seaweed production between 2003 and 2009 (from a minimum of 40 to 400 tonnes of dried seaweed) were attributed to: (i) high costs and drastically reduced prices; (ii) access to financially more attractive sources of income (e.g. the opening and closing of the bêche-de-mer fishery); (iii) losses due to fish grazing; (iv) outbreaks of the filamenteous epiphyte *Polysophonia*, or 'ice-ice' caused by stress due to poor salinity and high water temperatures; and (v) loss of production sites due to sedimentation effects after a tsunami (*ibid*). These fluctuations have reduced the viability of seaweed farming and have severely affected the local industry (Kronen *et al.* 2010, and pers. comm. from Wagina Island site visit).

Province-wide data suggest that approximately 90% of Wagina Island people partake in subsistence activities such as fishing and gardening. The population is heavily reliant on subsistence activities including:

- subsistence fishing;
- cultivating garden crops; and
- collecting mangrove and plantation products (e,g, for timber and building materials, and for food and medicine).

Fish, turtles (both meat and eggs) and coconuts are reported to be the staple diet (Envi-Green Pacific Consultancy 2012) on Wagina Island. The main ecosystems on and around Wagina Island are tropical forest, lowland swamps, mangroves, coastal fringe, and the marine environment (coral reefs and lagoons). These ecosystems are utilised heavily by residents and many have unique and significant biodiversity and existence values. In addition to providing food, water and material for shelter, the surrounding ecosystems also support social activities such as cultural and traditional practices and recreation.

While commercial logging occurs on Choiseul Island, there is no commercial logging conducted by local residents on Wagina Island; non-residents engage in periodic logging but this is not well accounted for. The province more broadly is one of the last remaining areas in Solomon Islands yet to be extensively logged – if this were to change and logging were to be undertaken on Wagina Island, it would have a major impact on the local populace.

A process is currently under way for the potential development of a bauxite mine on Wagina Island (referred to in mining documentation as 'Vaghena' Island). The proponent of the mine is Solomon Bauxite Limited, which is backed by the Southwest Pacific Bauxite Group based in Australia (which has a 75% interest in the Vaghena Island project) (Southwest Pacific Bauxite 2014). Wagina is reportedly a medium grade bauxite deposit, the development of which will therefore involve mining, screening and possibly some drying prior to direct shipment to the international market (Envi-Green Pacific Consultancy 2012). The project holds tenements covering some 45 square kilometres on the eastern side of Wagina Island (over half of the total island land mass) (Southwest Pacific Bauxite, 2014). Should mining proceed, the impact on the local populace would be significant.

5 Wagina Island – ecosystems and ecosystem services

This section provides a description of the key ecosystems directly utilised by the Wagina community and additional ecosystems and/or ecosystem services (where relevant) identified by the project team. Note that the team concentrates on the former, since this report is the first known all-inclusive attempt to document the use of both land and sea resources by the Wagina community. Also, being isolated from both the provincial capital Taro and priority terrestrial conservation locations elsewhere in Choiseul, Wagina Island has largely been overlooked by the environmental literature. With the exception of works associated with the nearby ACMCA, the only known environmental assessments to have focused on the island itself are the environmental impact assessments relating to the mining development presently proposed on the island (Envi-Green Pacific 2012; Envi-Green Pacific 2013).

Further, in order to accurately document and convey the concepts and values communicated to us by the community, we have attempted to retain a similar differentiation of 'ecosystem types'. For cultivated terrestrial land, for example, the community clearly distinguishes between 'gardens' and 'plantations' in terms of the ecosystem services and management challenges for each.

First, there is an overview (Section 5.1) of the key ecosystems and ecosystem services, followed by a more detailed examination of each ecosystem / service in the subsequent sections (Sections 5.2 to 5.13).

5.1 Overview – ecosystems and ecosystem services

5.1.1 Community-derived identification

The Wagina community consistently recognised 12 main ecosystems on which they were directly dependent.

- cultivated land – gardens
- cultivated land – plantations
- rivers and streams
- mangroves
- marine lagoons
- reefs
- rocky shores
- marine (other)
- terrestrial forest
- lowland swamps
- sandy beaches and islands
- groundwater

Other ecosystems and/or services derived from elsewhere (e.g. drinking water from rainfall to rainwater tanks) were also occasionally recognised.

A map showing the spatial distribution and extent of these ecosystems is provided in Figure 5-1. Note that this mapping is to be considered indicative only, and has been derived from existing GIS data, discernment of ecosystems through remote sensing, community-derived information, and rapid field mapping (at areas of high utilisation and in the upper Seleana River). Extensive and/or detailed ground works to verify and validate ecosystem maps were not undertaken as part of this project. Lowland swamps and groundwater, in particular, are two ecosystems that are not well represented in the mapping as they are difficult to detect remotely.

The villages, and associated built-up areas and cultivated lands, are largely confined to the southern coast and some informal settlements have been established on the small islands adjacent to major seaweed farming areas. Much of Wagina Island's land area is uninhabited and ecosystems generally remain in good condition, devoid of major habitat modification or degradation.

Table 5-1 lists the ecosystem services for each ecosystem, as identified by the Wagina community. The relative frequency that each ecosystem service was identified at each village consultation is also provided as an indicator of the importance of that service (and associated ecosystem), as perceived by the local community. Based on this indicator, the essential ecosystem and/or ecosystem services on which the community is most reliant are listed below.

- Cultivated lands (especially 'garden areas') for the provision of food
- Fishing grounds around marine reefs and lagoons for the provision of food (for both domestic consumption and small-scale commercial trade)
- Ecosystems providing timber and other building or house materials (i.e. timber from mangroves and terrestrial forests, other materials from sago palm, coconut and pandanus plantations)
- Marine lagoons for supporting the main commercial industry, seaweed farming
- 'Water sources' for the provision of water for drinking and domestic uses (includes groundwater, freshwater springs and streams)
- Both pandanus and coconut plantations for the provision of multiple products (i.e. building materials, food, toddy, medicine)
- Lowland swamps for food security during times of food shortages, especially for supporting the production of giant swamp taro, *Cyrtosperma chamissonis* (also known locally as *babai* or *kakake*)
- Sandy beaches and reefs for the provision of building materials (i.e. sand, gravel, coral rock)
- Rivers and the seashore (relied on heavily for waste disposal/dispersal and sanitation)

It can be seen in Table 5-2 that some broad ecosystem services/products, such as building materials or food, are sourced from a wide variety of ecosystems. In contrast, some ecosystems services/goods are more specialised, often associated with only two ecosystems (e.g. drinking water sources; marine lagoons supporting commercial seaweed farming). This is important in the context of climate change adaptation, as there may be limited alternative sources for some ecosystem services if the original source ecosystem is undermined.

Areas of direct community utilisation of land and sea resources are shown spatially in Figure 5-2. Generally, the community accesses and uses the full range of ecosystems on and immediately surrounding Wagina Island, occasionally venturing further afield (such as to Arnavon Islands). In brief, all cultivated lands and marine lagoons and reefs, particularly those in closest proximity to the villages, appear to be intensely utilised. The Fourth River and Crocodile Passage are the most intensely used mangrove areas for the provision of mangrove-derived timber and food. Hunting activities are spread across a large area of the island’s interior, and are therefore considered to be a low intensity activity in the terrestrial forests. Relatively intensive harvesting (in the context of the area and regeneration time of the resource) occurs for timber for canoes, mostly in proximity to the Seleana River and major estuaries.

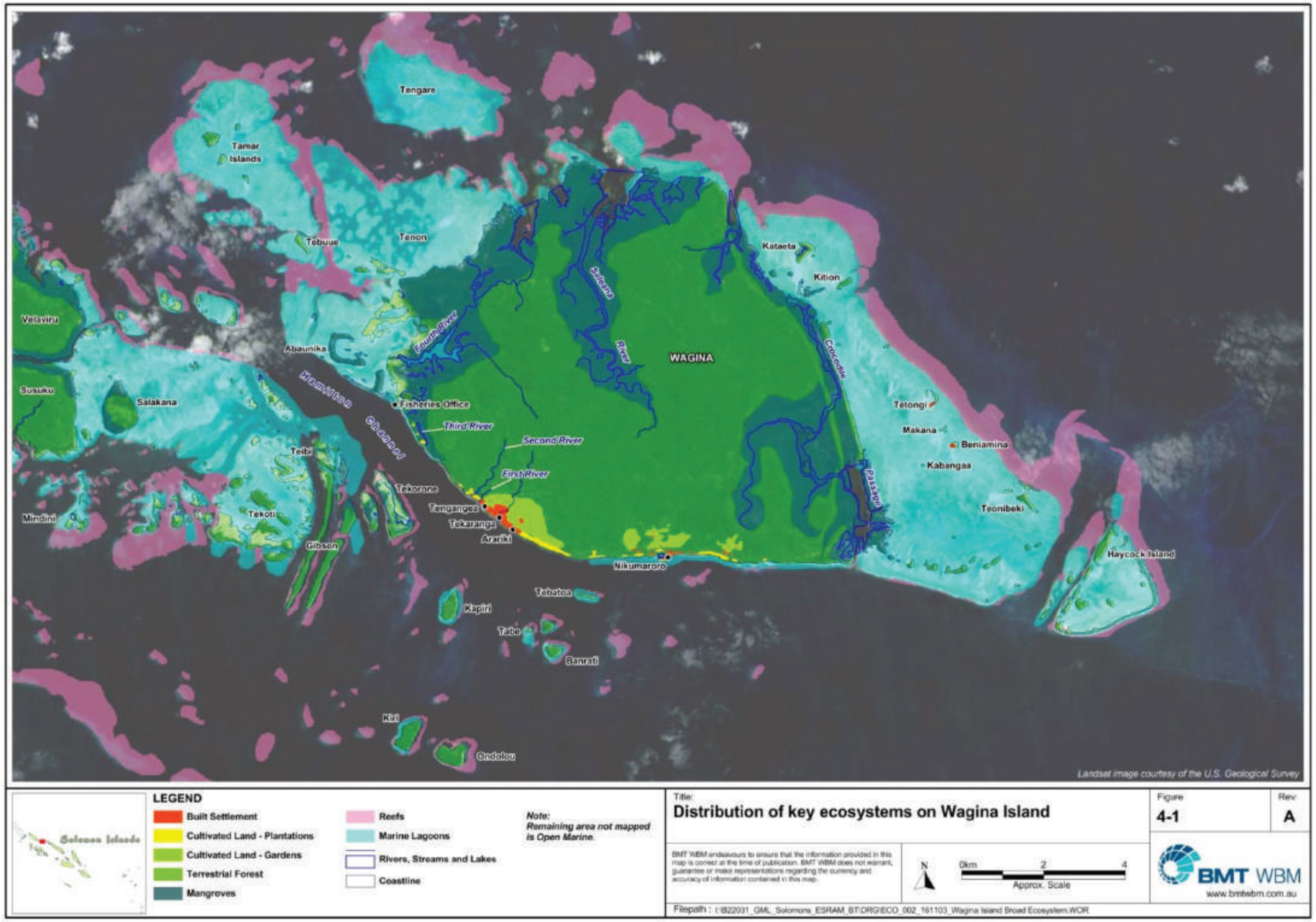


Figure 5-1 Distribution of key ecosystems on Wagina Island

Table 5-1 Inventory of ecosystems and ecosystem services identified by Wagina community (✓ denotes the frequency of each ecosystem service identified at each village)

Ecosystems	Key Ecosystem Services identified by Wagina Island community	Frequency of identification by each village (four groups per village)			
		Nikumaroro	Arariki	Tekaranga	Tengangea
Terrestrial forest	Hunting ground for food (pigs and other terrestrial fauna)	✓✓	✓	✓✓✓✓	✓✓✓
	Timber source - building materials	✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓✓
	Timber source - canoe trees / canoe making	✓	✓✓	✓	✓✓✓
	Timber source - fuelwood / firewood		✓		✓
	Timber milling area			✓	
	Toilet place			✓	
Lowland swamps	Sago palm (food and building materials)	✓✓		✓✓✓	
	Timber milling area			✓	
	Babai / kakake swamps (*Cyrtosperma chamissonis* or giant swamp taro – food security, food source during shortages)	✓✓✓	✓✓	✓✓✓✓	✓✓✓✓
Gardens	Garden food source (fruit and vegetable crops primarily for domestic use, e.g. banana, papaya, cassava, sweet potato, taro)	✓✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓
	Sup sup garden (raised domestic vegetable garden by house)			✓	
Sandy beaches and islands	Sand and gravel for building material, includes coral rubble on beaches)	✓✓	✓	✓✓✓	✓✓
	Canoe/boat landing		✓		
	Food source (coconut crab and megapode)				✓
Other substrates	Rocky shores	✓			
Rivers, streams and freshwater springs	Canoe landing (1st an 2nd Rivers)			✓	
	Water source (drinking, washing, cooking, other)	✓✓✓	✓✓	✓✓✓✓	✓✓✓
	Toilet place and waste disposal area		✓✓	✓✓✓	
	Washing area			✓	
	Stream side gardens (e.g. banana)		✓✓		
	Timber source (accessible)		✓✓	✓✓	
	Food source (fish, shells)				✓

Ecosystems	Key Ecosystem Services identified by Wagina Island community	Frequency of identification by each village (four groups per village)			
		Nikumaroro	Arariki	Tekaranga	Tengangea
Mangroves	Timber – building materials, seaweed farms, fuelwood / firewood	✓✓	✓✓✓	✓✓✓	✓✓
	Fishing grounds – food source	✓			
	Mangrove shells (bivalve molluscs – food source)	✓✓	✓✓	✓✓	✓✓✓✓
	Other food (mud crabs, mangrove fruit)		✓	✓✓	
	Timber – export to Honiara		✓		
Marine lagoons	Fishing areas – food source and small-scale commercial/trade	✓✓✓	✓✓✓✓	✓✓✓✓	✓✓
	Seaweed cultivation areas / source of primary industry and employment	✓✓	✓✓✓✓	✓✓	✓✓
Groundwater	Water supply (drinking, washing, cooking)	✓	✓✓	✓	
Reefs	Fishing (e.g. trochus, fish, turtle, beche-de-mer, crayfish), food source and small-scale commercial/trade	✓✓✓	✓✓✓✓	✓✓✓	✓✓
	Coral source – lime (for chewing betel nut) and coral rock harvest for building material	✓	✓✓		
Marine (other)	Turtle marine products – food source and small-scale commercial/trade	✓			✓
	Fishing (shark) – food source and small-scale commercial/trade	✓	✓		✓
	Medicine (e.g. seaweed)			✓	
Terrestrial (Pandanus)	Building material (leaves for weaving mats and baskets)	✓		✓	✓✓✓
	Medicine	✓✓			✓✓
	Traditional costumes	✓			✓
	Food source (pandanus fruit)	✓			
Terrestrial Plantations	Betel nut plantation – small-scale commercial			✓	
	Coconut (food, toddy, building materials?)	✓✓✓✓	✓✓	✓✓✓	✓✓✓✓
	Sago palm, cocoa				✓✓✓
Terrestrial (other)	Medicine	✓	✓	✓✓	
	Roads for human transport/access	✓			
	Coconut crab (food source)		✓	✓	

Ecosystems	Key Ecosystem Services identified by Wagina Island community	Frequency of identification by each village (four groups per village)			
		Nikumaroro	Arariki	Tekaranga	Tengangea
	Land for housing, market area, recreation			✓	
Seashore	Swimming/recreation			✓✓	
	Fish cleaning		✓		
	Toilet place		✓		✓
	Anchorage		✓		
Other	Rainfall (drinking water)		✓		

Table 5-2 Summary of ecosystem sources for key ecosystem services

Key Ecosystems	Food (land)	Food (sea, river)	Water (drinking)	Water (other)	Building materials	Fuelwood	Timber (other)	Mats and other materials	Toilet/sanitation	Transport service	Waste disposal	Industry (seaweed)	Industry (other) / commercial	Medicine	Recreation
Terrestrial forest	✓				✓	✓	✓		✓				✓		
Lowland swamps	✓				✓										
Gardens	✓												✓		
Sandy beaches and islands	✓				✓					✓					
Other substrates					✓										
Rivers, streams and freshwater springs	✓	✓	✓	✓	✓	✓			✓	✓	✓				
Mangroves		✓			✓	✓	✓					✓			
Marine lagoons		✓										✓	✓		
Groundwater			✓	✓											
Reefs		✓			✓								✓		
Marine (other)		✓											✓	✓	
Terrestrial (Pandanus)	✓				✓			✓						✓	
Terrestrial Plantations	✓				✓			✓					✓		
Terrestrial (other)	✓				✓					✓				✓	✓
Seashore									✓	✓	✓				✓
Other (rainfall)			✓												

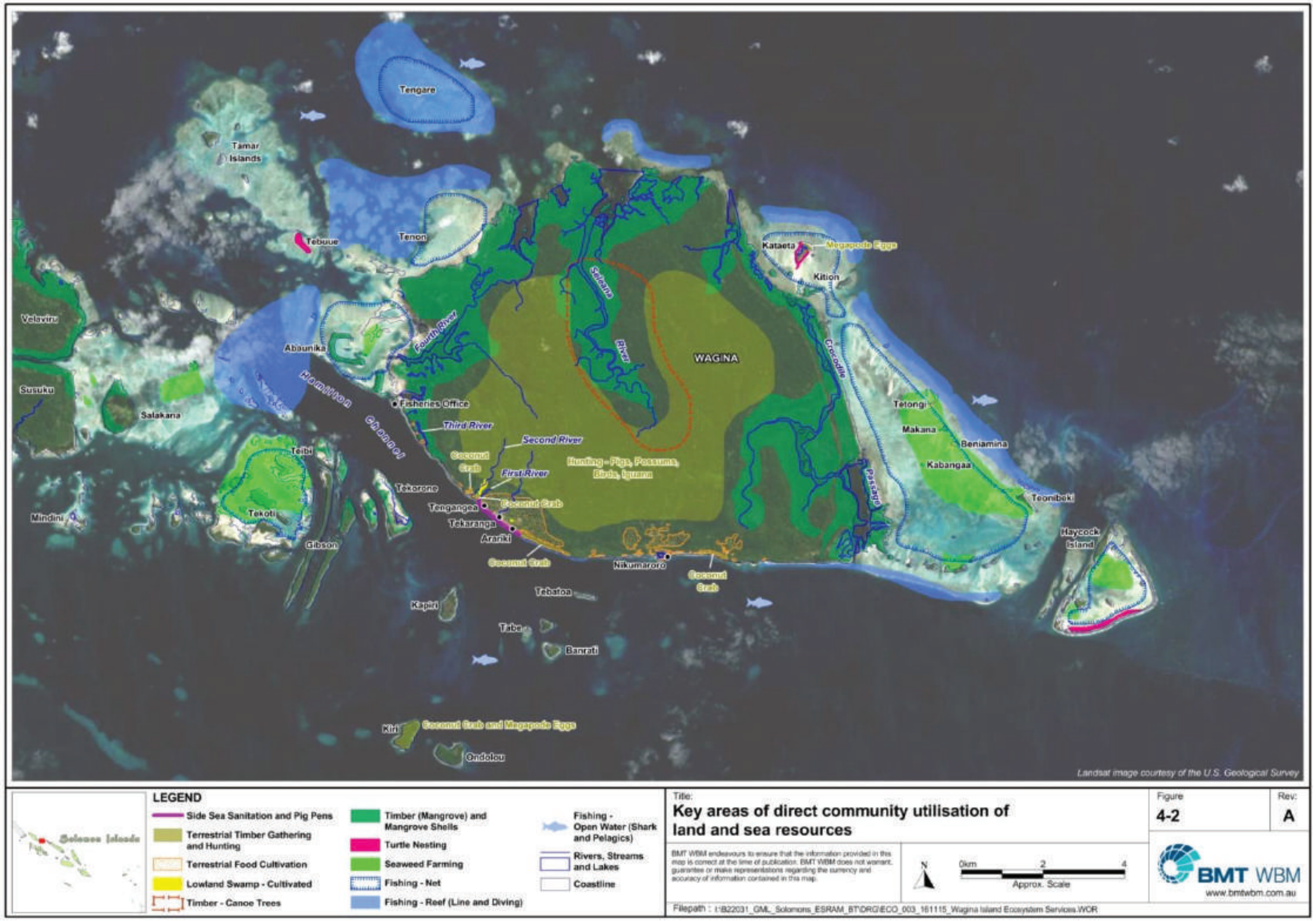


Figure 5-2 Key areas of direct community utilisation of land and sea resources

5.1.2 Additional ecosystem services identification

Most of the ecosystem services recognised by the Wagina community would be classified as provisioning services (i.e. the provision of food, water and raw materials). In addition to these , there were a number of additional services not accounted for. These include regulating, habitat and cultural services, which have been listed in general terms in Table 5-3, based on a study by de Groot *et al.* (2012) which builds on over 320 publications (and incorporates over 655 value estimates for ecosystem services). The services listed apply differently to the various ecosystems, and often apply to multiple ecosystems. For example, maintenance of habitat connectivity would apply to multiple ecosystems. In this manner, they also represent bundled or aggregated ecosystem services, e.g. raw materials could include rocks, wood, leaves and sand, depending on the ecosystem type. Ecosystems that provide multiple ecosystem services, particularly those that are critical services (i.e. provision of water and food), are considered crucial to the resilience of the Wagina community.

Note that the list of services in Table 5-3 was applied across different ecosystems (where relevant) during the economic valuations, in order to fill gaps where services were not identified by the local community. This approach was taken in order to: (i) adopt local residents' description and understanding of ecosystem services first; (ii) minimise gaps in the ecosystems services (as per the total economic value approach); and (iii) to avoid duplication. A table of ecosystems, services and value estimates from de Groot *et al.* (2012) can be seen in Appendix B.

Table 5-3 General ecosystem services (adapted from de Groot *et al*. 2012)

Service category	Service
Provisioning services	Food
	Water
	Raw materials
	Genetic resources
	Medicinal resources
	Ornamental resources
	Supporting industry
Regulating services	Air quality regulation
	Climate regulation
	Disturbance moderation
	Regulation of water flows
	Waste treatment
	Erosion prevention
	Nutrient cycling
	Pollination
	Biological control
Habitat services	Biodiversity
	Nursery service
	Habitat connectivity

Service category	Service
Cultural services	Aesthetic information
	Education
	Recreation
	Inspiration
	Spiritual experience
	Cognitive development

It is one thing to identify ecosystem services, but in order to make an assessment of the effects of climate change (or other changes/threats) to ecosystem services, it is essential to recognise the underlying ecosystem components and processes that give rise to a particular ecosystem service. For garden crops, for instance, what are the underlying ecosystem components and processes that support the service of food provision, and how would each of the components and processes be affected by a given climate change impact? In this example, one needs to consider the effects of climate change on other non-provisioning ecosystem services (e.g. nutrient cycling, pollination, soil erosion prevention), as well as other environmental processes (e.g. water flows, biological competition between cultivated and weed species.).

Key ecosystem services typically requiring consideration (depending on the ecosystem service being assessed) include, but are not limited to:

- regional climate and hydraulic processes – tides, storm surges, wind stresses and potential sea-level rise;
- geology and geomorphology – including both fluvial (land-based) geomorphology and coastal processes, such as erosion and accretion;
- freshwater flows;
- nutrient and carbon cycling;
- groundwater resources and interactions between groundwater and other ecosystem components (e.g. surface water, geology, marine waters); and
- biological processes – including primary productivity, carbon cycling by bacteria, zooplankton grazing, bioturbation and other fauna interactions (competition, predation, reproduction).

Needless to say, ecosystem services are often dependent on complex interactions between biological, physical and chemical ecosystem processes. Further, predicting the effects of particular climate change impacts can be difficult, particularly if the underlying ecosystem components/processes are likely to respond differently (e.g. a climate change impact may be beneficial to one underlying environmental process and detrimental to another).

5.2 Cultivated land – gardens

5.2.1 Description of ecosystem and ecosystem services

While in a highly modified state through human cultivation, subsistence food gardens represent the terrestrial ecosystem type most highly valued by the local community. Gardens are essential for food provision, with the community being solely reliant on their local subsistence produce for their fruit and vegetable needs. As stated by a workshop participant at Nikumaroro, *"Gardening is one of our main sources of food – all of us depend on garden food."*

Food gardens on Wagina Island include domestic fruit and vegetable crops (e.g. orchards, root vegetable patches) located either by houses or in dedicated agricultural – 'garden' – plots. These dedicated agricultural plots encompass much of the land immediately surrounding each village (Figure 5-1).

Staple vegetable crops include sweet potato, cassava and taro. They are often grown in dedicated monoculture plots (Figure 5-3). Gardens located around houses (i.e. within the village) are more commonly comprised of a mixture of various vegetables and/or fruits (Figure 5-4). Plant foods found around each village, and not necessarily in dedicated garden plots, include: a) breadfruit; b) betelnut – *korokua*; d) banana; e) paw paw; f) mango; and g) noni tree - *te noni* (Figure 5-5).

The heavy reliance on food gardens is not found in the Mataki *et al.* (2013) findings, in which Wagina residents were reported to be heavily dependent on food bought from shops. A possible reason for this inconsistency is Wagina's reduced seaweed production and income generation by seaweed farmers since 2013 and the associated shift to subsistence-based living to compensate for the reduced income generation. Another possible reason is the reduction in garden cultivation during peak seaweed production, as more households and family members participated in seaweed farming.

a) b) c) d)

Figure 5-3 Staple garden vegetable crops: a) sweet potato, b) cassava, c) greens, d) taro

Figure 5-4 Example of mixed produce (pumpkin, swamp taro, betel nut) garden in vicinity of houses at Nikumaroro

Figure 5-5 Staple garden fruits: a) paw paw, b) bananas

In addition to their primary service of food provision, gardens (particularly those in the villages) also provide a source of *kastom* medicines derived from plants such as noni and pandanus. The community identified the following as key *kastom* medicine sources: *te noni, te mao, te ango, te uri, te kaina, te nii*.

Resources from gardens (e.g. soil, propagules) may also be used to develop smaller gardens, which are small elevated garden beds. They are usually located near houses and used for growing smaller sized vegetables, such as spring onions, tomatoes, Chinese cabbage and various Asian greens (Figure 5-6).

Figure 5-6 ***Sup sup* garden, Tengangea village**

Small coconut trees among the village gardens are used to supply 'toddy', which is the sweet sap collected from a branch where the coconut fruit has been cut off (Figure 5-7). Toddy has a range of uses, such as for making sweet drinks, an alcoholic drink through fermentation, and boiled confectionary.

Figure 5-7 **Toddy collection**

5.2.2 Key threats

The local community identified the following as the key existing threats and concerns for gardens.

- Destruction by feral and other animals (wild pigs, chickens, megapode birds), noting that wild pigs are the worst offenders. Communities are starting to focus on protecting gardens from wild pigs through measures such as trapping and guarding gardens.
- Native vertebrate fauna use the gardens as a food source, particularly birds – parrots and flying foxes that favour fruit trees.
- Insect pests pose a high risk to cassava, potato, taro (e.g. taro beetle) and are a major management concern if they become well established. Moreover, the projected increase in temperature from climate change is likely to heighten the risk of food crops becoming more susceptible to pests.
- Anti-social behaviour in the form of stealing garden produce. This may become exacerbated by population growth, times of low food supply and limited land availability for gardens to expand to accommodate a growing population.
- Drought. This results in limited water availability for watering gardens, poor soil condition, dry soil and an increased risk of soil erosion, and hot weather/temperatures (i.e. garden plants stressed from heat and/or water loss).
- Heavy rainfall events and storms. These result in flooding, water-logging of garden ground and direct destruction of gardens.
- Excessive weed growth. This can dominate garden crops.
- Lack of knowledge on good farming practices. This results in issues such as soil overuse and reduced soil fertility.
- Increasing demand on gardens through population growth and limited opportunity for garden expansion. This can result in reduced fallow periods.

5.3 Cultivated land – plantations

5.3.1 Description of ecosystem and ecosystem services

When considering cultivated lands, plantations are seen by the local community as a distinct ‘ecosystem’ to the gardens (above). This is largely due to plantations being mainly comprised of different plants, providing different ecosystem services, and subject to some different threats. Plantations cover a large proportion of the southern coast, encompassing much of the land to the west of Tengangea, between Arariki and Nikumaroro, and extending eastward again from the other side of Nikumaroro. They also occur as dedicated plots in and around the villages.

Plantations are mainly dedicated to the cultivated tree crops that the community is reliant upon, including pandanus *Pandanus* spp., coconut *Cocos nucifera*, betel nut *Areca catechu,* and sago *Metroxylon solomonense* (Figure 5-8). Other plantation crops occur in small isolated areas including, cocoa *Theobroma cacao* (note that while cocoa was originally planted as a commercial endeavour it was not successful since the appropriate equipment and knowledge to harvest and process it properly was not available).

These plantation plants are very versatile in the range of services that they provide to the local community, especially as an essential source of building materials, fibres, food and *kastom* medicine. Of the plantation plants, pandanus (*Pandanus* spp.) appears to be the most highly valued. As one resident from Nikumaroro stated, *"Pandanus is very important to us – we use its leaves for weaving mats, baskets and dancing costumes. Its roots are very important for* kastom *medicine and fruits provide food."*

Betel nut is primarily grown for commercial purposes, to sell both locally and in Honiara. There appears to have been an increased effort to establish betel nut plantations in recent times.

In contrast, pandanus, coconut and sago are relied on by most households for:

- housing materials – sago leaves in particular provide the main source of material for thatched roofing and walls (Figure 5-9);
- provision of fibres for housing supplies (e.g. coconut and pandanus leaves for weaving mats, baskets and costumes (Figure 5-10); and
- direct provision of food (i.e. sago, coconuts, pandanus fruit).

There are also indirect food provisioning values associated with these plantations, such as land crabs. Land crabs are commonly harvested on Wagina and it is suggested that the 'land crab season' is more frequent than elsewhere in Solomon Islands, usually occurring around five days after the full moon every month (elsewhere land crab season is typically just once a year around December). Land crabs are usually harvested among the plantations, away from village disturbances. The largest land crab, the coconut crab (*Birgus latro),* (listed as vulnerable on the IUCN Red List but amended in 1996 to 'data deficient') is still present on Wagina and nearby islands.

In terms of plantation condition, it was noted (during the Wagina Island site visit) that many of the existing coconut plantations are quite old, having been established 50–60 years ago. Anecdotal evidence suggests that the aging trees in these plantations are no longer at optimum productivity and produce a lower yield of fruit than do the younger trees. There was no evidence to suggest that new coconut trees were being planted to compensate for the existing aging coconut plantations.

Figure 5-8 Main plantation crops: a) pandanus *Pandanus* spp., b) betel nut *Areca catechu*, c) sago palm *Metroxylon solomonense*, d) coconut *Cocos nucifera*

a)

b)

Figure 5-9 House roofing maintenance

a)

b)

Figure 5-10 Weaving mats from: a) pandanus and b) coconut leaves

5.3.2 Key threats

Both common (i.e. shared) and unique threats were identified for each plantation type, the unique threats arising in part from their different uses and geographic locations. Both common and unique threats are summarised below.

Common

- Further development encroaching on plantations directly or causing indirect effects (e.g. proposed mining development, expansion of village residential areas)
- Extreme climatic events, such as cyclones, which can cause destruction of coconut and sago palm plantations (and noting that the aging/tall coconut plantations are particularly susceptible to cyclonic winds)
- Sea-level rise and the risk to plantations in low-lying coastal areas
- Lack of knowledge on improving cultivation and associated management practices (e.g. sustainable resource use)

Coconut

- Cutting of young coconuts, whole trees (without replacement), or removing coconuts for toddy collection (can also include unlawful cutting, i.e. theft)
- Coconuts along, or in close proximity to, the shoreline are prone to coastal erosion, especially major event-driven erosion from cyclone and storm surge. This is of particular relevance to coconuts in the vicinity of Nikumaroro, where sandy shorelines are more common. It may also be exacerbated by unwise sand and gravel extraction along sandy shorelines.
- Pest damage from coconut beetle, Polynesian ship rats and birds
- Increasing demand on resources provided by coconut plantations as human population increases
- Aging plantations needing replacement with younger trees for improved resilience and productivity
- It was suggested that coconut productivity is vulnerable to temperature extremes, whereby increased temperatures can cause some trees to produce less/no fruit.

Pandanus

- Pandanus roots are cut and removed for medicinal purposes. Excessive cutting of the roots can undermine plant health and stability.
- The community is heavily reliant on pandanus and it was suggested that there may be insufficient supply to meet community needs, which will increase with population growth.
- Cutting of tall pandanus trees for medicinal purposes (i.e. cutting through trunk and leaving only the roots and lower trunk in place) undermines tree health, as well as plantation viability if replanting does not occur.

Sago

- Saline intrusion to sago plantations grown in or around lowland swamps (refer to Section 5.6 for further discussion).
- A high dependence on sago leaves for housing materials can lead to excessive cutting of leaves, which may stress the plant (i.e. cutting leaves quicker than they can be replaced, noting that sago palms grow relatively slowly). This threat will likely intensify with ongoing population growth.

Fauna resources

- Anecdotal evidence suggests that coconut crabs are particularly susceptible to overharvesting. Employing sustainable harvesting practices as demand increases with human population growth will be needed to ensure the long-term resilience of the species.

5.4 Mangroves

5.4.1 Description of ecosystem and ecosystem services

Mangroves are one of the major forest types on Wagina, contributing to approximately 41% (3,370 ha) of total forest cover. They are the dominant vegetation type around the coastal fringe, with the exception of the rocky intertidal shore along the southern coastline (i.e. in the vicinity of the villages). They also characterise the extensive estuarine systems present, particularly Crocodile Passage and Seleana River.

With the exception of localised areas of natural or anthropogenic disturbance, mangroves were generally found to be in excellent condition (Figure 5-11 and Figure 5-12). This appeared to be particularly true for the mangroves located a greater distance from human habitation and or high-use areas. Localised areas of mangroves in poor condition tend to be associated with areas of concentrated human use (e.g. harvesting mangrove timber) and areas of presumably natural prolonged inundation and drainage alteration. These are discussed further in the following section about key threats.

The mangrove communities of Wagina Island tend to be dominated by species of *Rhizophora*, *Bruguiera*, *Lumnitzera*, *Xylocarpus*, and *Soniaratia*, along with *Nypa fruticans*. Examples of some of these mangrove types are shown in Figure 5-13.

a)

b)

Figure 5-11 Mangrove communities in good condition along the Seleana River: a) downstream and b) midstream

Figure 5-12 Example of old growth mahogany (*Xylocarpus* sp.) mangroves in the upstream reaches of Seleana River

Mangrove ecosystems are highly valued by the people of Wagina. They supply timber, which is usually the preferred and most accessible source of timber for housing, seaweed farm stakes and drying tables, meeting houses *(maneaba)* and fencing pig pens because it is durable in saline environments and often small enough to avoid the use of a chainsaw. The local community indicated that the mangroves they refer to as *te tongo-buangui* and *te tongo-roro* are commonly used for housing (Figure 5-14). Mangrove timber is also sent for sale in Honiara as a means of income generation.

In addition to timber supply, mangroves are a common source of firewood for cooking, and also provide food. The main food types sourced from mangrove ecosystems on Wagina Island are listed below.

- Mangrove shells (bivalves) – most notably the mangrove cockle (*Polymesoda erosa – te toa),* but also mangrove oysters (e.g. those referred to locally as *te pukikakang* and *kaintaibora,* as well as *Pinctada* spp. and *Crassostrea* spp.) – see Figure 5-15. Note that *te toa* are important to food security, providing a key protein source during food shortages (e.g. following cyclones).
- Mud crabs (*Scylla serrata*), various fish, crocodile *Crocodylus porosus,* and birds (e.g. herons, pigeons)
- Mangrove fruit, which is a relatively recent introduction to their diet, introduced by people from elsewhere in Solomon Islands.

The community also acknowledged that mangroves provide regulating and habitat ecosystem services in the form of providing the essential habitat for estuarine fauna, and serving a major role in shoreline protection and stabilisation.

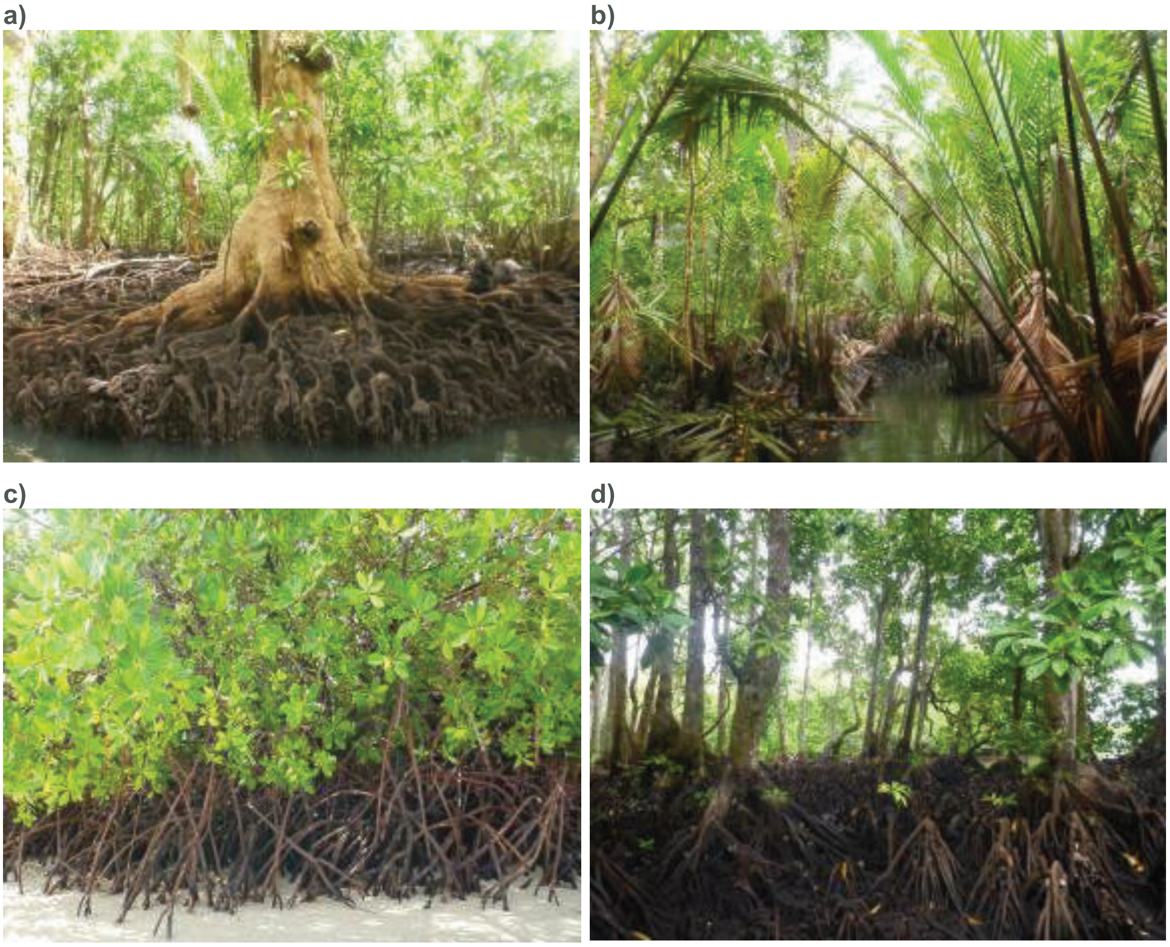
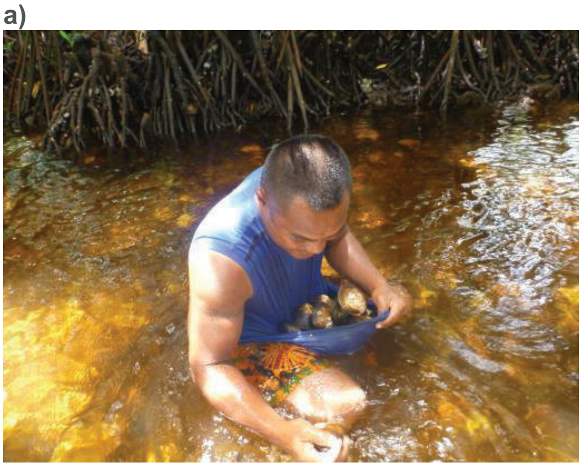


Figure 5-13 Example mangrove species dominating Wagina Island: a) *Xylocarpus* sp., b) *Nypa fruticans*, c) *Rhizophora* .sp., d) *Bruguiera* sp.

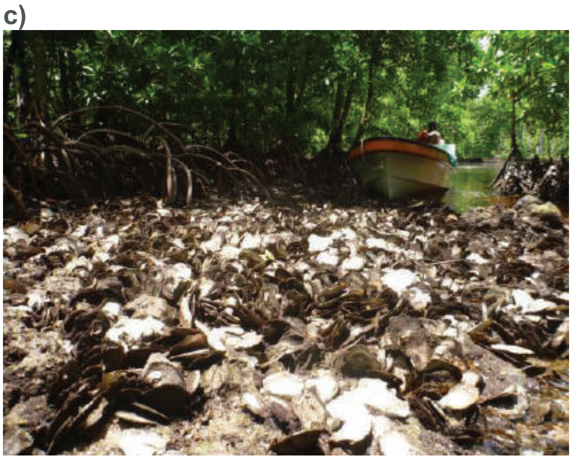
Figure 5-14 Preparation of mangrove timber for house construction or maintenance

a)



b)

c)



d)

Figure 5-15 Common large estuarine bivalve molluscs at Fourth River: a/b) collecting *te toa*, *Polymesoda* sp., c) large oyster bed, and d) mixed oysters on mangrove roots

5.4.2 Key threats

Currently, there is no active management to ensure the sustainability of resources harvested from mangrove ecosystems on Wagina Island. Consequently, over-harvesting presents a key threat, both to mangrove plants (i.e. timber and fuel source) and foods derived from mangrove ecosystems, particularly in the face of population growth, climate change and other compounding threats. Key threats identified for the mangrove ecosystems are listed below.

- Over-harvesting and concentrated clearing of mangroves (with no replanting). Such practices already appear unsustainable at localised high-use areas such as around the Fourth River (Figure 5-16). Over-harvesting can also threaten the foods sourced in mangroves (e.g. mud crabs, mangrove cockles).
- Population growth increases the demand for mangroves ecosystem services.
- Mangrove shells (bi-valves) are susceptible to desiccation and spoiling during prolonged periods of low tide when air temperatures are hot.
- Localised reclamation and channelisation for an aquaculture venture (i.e. milkfish *Chanos chanos* farming). This is presently confined to mangroves in the vicinity of First/Second Rivers (Figure 5-17). (The venture is currently on hold due to an internal family situation.)
- The proposed bauxite mine presents a major threat to mangrove communities on the eastern side of the island through clearing and contamination.
- In the context of climate change, 'coastal squeeze' presents a potential threat to mangrove ecosystems, whereby developments adjacent to existing mangroves restrict the capacity of mangroves to adapt to sea-level rise (i.e. limited opportunity to migrate up shore).
- Evolving coastlines, particularly on the smaller islands surrounding Wagina where coastlines are more dynamic, threaten mangroves through processes such as coastal erosion and altered hydrology that can cause prolonged inundation (Figure 5-16).

a)

b)

Figure 5-16 Mangrove area with a high level of clearing for timber (top), and sparse mangrove canopy at location affected by prolonged inundation

a)

b)

Figure 5-17 Loss and alteration of mangrove habitat for milkfish *Chanos chanos* farming through a) reclamation, and b) channelisation/bunding

5.5 Terrestrial forest

5.5.1 Description of Ecosystem and Ecosystem Services

Wagina Island is heavily vegetated, with tropical forest covering the bulk of the interior. Note that mangrove, lowland swamps, cultivated land and built-up village areas comprise the remaining land. The forests provide important ecosystem services for the local community (Figure 5-18), including the provision of food, fibre, timber and fuel. The ecosystem services were identified by the local community as necessary for daily life, and include:

- timber for housing and canoe-making (as emphasised by one local, *'Everyone needs a canoe!'*) (see Figure 5-19);
- food provision, primarily as a habitat for hunting land-based animals, which are important for supplementing sea-derived protein sources; and
- fuel wood (for cooking).

Forests also provide regulating and supporting services such as climate regulation, prevention of soil erosion, habitat provision, primary productivity and maintenance of stream water quality.

a) b) c) d)

Figure 5-18 Variation in terrestrial vegetation communities in village surrounds

a)

b)

Figure 5-19 Provision of timber for housing (top) and canoes (bottom)

The terrestrial forests of Wagina Island tend to be in very good condition (see the example of lowland rainforest, Figure 5-20). Degradation is primarily restricted to edge effects in the vicinity of villages, cultivated land and tracks, as well as the more accessible areas targeted for timber or timber milling. Some widespread clearing occurs from time to time, usually for the purposes of creating land for cultivation.

In terms of food provision and hunting, pigs are usually the primary target. However, the community has a versatile diet and will also opportunistically hunt possums, monitor lizards, megapodes, flying fox and birds such as parrots, pigeons (*kuru kuru*), and heron/egrets (*tikai*). These fauna may also be hunted when they enter the villages or gardens, although the forest remains their main habitat.

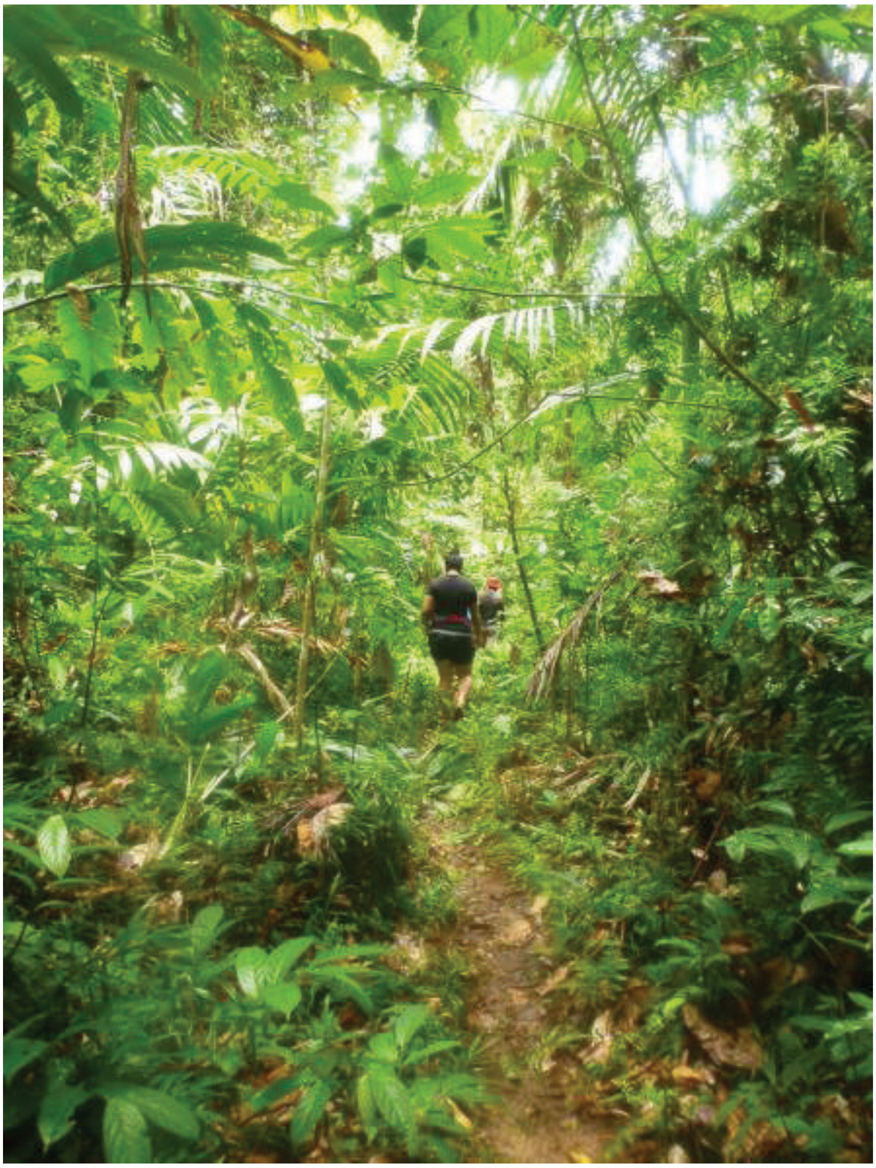


Figure 5-20 Lowland rainforest in central interior of Wagina Island

5.5.2 Key threats

The key threats identified by the community captured not only direct threats to the forest itself, but also threats to the other ecosystem components (i.e. animal food sources) that they consider to be essential resources. The primary threat is forest clearing and the risk of over-harvesting timber, particularly as the growing population places an increased demand on forest and land resources. Note that no specific management measures are in place (e.g. replanting, protected areas, recommended sustainable timber/logging practices).

There was a strong awareness among the community that some target forest trees (especially canoe trees, Figure 5-21) are getting harder to find, indicating that current practices may be unsustainable. This was accompanied by the acknowledgement that some of the target species are slow growing, and that the local human population (and associated resources requirements) may be increasing at a rate greater than tree regeneration.

Observations by the study team suggest that these concerns are well founded. In addition to the pressures on forests by the local community, the forests of Wagina are highly valued by the people of southern Choiseul Island as a source of canoe trees. At the time of the ESRAM field work, a logging group from southern Choiseul was present on Wagina Island, harvesting timber to make canoes for sale elsewhere (e.g. Choiseul, Honiara). Discussions with the logging party indicated that they tend to have two expeditions to Wagina per year, felling in excess of 200 canoe trees annually.

Other key existing or potential threats included:

- the proposed mining development, which would necessitate the widespread clearing of approximately 25% of the island’s terrestrial forest;
- deforestation, where clearing occurs to replace forests with cultivated gardens (Figure 5-21);
- extreme weather events, particularly cyclones, which can fell many trees; and
- the potential for unsustainable hunting of forest fauna (both native and introduced) as the human population grows and their resource demands increase.

a)

b)

Figure 5-21 Area cleared of terrestrial forest for replacement by garden crops (a), and canoe tree felled in interior of Wagina Island (b)

5.6 Lowland swamps

5.6.1 Description of ecosystem and ecosystem services

Freshwater lowland swamps are generally located around small surface expressions of groundwater or artificially constructed in/adjacent to streams. Lowland swamps are important for services such as flood control, shoreline protection from storm surge, and the provision of important habitat for aquatic flora and fauna. Lowland swamps are not well represented in the mapping prepared for this assessment due to a combination of their small size (sometimes only a few metres in diameter) relative to the scale of the mapping, and also from being obscured by overhanging canopies, making them difficult to detect.

Lowland swamps are primarily valued by the community as a location that provides suitable conditions for growing swamp taro *Cyrtosperma chamissonis* (*kakake, babai*). Swamp taro (Figure 5-22) is not usually consumed on a daily basis, rather it is cultivated as a means of food security for times of food shortages, such as following cyclone events.

Sago plantations are also commonly located around lowland swamps, providing an essential source of building materials, as well as food (refer to Section 5.3 for further discussion on sago plantations).

The above community uses are concentrated on the swamps located along the southern coastal fringe of Wagina Island (i.e. those most accessible and/or in close proximity to the villages).

Figure 5-22 Swamp taro (*Cyrtosperma chamissonis*) in lowland swamp west of Tengangea

5.6.2 Key threats

Key existing threats to lowland swamps and the resources provided by them are saltwater intrusion, climate effects, increasing population pressures and degradation by wild pigs and other pests.

Saltwater intrusion occurs in swamps near the coast as a result of storm surge or very high tides, and also as a result of human modification to shorelines (e.g. lowering the coastal berm through sand extraction). The incidence of saltwater intrusion is likely to increase with sea-level rise. When saltwater intrusion occurs, swamp taro can die. This is a major issue, as swamp taro can take ten years before it is ready for harvesting, so some people are now making a concerted effort to plant swamp taro further inland. Saltwater intrusion is also likely to affect the biodiversity of lowland swamps, but further information is needed to understand the species that inhabit these ecosystems.

In terms of other threats, the following is noted:

- drought and hot temperatures cause the swamps to dry out periodically;
- increasing population size may increase the demand on swamps for taro cultivation; and
- while wild pigs create the most obvious physical disturbance to swamps, but there are also other diseases and pests (e.g. beetle pest) that directly affect swamp taro plants.

5.7 Reefs

5.7.1 Description of ecosystem and ecosystem services

Wagina Island residents rely heavily on the marine environment as a source of food, as well as for seaweed farming (see marine lagoons below, Section 5.8). Furthermore, marine environments play an important role in providing regulating and supporting services, such as natural hazard protection, and sanitation and waste dispersal services. Coral reefs are a prominent feature of the local marine environment, surrounding much of Wagina Island and comprising barrier, fringing and patch reef forms (Figure 3-3).

Dedicated reef assessments were not undertaken for this assessment. However, Turak (2006) found reefs in the vicinity of Wagina Island to be in very good health. It is assumed that the reefs have remained in this good condition due to the low level of unnatural fluvial inputs. Regarding the latter, there are presently no major land-clearing activities on the island and, with the exception of Seleana River, no other major river systems to provide a source of additional sediment loads to the local reefs (i.e. beyond natural sediment inputs). Further, the community indicated that there had not been a recent increase in coral bleaching in recent months, as seen elsewhere in some parts of the western Pacific earlier in 2016 due to warm sea temperatures.

The primary ecosystem service valued by the local community is the provision of reef-based food sources, which (together with other marine-sourced foods) provide the primary protein component of the local diet. Animals sourced from, or otherwise dependent on reef habitats, are primarily used as food, but also provide an important means of income through the sale of such products at the local market, to visiting vessels and further afield at Honiara.

Key fauna targeted for consumption and/or sale include:

- reef associated fish, including sharks (see special mention of shark harvesting below), targeted via diving and line fishing;
- sea turtles for meat and turtle products; and
- invertebrates such as crayfish, trochus (*Tectus niloticus, Trochus niloticus*), clams and sea cucumbers (Note: There is now a national ban on *bêche-de-mer* harvesting. Previously, the Wagina community did not eat sea cucumbers themselves, but it was a major source of income prior to the ban and the introduction of seaweed farming).

Coral, both dead and live coral, is also harvested from the reefs to provide construction materials (e.g. coral rock for building seawalls – Figure 5-23), and lime is sold to accompany betel nut. Reefs are also locally recognised for providing coastal protection through the dissipation of wave energy, and for creating marine lagoons, which are another highly valued marine ecosystem.

Figure 5-23 Coral rock used to construct a seawall

The community has always harvested sharks and is mindful of using the whole shark (i.e. minimal wastage). Sharks also have some cultural value for the local community. For example, the ability to spear a shark is a traditional indication of coming of age for boys. Based on the observations of the study team while in Wagina, present shark harvest numbers appear to be very high and unsustainable (Figure 5-24). Discussions with local community members confirmed that the number of sharks harvested has increased significantly over the last few years. This has been driven by the need to supplement incomes when seaweed prices declined. Shark products include fresh meat, smoked/salted and dried meats, and shark fins (Figure 5-25).

Note that shark fins are particularly profitable and enticing as a source of income, fetching up to SBD 600/kg (USD 77/kg) for large sized fins. Fresh shark meat is also more popular than smaller fish at the local market, since it has a lower price per kilogram (i.e. is a cost-effective meat product).

a)

b)

Figure 5-24 Typical shark (and turtle) catches

a) b) c) d)

Figure 5-25 Preserved shark products: a) and b) smoked or salted and dried meat; c) and d) drying shark fins

Turtle harvesting is also worth a special mention, particularly in the context of local conservation efforts (Anarvon Community Marine Conservation Area – ACMCA) and the international conservation status of turtles. Green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) are the species most commonly harvested (listed as Endangered and Critically Endangered, respectively by IUCN). Some islanders suggested that turtles are opportunistically harvested, rather than the being the subject of targeted hunting, and that harvested numbers have decreased since improved awareness and the community involvement in turtle conservation directed by ACMCA. To help reduce the increased poaching observed in recent years on Sikopo Island in the Arnavons, a new ranger station is being constructed in ACMCA.

Note also that the introduction of seaweed farming as an industry for the Wagina community was specifically aimed as a deterrent to turtle poaching in ACMCA by providing an alternative source of income. Despite the combination of these measures, anecdotal evidence reports that poaching still occurs in ACMCA. During the Wagina site visit, the project team was informed by local residents that intensive turtle harvesting is undertaken in ACMCA during the ranger’s shift swap, when the ranger station is left unmanned for 24 hours.

5.7.2 Key threats

It has been suggested that over-harvesting of reef resources – even reef fish – is already evident. As mentioned by one elder at the community workshops, *'We used to get big fish near the village, now we have to fish further away.'* Trochus wasalso reported to be in less abundance.. Given the high importance of reef resources for food, unsustainable harvesting is a major concern in the face of human population growth and the increasing fishing pressure to supply food.

In addition to harvesting by the local community, there was also concern about the contribution of illegal fishing (i.e. visiting boats fishing in artisanal – 3 NM – waters without permission). This includes, for example, boats bringing cargo to the island and those fishing while in the area to collect seaweed products.

Other key threats include:

- direct physical destruction of reefs from anchors, cyclones and the collection of coral (coral rock, lime);
- the potential effects from the proposed mine development, including increased pressure on reef resources to support the mine workers and their families (estimated to double the current population of Wagina), as well as pollution in the form of sediment run-off from land-clearing and contaminant inputs;
- climate change risks such as increased sea temperature, coral bleaching, ocean acidification and damage from more frequent or more intense storms/cyclones; and
- given the poor waste management and sanitation practices on the island, there is recognition that pollution from these sources may be having an effect on the surrounding reefs and reef resources. However, the environmental responses and extent of effects is not known.

5.8 Marine lagoons

5.8.1 Description of ecosystem and ecosystem services

Extensive coral reefs form large expanses of marine lagoon areas around Wagina, particularly adjacent to the western, northern and eastern coasts (i.e. limited lagoons in close proximity to the southern coast, Figure 5-1). These lagoons are typically characterised by comparatively shallow and protected waters with sandy substrata. Small vegetated islands/islets, either sandy or limestone-based, often occur around the outer extent of the lagoon.

Seagrass meadows are common in the lagoons, particularly in the shallower waters (Figure 5-26). They provide an important fauna habitat (e.g. Figure 5-27) and ecosystem services such as primary productivity and the basis of lagoon food webs, nutrient and carbon cycling, and substrate stabilisation. Seagrass meadows in the lagoons around Wagina tend to be dominated by *Cymodocea* and *Halophila* species, as compared to seagrass meadows in more enclosed 'estuarine' waters that are dominated by *Enhalus* spp. The seagrass meadows observed during the field work for this project were in excellent condition, with a high seagrass coverage and the plants in good health (Figure 5-26). Note that, while not a major ecosystem service of the marine lagoons, seagrasses (*Halophila* spp.) are occasionally used as a source of *kastom* medicine.

a)

b)

Figure 5-26 Seagrass meadows in lagoon adjacent to the eastern side of Wagina Island

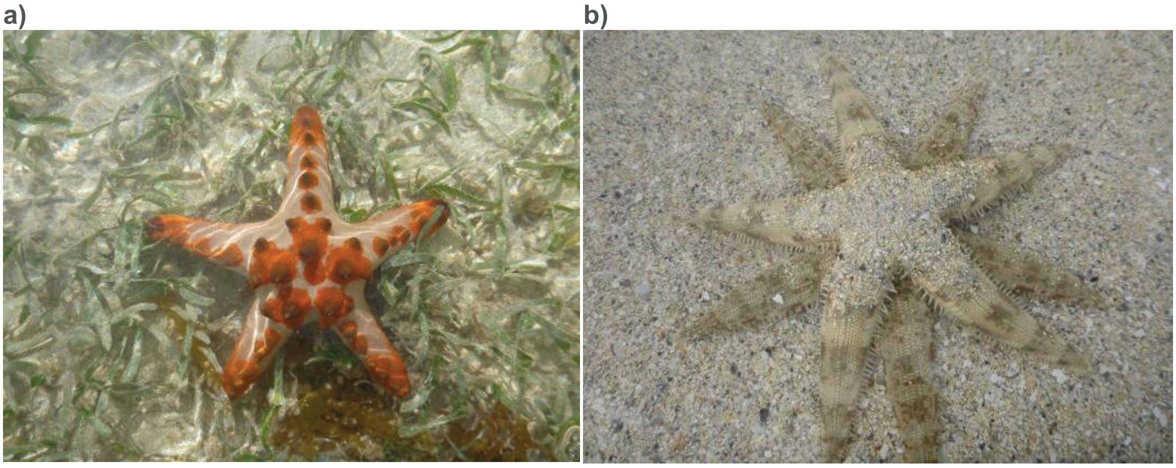


Figure 5-27 Starfish common in marine lagoons around Wagina Island: a) *Protoreaster nodosus*, b) *Astropecten* sp.

There are two main ecosystem services provided by the marine lagoons that are highly valued by the local community, namely: (i) the provision of fish as a vital food source; and (ii) the provision of an environment suitable for supporting the main commercial industry, seaweed farming.

Net fishing is the main fishing method used in the lagoons, primarily targeting species such as milkfish (*Chanos chanos*). Net fishing occurs in all major lagoon areas surrounding Wagina Island, providing a source of sustenance, as well as a source of income through commercial trade at the local market and externally at Honiara. Marine lagoons also provide other food sources, such as the green macroalgae (*Caulerpa lentillifera*), a seaweed delicacy, and other edible *Caulerpa* species.

Seaweed farming is a relatively recent introduction (commencing mainly in 2004–2005), and is the main commercial industry for the Wagina community. In fact, Wagina is the top exporter of seaweed in the country (Kronen 2010). The farms are solely located in the marine lagoons of the island and a high proportion of Wagina households are directly dependent on seaweed farming for their livelihoods (Kronen 2010).

Kappaphycus alvarezii is the species of seaweed farmed. Globally, it is one of the main commercial sources of carrageenans, gelling agents used in food, cosmetic and medical products, as well as in other industries. It is not native to the local area; the original seaweed farming trials in Solomon Islands imported this species from Fiji (Kronen 2010). Farming methods are relatively basic and involve establishing a plot, consisting of parallel ropes supported by a wooden stake at each end. Small branches of seaweed are tied at intervals along each rope and left *in situ* (Figure 5-28) to grow for three to four months before manual harvesting. It is very fast-growing and can double its biomass in 15 to 30 days in optimum growing conditions (Abbott 1999).

Once harvested, the seaweed is sorted and dried, ready for sale to the local agent (Figure 5-30). In order to undertake seaweed farming, many of the people and families directly involved stay in informal settlements on sandy lagoon islands (Figure 5-29) during the week, typically returning to Wagina Island proper once a week to attend church and restock supplies. Further discussion on informal settlements on sandy islands is provided in Section 5.10.

Figure 5-28 Seaweed farm at Wagina Island

Figure 5-29 Informal settlement on one of the larger 'seaweed islands' near Wagina Island (source: Simon Albert)

5.8.2 Key threats

In terms of threats to the ecosystem services (excluding those related to seaweed farming) particularly the provision of food sources, the key threats are very similar to those identified above for reefs, namely:

- over-harvesting of marine resources by the local community, which is likely to worsen as demand increases with population growth;
- fishing by visiting vessels contributing to over-harvesting, especially when many of these vessels are often thought to be fishing in artisanal waters without appropriate permission;
- potential impacts from the proposed mining development, noting that pollution-related effects may be exacerbated in lagoons with higher water residence times (i.e. poorer flushing as compared to reefs, for example); and
- other pollution inputs via solid waste and sanitation inputs from the community, particularly informal settlements located directly in the lagoons.

a)

b)

Figure 5-30 Fresh (a) and dried (b) seaweed product

A number of threats were also identified as being of importance to the seaweed farming industry specifically. These are summarised below.

- Cyclones are the main concern as they can completely devastate the farms. After the destruction of seaweed farms it takes approximately three to four months to rebuild and become operational again (i.e. obtain and replant seaweed, rebuild drying tables and housing while waiting for the seaweed to be ready to harvest), during which time farmers would not be receiving income.
- Similar to the above, strong currents, tsunamis and storm events can affect farms and/or cause the seaweed to detach and float away.
- Herbivory of seaweed by fish and other animals (e.g. turtles – *teokaoka, tenimnai, eon*, squid – *teriro*, *terereba*).
- The drastic reduction in seaweed prices that has occurred in recent years (i.e. down from approximately SBD 5/kg dry weight to around SBD 1.50/kg) suggests uncertainty for the industry. As mentioned in Section 5.7, this can have flow-on effects to other ecosystems and/or resources provided by other ecosystems, when the community is required to supplement their income from these other sources.
- Seaweed can be vulnerable to extreme low tides if not planted in waters sufficiently deep, and is also thought to be affected from time to time by high rainfall events and increased water temperatures.
- There is uncertainty about the potential future interactions, both environmental and socio-economic, between seaweed farming and the proposed mining development.

5.9 Rocky shores

5.9.1 Description of ecosystem and ecosystem services

While rocky shores represent the minority shoreline type in total extent (compared with the sedimentary shorelines comprising much of the island's coastline), they are the prominent shoreline type along the southern coast. This includes the village areas, especially Arariki, Tekaranga and Tengangea. Where present, the rocky shores are a limestone base, derived from raised reef (Figure 5-31).

While the rocky shores provide habitat for marine fauna and flora, such as various invertebrates, macroalgae and fish (Figure 5-32), rocky shores are not highly valued as a food source by the local community (exceptions are crayfish and fish from locations away from the villages). Rather, the primary use of this ecosystem by the local community is as a waste disposal and/or waste dispersal site for sanitation, solid waste, fish cleaning, and as an area for locating pig pens. Hence, the rocky shores are recognised as a 'dirty' (i.e. polluted, contaminated) environment that is not suitable as a source of food. Shells may be collected for other (i.e. ornamental) uses, including the varieties locally known as *kaburaerae* and *te nibanikekeva*. Waters off rocky shores are also used for recreation (swimming) and bathing.

Figure 5-31 Typical limestone shore that dominates Wagina Island's southern coast

a) b) c) d)

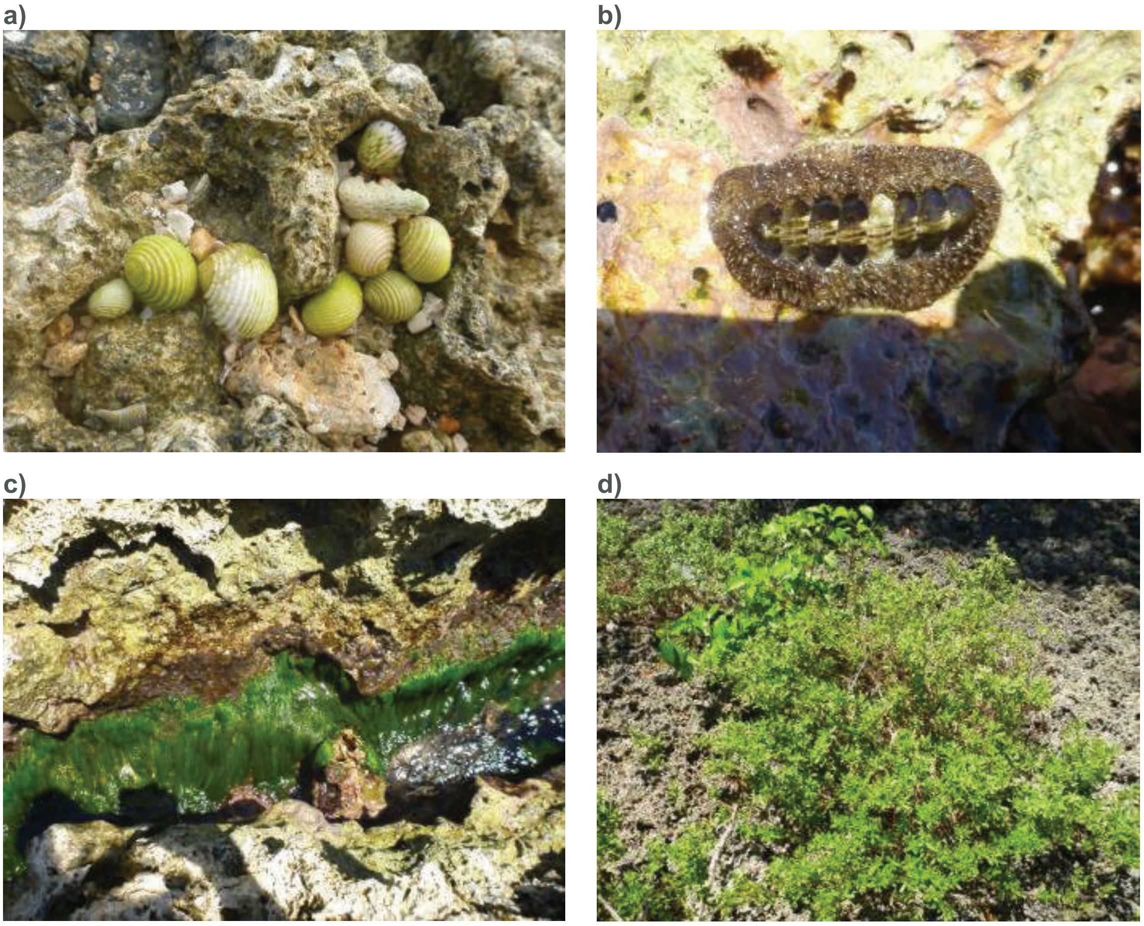


Figure 5-32 Common biota on Wagina's intertidal and supralittoral rocky shores: a) molluscs *Nerita* sp., b) Chiton *Liolophura* sp., c) mixed macroalgae, d) salt tolerant shrub

5.9.2 Key threats

The use of rocky shores is a prime example of the community utilisation of an ecosystem presenting the major threat to the ecosystem (and human) health, primarily through excessive pollution from (Figure 5-33):

- solid waste disposal (dumping rubbish), which is problematic for persistent contaminants and plastics; and
- use as a sanitation site and area for pig pens (i.e. faecal contamination and nutrient inputs).

Subtidal areas may also be damaged by anchors.

Note that rocky shores are not prone to coastal erosion in the manner that sandy shores are, so coastal erosion does not pose a major risk to villages fronted by rocky shores in the context of climate change. Rather, villages fronted by rocky shores are more vulnerable to coastal inundation via storm surge and sea-level rise.

a)

b)

Figure 5-33 Rubbish disposal and pig pens along rocky foreshores

5.10 Sandy beaches and islands

5.10.1 Description of ecosystem and ecosystem services

While much of the coastline of Wagina Island is dominated by muddy mangrove environments and rocky shores, sandy shores do occur. These include the coastline in the vicinity of Nikumaroro and small isolated sandy patches elsewhere along the southern coastline. Predominantly, however, they occur on the smaller nearshore islands and islets surrounding Wagina. Examples are shown in Figure 5-34.

Being further removed from villages than rocky shores, most sandy beaches do not appear to be as affected by solid waste disposal. Rather the more visually obvious disturbance was coastal erosion. The exception to this is the beaches and sand islands supporting informal seaweed farming settlements, which are affected by both coastal erosion and more concentrated waste disposal and sanitation use (see also Section 5.10.2).

Figure 5-34 Examples of sandy beaches and islands on and around Wagina Island

While comparatively small in land area, sandy beaches and islands tend to support a substantial variety of intertidal and terrestrial vegetation types (e.g. mangroves, coastal dune vegetation, lowland forest), which generally appear to be in very good condition (Figure 5-35).

Figure 5-35 Vegetation variety on sandy beaches and islands

Sandy beaches are most highly valued by the community as a source of sand and gravel (i.e. coral rubble), which are used in building construction requiring concrete and for other uses around the village, such as footpaths. Sand islands are most valued for their role in supplying land that can be used as a base to service seaweed farming (i.e. land for constructing seaweed drying tables and establishing farming settlements).

Other services valued by the community (refer to Figure 5-36) are listed below.

- They provide food sources on sand islands, such as coconut crabs, megapode eggs and turtle meat and eggs.
- Sandy beaches and islands have a role in supporting biodiversity and conservation efforts. This is particularly true with respect to beaches on sand islands being an essential nesting habitat for hawksbill turtles, and associated awareness through community involvement with ACMCA. Other islands off the southern coast of Wagina have also been identified by the

community as potential locations for future conservation endeavours, such as marine protected area(s) to support sustainable fisheries management. The frequent harvesting of turtles for their meat and eggs has, however, detrimental effects on these conservation efforts (see below).

- Sandy shores have a role in coastal protection and the prevention of saline intrusion (refer to saline intrusion of lowland swamps, Section 5.6).
- Sandy shores provide safe boat or canoe landing areas.

Figure 5-36 Sandy beach and island uses: gravel collection (a), land for farming settlements (b), land for seaweed drying tables (c), boat/canoe landing area

5.10.2 Key threats

Key threats for identified for sandy beaches and islands were primarily associated with coastal erosion and the over-reliance on small, localised areas for the extraction of sand and gravel. Specific concerns included (Figure 5-37, Figure 5-38):

- existing coastal erosion through cyclones, storm and rough seas;

- potential future exacerbation of coastal erosion through climate change effects (e.g. sea-level rise, increase in the frequency or intensity of cyclones);
- uncontrolled or excessive removal of sand and gravel from beach for construction purposes, without allowing the sand/gravel source to recover;
- clearing of vegetation on sand islands and the potential flow-on effects to food sources harvested on islands, as well as the over-harvesting or inappropriate harvesting of these food sources (e.g. collection of undersized fauna); and
- modification of sandy shores through foreshore protection works and the construction of built structures such as seaweed drying tables (and whether such foreshore works will adversely affect natural shoreline processes).

a) b) c) d)

Figure 5-37 Foreshore protection works (a), sand island vegetation clearing (b), reclamation and sanitation works at farming settlement (c), built structures traverse beach (d)

Figure 5-38 Coastal erosion and a small seawall along the sandy foreshore at Nikumaroro Village

In considering both existing and future threats, it is important to note that sandy shores are naturally highly dynamic environments that undergo processes of sediment erosion and accretion. This is illustrated in Figure 5-39, which shows changes in islet morphology in the lagoon on the eastern side of Wagina Island over a relatively short time frame (2010 to 2013).

Even in the absence of climate change, the implications of this high dynamicity are that the construction of built structures in this environment can be risky in terms of coastal erosion and the effort that may be required to protect, maintain and/or relocate such structures over time.

In the context of climate change and sea turtle beach use, particularly the hawksbill turtles nesting around Wagina and ACMCA, it is noted here that a unique climate change effect on turtles (and other animals with nest temperature-dependent sex determination, e.g. saltwater crocodile) is the effect of increased sand temperatures on nesting outcomes. It is predicted that hotter temperature from climate change will cause an increase in the proportion of female hatchlings and ultimately decrease the population growth rate. Further, sea-level rise has the potential to alter traditional nesting beaches through erosion or changes in tidal inundation, which could have detrimental effects on nesting success.

In addition to climate change effects, the over-harvesting of turtles has severe implications for biodiversity. During a Wagina Island site visit, over the course of one night, approximately 40 turtles (species unknown) and their eggs were removed from their nests while laying their eggs (pers. comms). It is unknown how frequently this activity occurs but the removal of turtle eggs indicates the practice is unsustainable for the long-term survival of turtles and the ecosystem services they provide the Wagina population, including food and cultural provision.

a) b)

Figure 5-39 Changes in islet morphology: a) 2010 to b) 2013 (note seaweed farms visible as dark lines in lagoon)

5.11 Marine (Other)

5.11.1 Description of ecosystem and ecosystem services

The remaining marine environments around Wagina Island primarily comprise deeper open waters and associated habitats, including deeper seabeds and pelagic waters (i.e. those marine habitats located beyond nearshore reefs). Open waters are utilised by the local community for line fishing pelagic species, such as game fish and sharks. These resources are used as food for both local sustenance and commercial trade, as well as the trade of other marine products such as shark fin (refer to previous discussion in Section 5.7).

While not specifically recognised during the community consultations, open water and offshore marine environments provide a broad range of additional ecosystem services that are essential, such as: climate, atmospheric and water cycle regulation; primary productivity by phytoplankton; and nutrient and carbon cycling by both phytoplankton and zooplankton.

5.11.2 Key threats

For open waters and offshore marine environments, the main existing threats identified were pollution and the risk of over-harvesting. They include:

- overharvesting of sharks and other fish, which may worsen due to rising fishing pressure as the local population increases;
- the potential contribution of external vessels to local over-harvesting when fishing in artisanal waters without permissio;
- pollution through the disposal of solid wastes (via rivers or seashores or ocean side), with plastics recognised as a persistent threat to offshore fauna; and
- climate change threats, including an increase in sea temperature and the associated coral bleaching and ocean acidification.

5.12 Rivers and streams

5.12.1 Description of ecosystem and ecosystem services

For the purposes of this assessment, non-marine waterways have been consolidated into a single ecosystem category and include the various streams, rivers and estuaries present on Wagina Island. The Seleana River is the largest river system on the island. With a wide river mouth and notable delta area on the northern coast, it is tidally dominated with tidal waters extending approximately nine km upstream to its upper reaches (to approximately two thirds across the island towards the south). At this point near the tidal limit (approx. 7°26'57.46"S, 157°46'12.84"E), waters were found to be fresh and slightly acidic (electrical conductivity = 239 μS; pH = 5.50).

Crocodile Passage is the other major estuarine system present. With no single defined river mouth, its complex network of estuarine passages and barrier islands dominate an approximately six kilometre stretch of the eastern coastline. Its tidal waters and/or associated mangrove vegetation extend approximately six kilometres upstream towards Nikumaroro village.

Other notable estuaries/rivers include the:

- First, Second, Third and Fourth Rivers, from Tengangea village westward;
- Te Rawa at Tekaranga, the river that acts as the main transport point of entry for Tekaranga village (note that the community at Tengangea utilises passages at the First River and Te Rawa for access);
- Te Rawa at Nikumaroro, a coastal lagoon at the main transport point of entry to Nikumaroro village; and
- some estuarine embayments on the northern coast.

The First, Second, Third and Fourth Rivers and Te Rawa are more commonly used by the local community than the Seleana River and Crocodile Passage, given their closer proximity to the villages.

The ecological condition and/or ecosystem health of the rivers and streams is highly variable, ranging from near pristine (typically for those located furthest from frequent human activity, such as Seleana River and much of Crocodile Passage) to highly modified, such as for Te Rawa at Tekaranga (Figure 5-40). Factors contributing to the highly modified nature of this river include:

- modified and constructed banks;

- alteration of riparian vegetation (e.g. natural riparian vegetation cleared for housing and food plants);
- long-term pollution inputs from solid waste disposal, sanitation uses and boating-associated chemical inputs (e.g. hydrocarbons); and
- unnatural catchment land use (e.g. catchment partly cleared for residential areas and cultivation of subsistence crops and plantations).

Te Rawa at Nikumaroro (Figure 5-41) was observed to be very full (i.e. high water levels) and contained fresh water, at least at the shallow edges where water quality measurements were taken (if stratified, brackish or salty water may persist at the bottom of deeper waters). At the time of visits to Nikumaroro for this assessment, this coastal lagoon was closed to the ocean, but would presumably break an entrance across the beach berm and partially drain once water levels are sufficiently high to overtop the berm.

Freshwater streams present on the island are primarily small, spring-fed steams that flow to the estuarine 'rivers' (Figure 5-41, Figure 5-42).

Figure 5-40 Highly modified Te Rawa river in Tekaranga village

a) b)

Figure 5-41 Coastal lagoon at Nikumaroro a), freshwater stream, tributary of Te Rawa river behind Tekaranga village b)

Figure 5-42 Freshwater springs feeding streams behind Arariki village

The community of Wagina Island is dependent on rivers and streams for a number of essential services, as listed below.

- Supply of fresh water – mostly for drinking when rainwater tank and/or well supplies are inadequate, but also for cooking, washing and bathing when well supplies are insufficient (e.g. dry wells). Springs are used (or were previously used) as a drinking water source (Figure 5-43) and feed fresh water to local streams.

- Transport (Figure 5-44) – boats are the only means of transporting both goods and people to/from Wagina Island. With a predominantly rocky shoreline fronting most villages, river entrances provide the main passages for safe access to the villages.
- Food sources – important for supplementing marine-derived protein, providing a means of food security, and providing variety in the diet, as mentioned in Section 5.4. Key fauna groups targeted in rivers for food include eel fish, various other fish and stingrays, shells (e.g. mangrove cockles) and crocodiles.
- Conduits for disposing of and dispersing waste – rivers, particularly those in proximity to villages, are commonly perceived as conduits for disposing of household and other solid waste, sanitation waste, and other waste requiring transfer away from the household or village (e.g. chemicals).

In terms of utilising freshwater springs as an accessible water source, there had been efforts approximately 30 years ago to install simple water infrastructure. This included a small concrete, spring-fed ‘tank’ (Figure 5-43a) on high ground behind Tengangea village with a pipe to the village. However, with inadequate maintenance and repair, this water supply infrastructure was damaged and has not been functional for several years.

Figure 5-43 Spring-fed freshwater supplies on high grounds behind Tengangea and Tekaranga feed local streams

Figure 5-44 Te Rawa at Tekaranga, the main transportation (vessel) hub on Wagina

5.12.2 Key threats

In terms of ecosystem health and the suitability of Wagina's rivers and streams as a source of direct provisioning services (particularly water supply) to the local community, the most significant concern is pollution and contamination from solid waste, sanitation, chemicals and sediment run-off. The following specific pollution inputs and risks were noted.

- Pollution from sanitation uses / toilets, domestic animals (especially pigs), rubbish disposal, vessel and outboard motor spills and leaks (fuel/oils)
- Lack of alternative waste management options
- Although not currently a threat, if increased, vegetation clearing on river/stream banks and adjacent land for the creation of new gardens, house sites or timber harvesting, could destabilise soils and banks, making them more vulnerable to soil erosion during high rainfall and/or flood events.
- The proposed mining development has the potential to further affect the water quality of any river or stream hydrologically connected to the development (i.e. not only those within the direct development footprint) through increased sediment loads and other contaminants associated with both the construction and operation of the mine (including supporting infrastructure, roads, etc.).

Additional key threats relating to habitats, hydrology and climate are described below.

- Habitat modification of banks and riparian areas (e.g. construction of artificial banks, bridges, clearing of riparian vegetation), which can limit the range of habitats available to support a diverse aquatic fauna, modify inputs from primary producers and destabilise banks.

- The combination of: (i) most streams being very small in size; and (ii) bankside clearing, suggests that streams may be vulnerable to landslides. Even a very small landslip may completely block a stream path and alter localised hydrology.
- Again, given the small size of streams, they are sensitive to drought and can dry up. In contrast, flooding of rivers close to villages can temporarily limit the services they supply in terms of transportation and waste transfer. It is expected that such effects may become more frequent or intensify with climate change.

Most of the above threats (see also Figure 5-45) primarily relate to the rivers and streams in proximity to the villages and other areas of frequent human use. An increase in the human population size would increase the reliance of the community on the ecosystem services provided by rivers and streams. Without effective management of rivers, streams and riparian banks, an increased reliance may cause further degradation from activities such as clearing of riparian vegetation and upstream habitat, and increased pollution input from sanitation and waste disposal intro waterways (due to lack of alternative waste management options).

a) b)

c) d)

Figure 5-45 Common disturbances for rivers and streams near villages: a/b) pig pens, modified banks, buildings and sanitation uses at river, c) constructed instream structures, d) clearing of land adjacent to stream

5.13 Groundwater

5.13.1 Description of ecosystem and ecosystem services

Groundwater is an ecosystem on which the people of Wagina are critically dependent. In the absence of major freshwater streams or rivers (refer to Section 5.12), the main sources of freshwater (in addition to rainwater tanks) is groundwater wells, surface expressions and springs. Tank water is typically reserved as the preferred drinking water source, but can dry out fairly quickly (within a month or two) during dry periods. At such times, groundwater and springs provide the only sources of freshwater for drinking and domestic uses (i.e. cooking, washing, bathing). Note that groundwater from the wells located throughout each village is continually used on a daily basis for non-drinking water uses.

While not specifically mapped, the groundwater resource is assumed to extend across much of Wagina Island, including under the sand islands bordering adjacent lagoons. During the Wagina Island site visit, fish were also commonly observed swimming in/out of the bottom of the wells, suggesting that the island's groundwater is highly connected. This is to be expected, especially for groundwater in the limestone/karst geological features.

Figure 5-46 and Figure 5-47 show examples of some of the types of constructed wells actively being used around Wagina for accessing groundwater as a resource for drinking and domestic use. This includes a well at one of the seaweed farming settlements on a sand island.

a) b)

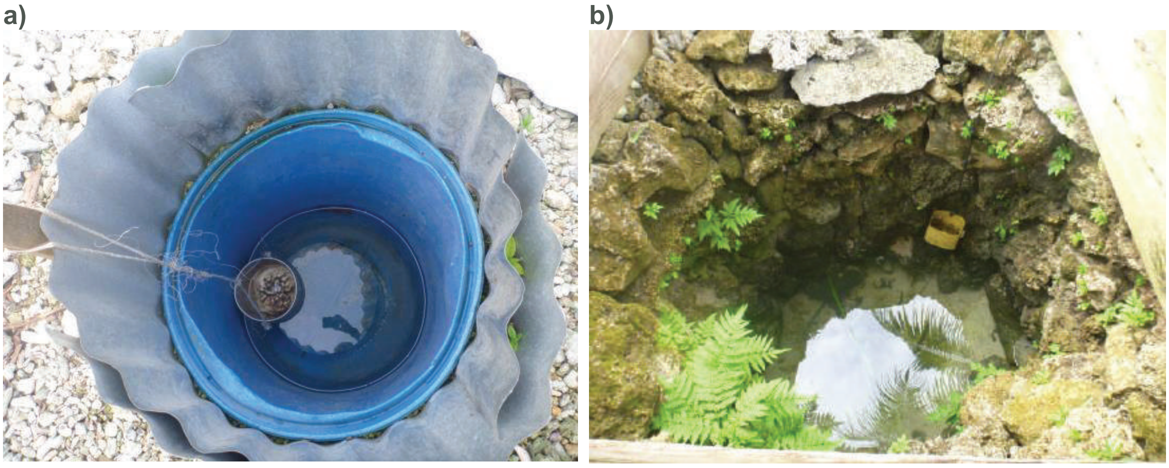


Figure 5-46 Examples of modern (a) and older (b) wells constructed on Wagina Island

Figure 5-47 Well presently in use at a seaweed farming settlement

5.13.2 Key threats

In the opinion of the authors, pollution is the primary threat to groundwater and the ecosystem service groundwater provides to the community of Wagina Island. This is especially true for pollution derived from faecal inputs and other waste sources that pose a high risk to human health. Given the assumed high connectivity of the groundwater, and the current poor sanitation and waste management practices, such contamination is likely already a major existing threat. A visually obvious example is shown in Figure 5-48, where a well located near pigs contained excessive growth of green algae. This is presumably due to increased nutrient inputs via the pigs.

However, it is noted that, during the community workshops, the community seemed more concerned about groundwater (well-water) supply and saline intrusion. Concerns about saline intrusion were often linked with palatability (i.e. ‘tastes salty’), rather than health risks. Both well-water availability (i.e. drying wells) and saline intrusion were usually associated with drought periods and/or very high tides, as well as the potential for saline intrusion to worsen with future sea-level rise.

Given the assumed high connectivity of groundwater, the proposed mining development presents an additional risk to groundwater, with future effects dependent on the management measures used for mitigation of such risks, together with the effectiveness of their implementation.

Figure 5-48 Growth of filamentous green algae at well with pigs kept adjacent

5.13.2.1 Groundwater well testing

The provision of drinking water by wells is a crucial ecosystem service to Wagina residents and sustains the community's resilience during prolonged dry periods when rainwater tanks are dry. However, concerns about the high salinity levels of well-water have been raised by the local residents.

As the community is heavily dependent on well-water for drinking purposes during dry periods, the potential loss of this ecosystem service is a critical resilience issue and may force communities to seek alternative water supply provisions. For this reason, electrical conductivity (and pH) testing was conducted at village wells to identify which wells were potentially affected by saltwater intrusion (Figure 5-49).[3]

Electrical conductivity is a measure of the saltiness of water, with fresh water typically between 0 and 1,500 uS/cm and sea water typically around 50,000 uS/cm. Water with electrical conductivity up to approximately 2,500 to 3,000 uS/cm can be consumed by humans, although most humans would prefer to drink water below 940 uS/cm (see below).

Measurements of pH can also be used to indicate saltwater intrusion, with pH of sea water typically around 8.0 and pH of groundwater (not affected by saline intrusion) typically around 5 to 7. While the ideal pH level of drinking water is typically between 6 to 8.5, the human body maintains pH equilibrium on a constant basis and is not usually affected by the pH of drinking water.

Water quality testing results are presented in Appendix C and summarised below.

[3] Water quality testing of well-water was undertaken as a one-off measurement only and does not provide any indication of temporal variation.

- Electrical conductivity of well-water was generally classed as 'good' (i.e. < 940 μS/cm) and suitable for drinking from a salinity perspective. Approximately 20% (i.e. one in five) of wells were considered poor to unacceptable for drinking, based on electrical conductivity.
- Spatial mapping of water quality data was undertaken and indicated two things.
  - For electrical conductivity, all records for Nikumaroro were classified as good to fair. Poor to unacceptable electrical conductivity was recorded at only the three western villages, and generally only at wells in proximity to the coastal side of the main road. The maximum distance from the coastline for an 'unacceptable' reading was approximately 100 m.
  - The more acidic water quality results tended to be recorded at the two most western villages of Tekaranga and Tengangea. These villages are bounded by rivers (Te Rawa, First and Second Rivers) which are tannin stained (dystrophic) and may have acidic characteristics interacting with the ground water.

Wells indicated as being suitable for drinking purposes should be the focus of future management plans to conserve water resources for Wagina Island residents.

While not able to be tested in the field,[4] of greater concern regarding the suitability of groundwater for drinking is the likely contamination of groundwater. Faecal contamination from poor sanitation practices is a particular concern which, together with nutrient and chemical inputs, is assumed to occur and present a serious human health risk. It is noted that the community had mentioned that outbreaks of diarrhoea were frequent among the local community.

The potential contamination of Wagina's back-up drinking water supply severely reduces the resilience of communities to the effects of climate change, particularly if wells are increasingly affected by salt water intrusion which is very difficult to mitigate. Wells that are identified as being suitable for drinking purposes must be effectively managed and protected from human-induced contamination.

[4] Testing of bacteria requires collected water samples to be incubated for 24-48 hours under controlled conditions. This is usually performed in a laboratory, with time between collection of samples in the field and receipt of samples at laboratory required to be less than 24 hours. As such, testing of bacteria in groundwater wells was not able to be undertaken for this study.

Figure 5-49 Testing water quality at surface expression of ground water

5.14 Summary of human-induced threats to ecosystem services

Table 5-4 provides a summary of the key threats to Wagina Island's ecosystems and services. The concept of social-ecological resilience recognises the interdependence between people and nature, which is reflected above in the community's heavy reliance on ecosystem services for survival. Despite the critical contribution ecosystem services provide to human resilience, ecosystems are subject to significant anthropogenic threats such as pollution and over-harvesting of marine resources. Furthermore, these threats are exacerbated by the current and projected adverse effects of climate change (to be explored further in Section 7).

By identifying key ecosystem services that are under threat by these pressures, targeted management options can be designed to build and strengthen the resilience of ecosystems services and, in turn, the resilience of the people of Wagina Island to future climate change effects.

Table 5-4 Summary of key threats to each ecosystem service (services identified by community)

Key Ecosystems	Key Ecosystem Services identified by community	Climate-related Threats												Non-Climate Related Threats								
		Sea level rise, storm surge, saline intrusion	Drought / decreased rainfall	Flooding / increased rainfall	Coastal erosion / current changes	River, gully, stream bank erosion	Hot days	Landslide	Ocean acidification	Cyclones (intens. freq.)	Invasives	Disease	Changing species distribution	Pollution (water-based)	Tsunami	Solid waste Mngt.	Development (e.g. resource devel.)	Land clearing / habitat loss & modification	Pop. Increase, loss of knowledge transfer	Change in land use / urbanisation	Inadequate resource management	Economic pressures
Terrestrial forest	Food (hunting)										✓	✓	✓				✓	✓	✓	✓	✓	
	Timber source – raw materials									✓		✓					✓	✓	✓	✓	✓	✓
	Timber source – fuelwood / firewood																		✓			
	Toilet place																		✓			
Lowland swamps	Raw materials (e.g. sago)	✓	✓	✓	✓					✓	✓	✓			✓		✓	✓	✓		✓	
	Giant swamp taro, sago – food security	✓	✓	✓	✓					✓	✓	✓			✓		✓	✓	✓		✓	
Cultivated land (gardens)	Food source	✓	✓	✓	✓		✓			✓	✓	✓			✓				✓	✓	✓	✓
Beaches and sand islands	Raw materials sources	✓			✓					✓					✓		✓		✓		✓	
	Canoe/boat landing	✓			✓					✓					✓		✓					
	Food source	✓			✓					✓	✓	✓	✓	✓	✓		✓		✓		✓	
Rivers, streams and freshwater springs	Canoe landing															✓						
	Water source		✓			✓		✓						✓		✓	✓	✓	✓	✓	✓	
	Toilet place and waste disposal		✓	✓															✓			
	Washing area		✓			✓		✓						✓		✓						
	Food source (stream side gardens)		✓	✓		✓				✓	✓	✓				✓			✓			
	Food source (aquatic fauna)					✓					✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
	Timber source			✓		✓				✓		✓						✓	✓	✓	✓	
Mangroves	Timber/trade source – raw materials									✓		✓	✓	✓	✓		✓	✓	✓		✓	✓
	Timber source – fuelwood/ firewood									✓		✓	✓	✓	✓		✓	✓	✓		✓	✓
	Food source (fish, molluscs, crustaceans)								✓			✓	✓	✓	✓		✓	✓	✓		✓	
	Food source (mangrove fruit)									✓		✓	✓	✓	✓		✓	✓	✓		✓	
Marine lagoons	Food/trade source (fish, molluscs, crustaceans)					✓			✓	✓		✓	✓	✓	✓	✓	✓		✓		✓	✓
	Primary industry – seaweed farming	✓		✓						✓			✓		✓	✓						✓
	Medicine (e.g. seagrass)	✓		✓		✓				✓	✓		✓	✓	✓		✓	✓	✓		✓	
Groundwater	Water supply	✓	✓											✓	✓	✓						
Reefs	Food/trade source (fish, molluscs, crustaceans, turtle)	✓				✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
	Coral source – coral rock, lime					✓			✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	

Key Ecosystems	Key Ecosystem Services identified by community	Climate-related Threats												Non-Climate Related Threats								
		Sea level rise, tides, storm surge, saline intrusion	Drought / decreased rainfall	Flooding / increased rainfall	Coastal erosion / current changes	River, gully, stream bank erosion	Hot days	Landslide	Ocean acidification	Cyclones (intens. freq.)	Invasives	Disease	Changing species distribution	Pollution (water-based)	Tsunami	Solid waste Mngt.	Development (e.g. resource devel.)	Land clearing / habitat loss & modification	Pop. Increase, loss of knowledge transfer	Change in land use / urbanisation	Inadequate resource management	Economic pressures
Marine (open water)	Food/trade (fish, shark, turtle)								✓		✓	✓	✓	✓		✓	✓		✓		✓	✓
Cultivated land (plantations)	Raw materials	✓	✓		✓					✓	✓	✓			✓				✓	✓		
	Kastom medicine/costumes	✓	✓		✓					✓	✓	✓			✓				✓	✓		
	Food source	✓	✓		✓					✓	✓	✓			✓				✓	✓		
	Betel nut (trade)		✓					✓		✓	✓	✓							✓	✓		
Terrestrial (other)	Land source (for housing, transport, services etc.)	✓		✓	✓			✓							✓				✓			
Seashore	Recreation													✓	✓	✓					✓	
	Waste disposal	✓													✓				✓			
	Toilet place	✓													✓				✓			
	Anchorage	✓													✓							

6 Valuation of ecosystem services

The purpose of quantifying values as part of the ESRAM process is to provide insights into the relative extent and magnitude of ecosystems and ecosystem service values across and between different environments. Ecosystem services contribute to economic well-being in two ways: through contributions to the generation of income and livelihoods (e.g. fishing, food crops, timber); and through the prevention of damage that imposes costs on society (e.g. coastal hazard protection by mangroves providing shoreline stabilisation and reefs buffering wave and storm energy).

While it may be simple to identify the existence of ecosystem services, valuing ecosystem goods and services such as clean air, clean water, and biodiversity is complicated, as these goods are often not traded in markets, meaning that they do not have an obvious economic value revealed through consumers' willingness to pay (market prices). As a result, unregulated markets or goods and services such as ecosystems services, often become compromised or collapse. By placing a value on ecosystem services, priorities can be given to protecting and restoring ecosystems through policies, programmes and projects. Additionally, if ecosystems and their services are not valued, they may be overused or damaged, as there is no incentive to protect or conserve the service (King and Mazzotta 2000).

6.1 Grouping of ecosystem services

As illustrated by the previous chapter, residents of Wagina Island are highly dependent on ecosystem services, with a long list of identifiable services developed in consultation with local communities, as well as from existing literature.

Valuing each discrete service (e.g. the value of pandanus for *kastom* medicine) is not feasible for the scope of this study, due to the project size, the lack of site-specific information available, and the lack of applicable valuation studies (for benefit transfer) for the more unique ecosystem services. Additionally, there are often dependencies between ecosystem services and it is sometimes difficult to estimate the unbundled value of discrete functions as distinct from other parts of the system (Boutwell 2013).

As a result, ecosystem services were aggregated and grouped for the purposes of evaluation. This also means that there is not necessarily a dedicated value for each of the services listed in the previous sections, rather there may be values that represent groups of services.

Before assigning ecosystem service values, the following categorisation of ecosystems was made:

- tropical forest;
- mangrove; and
- marine.

This was informed by the long list of ecosystem services and the availability of valuation studies. There is a subsection for each of the ecosystems listed above which discusses the key services in each and outlines ecosystem values.

Two key omissions from this list of identified services are cultivated terrestrial land (e.g. plantations and gardens) and freshwater systems (streams, creeks and groundwater). While agro-ecosystems provide a range of services and products to humans, and can also perform ecosystem services such as regulation of soil and water quality, they can also cause ecosystem disservices, e.g. contaminating water and increasing sedimentation run-off. The exact value of these types of systems are therefore a function of the services and disservices they provide and vary greatly, depending on the land-use type and the natural environment they are replacing. As a result, this assessment has not included values for gardens or plantations on Wagina Island, but could potentially reflect the costs and benefits of these resources in the options assessment.

In terms of freshwater systems, it was not possible to include the services provided by groundwater due to a lack of local information. While an exceptionally important ecosystem service, groundwater has been poorly captured in past ecosystem valuation studies and there is not a reliable global value that could be applied (see Greibler and Avramov 2013 for further information). While some values have been provided for the use value or purification value of groundwater systems, these were deemed not applicable to the study site and were also not representative of the full range of ecosystem services from groundwater (see Brink *et al.* 2011). Global median values for freshwater systems are also not considered applicable to Wagina Island, as the values are based on rivers and lakes, and the latter are not present on Wagina.

6.2 Tropical forests

6.2.1 Overview

Wagina Island is heavily vegetated, with tropical forest covering the bulk of the interior and mangroves and lowland swamps comprising the remaining significant land cover types. These forests are diverse and provide important ecosystem services for the local community. Several services related to the provision of food, fibre, timber and fuel were identified as important to the local community and necessary for daily life. This includes services such as:

- timber for canoe building;
- food, including habitat for hunting pigs; and
- fuelwood for cooking.

Additionally, forests provide regulating and supporting services, such as climate regulation, erosion control and water filtering.

6.2.2 Input values

6.2.2.1 Localised values

For valuation of forest-based ecosystem services a range of studies was reviewed. The most applicable valuation study to the Wagina Island context was by Kenter *et al.* (2011) and was conducted on Makira Island in the Kahua region.

The 2009 Solomon Island Census data show that Makira Island has a similar demographic composition and mixture of agricultural practices as Choiseul Province (Figure 6-1). This is important as it shows that the residents of both locations have similar household characteristics, increasing the comparability of the valuation study undertaken on Makira.

The Kenter *et al.* (2011) study titled, *The importance of deliberation in valuing ecosystem services in developing countries: Evidence from the Solomon Islands,* focusses on the value of increases in water quality, food (for subsistence purposes) and access to *gue* (a local plant material used for construction). While these values do not explicitly relate to forest services, the study also recorded the value of forest products (food, fibre, fuel and timber) for subsistence use (i.e. non -commercial). This was estimated through on-site surveys which required communities to estimate average annual consumption of products derived from the surrounding forest environment and value them based on equivalent market values. This yielded an average value of SBD 13,149 (2011) per household per annum. This is equivalent to SBD 16,787 (2015) or USD 2,147 (2015).

While non-use and indirect use value are not captured, it provides a useful value estimate for important ecosystem services that forest environments provide.

It was not realistically achievable to quantify the cultural and non-use values based on local studies, hence broad forest values based on global median average values for forest ecosystem services were used (see below).

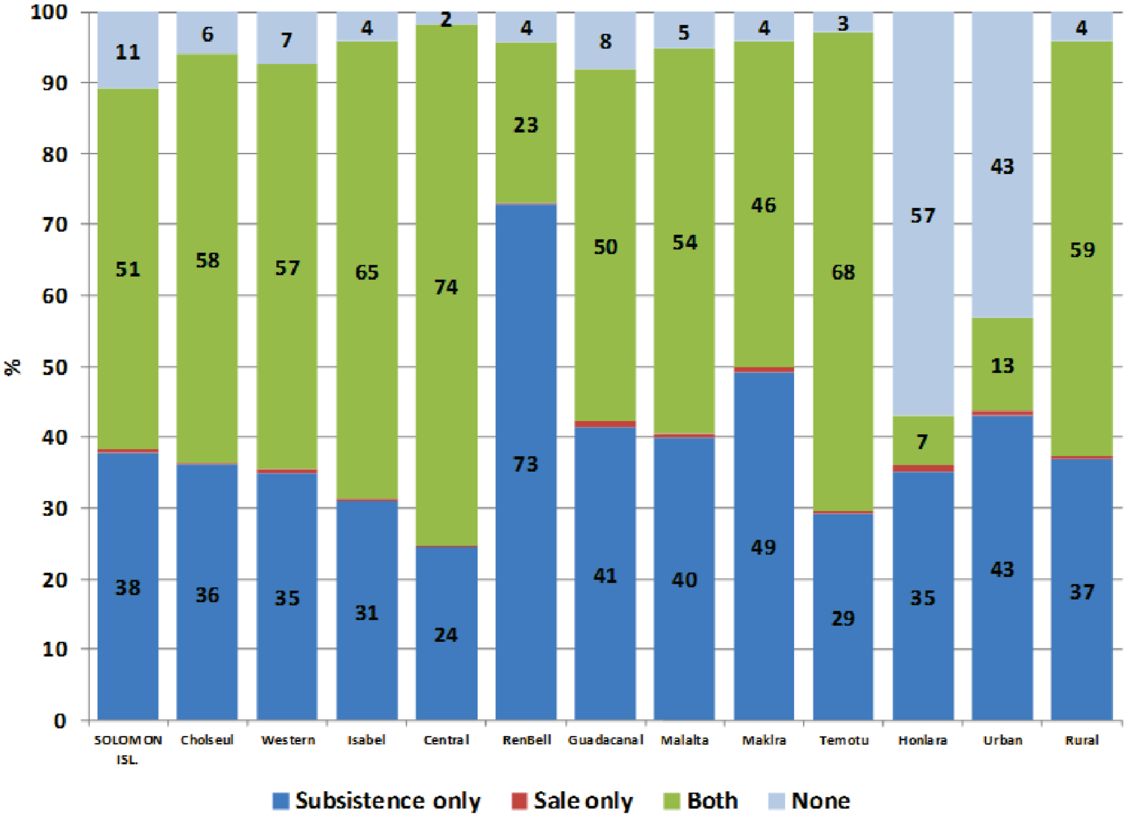


Figure 6-1 Proportion of private households by place of residence and whether involved in growing crops (%) (Solomon Islands 2009 Census Report)

6.2.2.2 Global median values

Tropical forests provide a range of provisioning, regulating, habitat and cultural services to Wagina Island residents and are estimated to cover 5,600 ha. Specific forest-based services and their monetary values are shown in Table 6-1. These values will help to capture some of the important ecosystem services identified by Wagina Island residents, such as the use of plants (e.g. Pandanus) for medicinal purposes, as well as the regulating services that support their water systems and sanitation.

Table 6-1 Summary of tropical forest values (adapted from de Groot *et al.* 2012)

Service category	Service	USD 2015, hectare/p.a.	USD Wagina Island/p.a.	SBD 2015, hectare/p.a.	SBD Wagina Island/p.a.
Provisioning services	Water	42	235,200	330	1,848,000
	Medicinal resources	1,715	9,604,000	13,405	75,068,000
Regulating services	Climate regulation	377	2,111,200	2,950	16,520,000
	Disturbance moderation	32	179,200	250	1,400,000
	Regulation of water flows	777	4,351,200	6,079	34,042,400
	Waste treatment	7	39,200	53	296,800
	Erosion prevention	15	84,000	116	649,600
	Pollination	60	336,000	472	2,643,200
Habitat	Genetic services	8	44,800	62	347,200
Cultural services	Recreation	96	537,600	753	4,216,800
Total	-	3,129	17,522,400	24,470	137,032,000

Note: The dollar values for recreation sourced from de Groot *et al.* 2012 include tourism, which is not present on Wagina Island. This figure will therefore over-estimate the value of recreation.

6.3 Mangroves

6.3.1 Overview

Mangroves are another important ecosystem on Wagina Island and make up a large part of the coastal fringe. Mangroves provide a source of food, fibre, fuel and timber, as well as regulatory and supporting services, such as land stabilisation and climate regulation (see Section 4.1, Table 5-2). Mangrove forest coverage on Wagina Island is approximately 2,823 ha.

6.3.2 Input values

6.3.2.1 Localised values

Warren-Rhodes *et al.* (2011) contains good comparable data for the range of ecosystem services provided by mangroves in Solomon Islands. It is considerably more relevant than the other valuation studies reviewed, but it is worth noting that it generally accords with values generated in other (somewhat) comparable settings.

It is also worth noting that Spaninks and Buekering (1997) observed that the economic valuations of mangroves have been highly variable in the past, due to inherent characteristics that may be difficult to quantify. Nevertheless, the study by Warren-Rhodes *et al.* (2011) provides estimates which appear

to ge) Making changes in order to reduce the vulnerability of a community, society or system to the negative effects of climate change

pacity Capacity of a system to adapt if the environment where the system exists is changing

Diversity within species, between species and of ecosystems; the variability among living organisms from all sources, including terrestrial, marine and other aquatic sufficiently robust and detailed for the scope and purpose of this project. The study compares mangrove ecosystem services and values across three geographic locations in Solomon Islands, the most relevant to Wagina Island being the village of Boeboe in Choiseul Province (approximately 40 km west of Wagina Island). Results from the study are presented in Table 6-2.

Table 6-2 Mangrove ecosystem services values (from Boeboe) (Warren Rhodes *et al.* 2011)

Ecosystem good	USD 2015 household/p.a.	SBD 2015 household/p.a.
Firewood	557	4,357
Building materials	18	114
Fishing in mangroves	655	5,122
Total	1,230	9,593

Based on the proximity to Wagina Island and the similar demographic and lifestyle characteristics, it was determined that these values could be directly applied to Wagina Island (adjusted to 2015 dollars). This equates to a total value of SBD 9,593 per household/p.a. for these services.

Additionally, MACBIO (2015) provides a per hectare value for mangroves for carbon sequestration of USD 391 (2015). This equates to approximately USD 3.5 million for the province of Choiseul (MACBIO 2015).

In addition to these values, mangroves as an ecosystem provide a range of other services which were included in the de Groot *et al.* (2012) inventory of values (see following subsection).

6.3.2.2 Global median values

Mangroves provide a range of provisioning, regulating, habitat and cultural services. Specific mangrove-based services and their monetary values are shown inTable 6-3.

Table 6-3 Summary of mangroves values (adapted from de Groot *et al.* 2012)

Service category	Service	USD 2015 hectare/ p.a	USD Wagina Island/p.a.	SBD 2015 hectare/ p.a	SBD Wagina Island/p.a.
Provisioning services	Water	54	151,200	419	1,173,200
	Medicinal resources	344	963,200	2,867	8,027,600
Regulating services	Climate regulation	13	36,400	98	274,400
	Disturbance moderation	2,324	6,507,200	18,174	50,887,200
	Waste treatment	1,182	3,309,600	9,243	25,880,400
	Erosion prevention	511	1,430,800	3,993	11,180,400
	Nutrient cycling	51	142,800	401	1,122,800
Habitat services	Nursery service	2,555	7,154,000	19,979	55,941,200
	Genetic services	1,246	3,488,800	9,742	27,277,600

Service category	Service	USD 2015 hectare/ p.a	USD Wagina Island/p.a.	SBD 2015 hectare/ p.a	SBD Wagina Island/p.a.
Cultural services	Recreation	269	753,200	2,104	5,891,200
Total	-	8,549	23,937,200	67,020	187,656,000

NB: The dollar values for recreation sourced from de Groot *et al.* 2012 include tourism, which is not present on Wagina Island. This figure will therefore over-estimate the value of recreation.

6.4 Marine

6.4.1 Overview

Wagina Island residents rely heavily on the marine environment as a source of food, as well as for seaweed farming. Furthermore, marine environments play an important role in providing regulating and supporting services, such as natural hazard protection and sanitation services.

For the purposes of this study, the marine environment has been considered as the coastal zone extending from the shoreline to the outer coral reefs (up to a few kilometres out to sea). This represents the main area in which Wagina Island residents interact with the marine environment through fishing and seaweed farming and includes not just coral reefs, but other habitats, such as shallow sand/rubble, seagrass meadows and nearshore open ocean. The marine environment did not consider mangroves, which have been considered separately.

6.4.2 Input values

6.4.2.1 Local values

Fishing

Wagina Island residents fish for subsistence and for commercial purposes, with most residents heavily reliant on fish as a food source. As a result, fish, as an ecosystem service (i.e. provision of food) from the marine environment, has a significant value. A range of studies have been undertaken to estimate what this value may be, with relatively similar results providing some confidence in the accuracy of estimations.

The key input values identified here come from a study by Albert *et al.* (2015), with values shown in Table 6-4. The values were considered appropriate, due to a few key shared characteristics of the study scope and the target location of Wagina Island, including the fact that the marine environment was considered as the coastal zone extending from the shoreline to the outer coral reefs (up to a few kilometres out to sea). This means the ecosystem was not exclusive to coral reefs, but other habitats, such as shallow sand/rubble, seagrass meadows and nearshore open ocean. The marine environment did not consider mangroves, which have been considered separately. Furthermore, the study obtained information from a range of regional locations in Solomon Islands, including communities from Western Province and Central Province, which displayed relatively similar characteristics to the Wagina Island community (e.g. substantial distance from national market, small populations, high levels of subsistence).

Table 6-4 Marine ecosystem services values (Albert *et al.* 2015)

Ecosystem good	USD 2015 per person/ p.a.	USD Wagina Island (based on 2,000 ppl)/p.a.	SBD 2015 per person/p.a.	SBD Wagina Island (based on 2,000 ppl) /p.a.
Fish	1,668	3,336,000	13,041	26,082,000
Shellfish	1,751	3,502,000	13,690	27,380,000
Shark, shark fin	145 456	290,000	1,134	2,268,000
Total fisheries	5,173	912,000	3,565	7,130,000
Coral products (sand, rubble, stone, etc.)	2,213	10,346,000	40,446	80,892,000
Total	7,842	4,426,000	17,303	34,606,000

Notes The figures above are per person engaging in the activity based on respondents' interviews, this means values will need to be multiplied by the number of communities engaging in the activity at the community level to generate a figure. If this is not feasible, global median values may be used.

The high value attributed to coral products is likely due to construction values and coastal protection. This is representative of Wagina Island in that sea walls are constructed from coral rubble and stone.

Supplementing these values, MACBIO (2015) provided the following values for subsistence, and commercial inshore fishing. Additionally, it is worth noting that these values are for the population of Choiseul Province, and not necessarily those that are most reliant on subsistence or inshore fishing, while the values from Albert *et al.* (2015) are from interviews with rural, coastal-dwelling and subsistence-based communities.

Table 6-5 Summary of Choiseul Province marine ecosystem service values

Ecosystem	USD 2015 per person/p.a	USD Wagina Island (based on 2,000 ppl)/p.a.	SBD 2015 per person/p.a.	SBD Wagina Island (based on 2,000 ppl) /p.a.
Subsistence fisheries	171	342,000	1,337	2,674,000
Commercial artisanal inshore fisheries	152	304,000	1,188	2,376,889

Seaweed

Based on monthly production figures, the average value of seaweed production annually, calculated at current prices of SBD 1.80/kg (dry weight) equates to SBD 831,600 per annum (based on annual production figures from Kronen *et al.* 2010 or ~460 tonnes).

6.4.2.2 Global median values

The de Groot *et al.* (2012) study divides the marine environment into coral reefs and coastal systems. Coastal systems have been defined as sea-grass fields, shallow seas of continental shelves, rocky shores and beaches, which are found in the terrestrial near-shore as well as the intertidal zones, whilst coral reefs are considered a distinct ecosystem.

The values shown in Table 6-6 are for coral reefs, while the values shown in Table 6-7 are for coastal systems. Coral reefs are estimated to cover 2,460 ha in areas surrounding Wagina Island, while marine lagoons are estimated to total 6,160 ha.

Table 6-6 Summary of marine values (coral reefs) (adapted from de Groot *et al.* 2012)

Service category	Service	USD 2015, hectare/p.a.	USD Wagina Island/p.a.	SBD 2015, hectare/p.a.	SBD Wagina Island/p.a.
Provisioning services	Genetic resources	37,675	92,680,500	294,564	724,627,440
Regulating services	Climate regulation	1,985	4,883,100	15,522	38,184,120
	Disturbance moderation	1,727	4,248,420	13,499	33,207,540
	Waste treatment	97	238,620	758	1,864,680
	Erosion prevention[5]	175,423	431,540,580	1,371,564	3,374,047,440
Habitat services	Genetic services	47	115,620	365	897,900
Cultural services	Recreation	1,658	4,078,680	12,960	31,881,600
	Cognitive development	90	221,400	704	1,731,840

[5] This figure appears high and was drawn from a limited number of studies (including one with particularly high values) – while it would go against the consistent method applied in treating de Groot values for use in this project to remove the value, it may need to be reconsidered or further tested in undertaking the economic analysis.

Service category	Service	USD 2015, hectare/p.a.	USD Wagina Island/p.a.	SBD 2015, hectare/p.a.	SBD Wagina Island/p.a.
Total	-	218,702	538,006,920	1,709,936	4,206,442,560

Notes: The dollar values for recreation sourced from de Groot *et al.* 2012 include tourism, which is not present on Wagina Island. This figure will therefore over-estimate the value of recreation.

Table 6-7 Summary of marine values (coastal systems) (adapted from de Groot *et al.* 2012)

Service category	Service	USD 2015, hectare/ p.a.	USD Wagina Island/p.a.	SBD 2015, hectare/p.a.	SBD Wagina Island/p.a.
Regulating services	Erosion prevention	28,920	178,147,200	226,110	556,230,600
Habitat services	Nursery services	106	652,960	829	2,039,340
	Genetic services	205	1,262,800	1,604	3,945,840
Cultural services	Recreation	300	1,848,000	2,344	5,766,240
Total	-	29,531	181,910,960	230,887	567,982,020

6.5 Summary of economic valuations

Where data were available, the economic value of Wagina's ecosystem services was estimated, based on global median values and local inputs, while total area and per person ratios were also applied, where possible. The estimates above clearly demonstrate the significant value communities derive from ecosystem services.

At an ecosystem level at Wagina Island, the estimated economic values for ecosystem services considered above are: coral reefs USD 538,006,920 (2015) and SBD 4,206,442,560; marine lagoons USD 181,910,960 (2015) and SBD 567,982,020 (2015); mangroves USD 23,937,200 (2015) and SBD 187,656,000; and forests USD 17,522,400 (2015) and SBD 137,032,000.

The value of coral reefs is substantially higher than that of other ecosystems, probably due to the diverse services they provide and the significant contribution to erosion prevention. A high value is also attributed to erosion prevention for marine lagoons. Comparatively, erosion protection by mangroves is not valued on the same scale, which is not a true representative of the key role mangroves play in this ecosystem service. The unbalanced valuation is probably due to the small number of erosion prevention studies used for the global median values. Hence, further research may be needed in this field. Nevertheless, ensuring that these erosion protection services provided by reefs, marine lagoons and mangroves are functioning at full capacity will be crucial to the island's resilience to future adverse effects of climate change, particularly when considering the projected sea-level rise, the increase in extreme rainfall events and higher intensity tropical cyclones (see Section 7 for climate change projections).

The provision of food by marine ecosystems is a critical service for the people of Wagina Island for both subsistence and income-generation purposes. Based on the values provided by Albert *et al.* (2015), the value of fisheries is estimated to be USD 5,173 (2015) and SBD 40,446 (2015) per person each year. Based on the estimated population of Wagina Island (2,000 people), total fisheries are valued at USD (2015) 10,346,000 and SBD 80,892,000 (2015) per annum. The heavy reliance on marine resources for the well-being and livelihood of Wagina residents, coupled with the high economic value of fisheries, highlights the need for sustainable harvesting of marine resources and protection and effective management of marine ecosystems.

Ecosystem valuations provide the support and justification for policy and programmes to protect ecosystems and prioritise the allocation of programme spending to maximise the environmental benefits per dollar spent (King and Mazzotta 2000). The values presented above and the heavy dependence Wagina residents have on ecosystem services, reiterate the strong economic case for investing in ecosystem services. There is also a need for Wagina residents to better understand the value of ecosystem services, which may play a role in the improved management of ecosystems and their services.

7 Climate change vulnerability assessment

The following climate change threats have been identified for Solomon Islands:

- sea and air temperatures will continue to rise, potentially up to 1.0°C by 2030 and up to 2.0–4.0°C by 2090;
- sea level will continue to rise, with potential increases of 5–15 cm by 2030 and 20–60 cm by 2090;
- ocean acidification will continue to increase with an associated decline in aragonite concentrations, potentially to 3.5 around 2030, below 3.5 by 2045, and could potentially continue to decline to 2090, and after, to < 3.0; and
- more extreme rain events could potentially occur with the current 1-in-20-year daily rainfall amount increasing by 9 mm by 2030 and 43 mm by 2090, and becoming a 1-in-4-year event by 2090.

As discussed in Volume 1, Section 2.5 (BMT WBM 2017a), the vulnerability of ecosystem services to climate change is the degree to which a system is susceptible to the adverse effects of climate change. This is a function of its exposure to climatic variations, its sensitivity to the climate variation and its adaptive capacity, or ability to adjust or cope, with climate change.

This section provides a vulnerability assessment to calculate exposure, sensitivity and adaptive capacity of key ecosystem services for Wagina Island to the main climate change threats identified for Solomon Islands: temperature rise, sea-level rise, ocean acidification and more extreme rain events. Whilst this list of climate threats is not comprehensive, it includes those that have high to very high confidence of occurring and represent the highest risks to Solomon Islands. Projections for drought, more intense cyclones and altered wave patterns are not well established and have been considered only in the context of other climate change threats, where relevant (refer to Appendix D for the results of the Wagina Island vulnerability assessment).

Based on the critical climate variables or threats assessed for this project, by 2030 sea-level rise could potentially affect a range of ecosystem services essential to the communities of Wagina Island. Whilst sea-level rise will continue to affect coastal ecosystem services to 2090 and beyond, the projected magnitude of temperature increase for both air and sea temperature, is predicted to become the dominant climate change threat to the largest proportion of Wagina Island's ecosystem services. Coral reefs and their services will be highly vulnerable to projected ocean acidification levels by 2090, which may also be exacerbated by sea temperature rise.

7.1 Ecosystem service vulnerability to climate threats

7.1.1 Sea-level rise

2030 Sea-level Rise Projection Summary

- Sea-level rise of between approx. 7 cm and 18 cm
- Mean change: 13 cm
- Confidence level is medium

The vulnerability of ecosystems and their critical services to climate change increase as sea levels rise around Wagina Island. By 2090, projected sea-level rise potentially presents a high threat to many of Wagina's ecosystem services. At an overall ecosystem level, those potentially most vulnerable to 2030 and 2090 (and beyond) sea-level rise are fresh groundwater, freshwater lowland swamps, and beached and sand islands. Fresh groundwater ecosystems and services, including wells, surface expressions and springs, all have low adaptive capacity to saline intrusion. Groundwater is an extremely vital ecosystem for the people of Wagina as it provides their primary water source, following rainwater, which is limited at times of the year and tanks are prone to drying out after one to two months. Given the potential groundwater connectivity (see Section 5.13.1), the risk of saline intrusion may affect groundwater sources across the island, but the effects will depend on aquifer dimensions and local hydrological regimes.

2090 Sea-level Rise Projection Summary

- Sea-level rise of between approx. 40 cm and 89 cm
- Mean change: 63 cm
- Confidence level is medium

The vulnerability of lowland freshwater swamps to sea-level rise is also high, due to low adaptive capacity and high sensitivity to saltwater intrusion. Freshwater wetland ecosystem services that may be highly vulnerable to sea level rise are the provisioning of house materials (sago leaves) and food sources, including emergency food provisions (e.g. swamp taro) in times of food shortages and following extreme weather events, such as cyclones. Extreme events, such as drought and increased cyclone intensity, may increase in the future (low confidence), and may place added pressure on these essential services.

Rocky shores provide a barrier to residents from the effects of coastal erosion, but villages are likely to be more vulnerable to coastal inundation via storm surge and sea-level rise. Rising sea levels of an estimated 40 to 89 cm by 2090 are expected to increase the vulnerability of ecosystem services provided by beaches and sand islands. Ecosystem services most vulnerable are the provision of land by sand islands and the provision of food sources (e.g. turtle and megapode eggs). Sand islands surrounding Wagina Island are used to service the seaweed farming industry, including the construction of drying beds and informal settlements for the seaweed farm workers. As an increased number of islands surrounding Wagina are at risk of becoming permanently inundated by rising sea levels, the adaptive capacity of these sand islands to provide the necessary land for seaweed farms will decrease. Beach-dependent food sources have a high vulnerability to sea-level rise due to low adaptive capacity, such as turtle nesting sites and megapode eggs.

Mangroves are likely to be less vulnerable to rising sea levels due to the high adaptive capacity to migrate landwards. An increasing population and increasing development away from the rocky shores may pose a future threat, whereby developments adjacent to existing mangroves restrict the capacity of mangroves to migrate up shore.

7.1.2 Air and sea temperature

As discussed in Volume 1, Section 6.1.2 (BMT WBM 2017a), surface air temperatures in the Pacific region are closely related to sea surface temperatures. Projected changes to air temperatures therefore can be used as a guide to changes in sea surface temperatures (Australian Bureau of Meteorology and CSIRO 2014a).

Although an increase in annual air temperature and an increase in extreme air temperature projections are different, the potential impacts from these climate threats, combined with the adaptive capacity of ecosystem services, are likely to result in the same level of vulnerability. Hence, for the purpose of this report, both air temperature climate variables are grouped and discussed as a single threat: increase in air temperature.

2030 Air and Sea Temperature Projection Summary

Temp increase up to 1.0°C relative to 1995

Mean change: 0.7'C

Confidence level is very high

2030 Extreme Air Temperature Projection Summary

Temperature on extremely hot days is projected to increase the same amount as average temp

Frequency of extremely hot days is also expected to increase.

Temp of the 1-in-20-year hot day is projected to increase by approx. 0.8°C

Confidence level is very high

The ecosystems on Wagina Island considered to be most vulnerable to the projected 2030 increase in air and sea temperatures are marine ecosystems, primarily due to the increased risk of coral bleaching and its associated effects on marine lagoon communities. Given the magnitude of temperature change, all other ecosystem services are expected to demonstrate high adaptive capacity to a 1.0°C temperature increase.

2090 Air and Sea Temperature Projection Summary

Temp increase up to 2–4°C

Mean change: 2.8'C

Confidence level is very high

2090 Extreme Air Temperature Projection Summary

Temperature on extremely hot days is projected to increase the same amount as average temp

Temp of the 1-in-20-year hot day is projected to increase by approx. 2.9°C

Confidence level is very high

By 2090, however, the projected increase in air temperature by 2–4°C poses a greater potential climate change risk to a broad range of ecosystem services, with the exception of those associated with rocky shores. Reefs, marine lagoons and the marine open water will have increasing sensitivity to projected temperatures in 2090 and may have low capacity to adapt to these environmental changes, particularly in the context of other 2090 climate change threats, such as ocean acidification. By 2090, marine ecosystem services depended upon by the people of Wagina Island may be highly vulnerable to temperature rise. These include, food provisioning (e.g. fish, molluscs, crustaceans, turtles, trochus, clams), along with raw material provisioning (e.g. coral rock, lime and sand), biodiversity, coastal protection, medicinal provisions, and income generation (seaweed farming).

Mangrove ecosystem services are predicted to be moderately to highly vulnerable to the projected temperature change for 2090. Whilst mangroves themselves may have some adaptive capacity to increasing temperature, food provisioning services provided by these ecosystems (e.g. estuarine fauna such as crustaceans and molluscs) may be highly vulnerable, due to their high sensitivity and low adaptive capacity to water quality, which may be affected by temperature rise (which is linked with toxic absorption, salinity and dissolved oxygen). Intertidal fauna (such as mangrove shells) may also be vulnerable to increased temperature when combined with prolonged periods of low tide, resulting in desiccation and spoiling. Some mangrove biodiversity services may be less vulnerable to increased air and sea temperatures, due to the increased adaptive capacity of some terrestrial mangrove fauna to relocate to other habitats (e.g. birds).

Habitat and biodiversity services provided by freshwater ecosystems are predicted to be vulnerable to the projected temperature change for 2090 due to their high sensitivity and low adaptive capacity to poor water quality, which may be affected by temperature rise. Similarly, the projected temperature change by 2090 on terrestrial ecosystems may include an increase in the vulnerability of plantations and subsistence gardens. These include a potential decrease in crop yield, a reduction in soil cohesion and stability, and an increased exposure to pests and disease. The vulnerability of both freshwater and terrestrial ecosystems would increase during prolonged dry periods (i.e. drought).

7.1.3 Ocean acidification

Reefs are a prominent feature of the local marine environment, surrounding much of Wagina Island. Reefs and their dependent ecosystem services are vulnerable to ocean acidification. Aragonite, a metastable form of calcium carbonate, is used by reef building corals and shellfish to build skeletons and hard shells (PACCSAP 2014b). As oceans acidify, the carbonate ion concentration in sea-water decreases, making it harder for corals to grow. For corals, saturation states above 4 are optimal, 3.5–4 adequate, and between 3–3.5 marginal, with no corals historically found below 3 (Guinotte *et al.* 2003).

2030 Ocean Acidification Projection Summary

- Median aragonite saturation state will transition to marginal conditions (3.5) around 2030.
- Mean change: –0.4 Ωar
- Confidence level is medium

Based on the projections, aragonite concentrations by 2030 may be adequate for corals and shellfish but, by 2090 and beyond, the median aragonite saturation state may continue to strongly decline to values where coral reefs have not historically been found (< 3.0). Due to the high sensitivity of reefs to the projected decline in aragonite concentration levels and the low adaptive capacity to withstand the predicted conditions, the Wagina Island reef ecosystem is highly vulnerable to ocean acidification. Based on current projections, critical services considered highly vulnerable by 2090, include: food provisioning (reef-based food provides the primary protein component of the local diet); local biodiversity; income generation (sale of reef products such as reef fish, turtles, crayfish, and clams at local markets, and to visiting vessels and Honiara); coastal protection (the reef structure provides a buffering system to the coastlines from wave damage and storm surge); and the provision of raw materials (e.g. coral rock and lime). Given the dependence of marine lagoons on coral reefs, many associated services, such as biodiversity and food provisioning services, are also likely to be highly vulnerable. The effect of acidification on the health of reef and marine ecosystems for Wagina Island is likely to be compounded by other stressors, including coral bleaching, storm damage, water quality and fishing pressure, and will be an important adaptive challenge.

2090 Ocean Acidification Projection Summary

- Median aragonite saturation state will continue to strongly decline thereafter to values where coral reefs have not historically been found (< 3.0).
- Mean change: –1.5 Ωar
- Confidence level is medium

7.1.4 Extreme rainfall events

Given the relatively intact forest, river banks and riparian areas, extreme rainfall events in isolation for 2030 and 2090 are not predicted to be a high climate change threat to the ecosystem services of Wagina Island.

2030 Extreme Rainfall Events Projection Summary

Current 1-in-20-year daily rainfall amount to increase by approx. 9 mm

3% increase in annual rainfall

Confidence level for frequency and intensity of extreme rainfall events is high

Food provisioning services of cultivated land (i.e. plantations and gardens) are likely to be highly vulnerable to extreme rainfall events predicted for 2090, due to the high sensitivity of gardens to flooding, erosion and waterlogged soils, combined with the moderate adaptive capacity of gardens to be relocated or protected from heavy rainfall and flooding.

2090 Extreme Rainfall Events Projection Summary

Rainfall to increase by approx. 43 mm

Current 1-in-20-year daily rainfall event will become, on average, a 1-in-4 year event

6% increase in annual rainfall

Confidence level for frequency and intensity of extreme rainfall events is high

7.2 Summary of ecosystem service vulnerability

Based on the vulnerability assessment to climate threats, several ecosystem services of Wagina Island listed in Table 7-1 are predicted to have high to very high vulnerability to climate change for both 2030 and 2090. Climate variables shaded grey are considered to present the greatest threat to ecosystem services (rated very high vulnerability).

Given that the Wagina Island community is heavily dependent on the coast, based on the results of this vulnerability assessment, the key climate change threat to Wagina Island ecosystems and their services for 2030 is sea-level rise. Many of the ecosystem services vulnerable to this threat are critical provisioning services related to fresh water supply (groundwater wells); food provisioning (swamp taro which is an emergency food source); raw material provisioning (sago leaves) and income generation (land availability for seaweed farming related infrastructure).

As illustrated in Table 7-1, many ecosystem services are predicted to be highly vulnerable to 2090 climate threats. The predicted 2090 air and sea temperature increases of 2-4°C, the rising sea levels of 40–89 cm, coral bleaching, and aragonite concentration levels potentially declining to values where coral reefs have not historically been found, present the greatest threats to ecosystem services. Food provisioning services by crops are likely to be highly vulnerable to an increase in extreme rainfall events by 2090. Those ecosystem services considered most vulnerable are summarised below with the associated critical climate change threat.

- Fresh water quality for drinking, provided by groundwater wells, surface expressions and freshwater springs (vulnerable to saline intrusion by sea-level rise)
- Food provision services, provided by reefs and marine lagoons (vulnerable to rising temperatures, coral bleaching and ocean acidification), lowland swamps (vulnerable to saltwater intrusion from sea-level rise) and cultivated gardens and plantations (vulnerable to extreme rainfall events causing soil erosion and waterlogged soils of cultivated land)

- Income generation, provided by seaweed farms in marine lagoons (farms vulnerable to inundation by sea-level rise and increasing sea temperatures)
- Biodiversity and habitat, provided by reefs and marine lagoons (vulnerable to coral bleaching due to rising temperatures and coral dieback associated with ocean acidification), lowland swamps (vulnerable to saltwater intrusion from sea-level rise) and beaches (vulnerable to sea-level rise).
- Raw materials, provided by reefs and marine lagoons (vulnerable to poor water quality associated with temperature rise and coral dieback associated with ocean acidification and coral bleaching), lowland swamps (vulnerable to saline intrusion by sea-level rise) and cultivated plantations (vulnerable to extreme rainfall events)
- Coastal protection provided by reefs (vulnerable to bleaching associated with temperature rise and dieback associated with ocean acidification)

Table 7-1 Highly to very highly vulnerable ecosystem services

Ecosystem	Ecosystem Services	2030 *	2090					
		Sea Level Rise	Sea Level Rise	Increased Sea Temp	Extreme Rainfall Events	Extreme Air Temp	Annual Air Temp	Ocean Acidific-ation
Beaches and sand islands	Food source	✓	✓					
	Land source (for housing, transport, services)	✓	✓					
	Biodiversity		✓					
Cultivated land (plantations)	Food source				✓	✓	✓	
	Raw materials (pandanus, coconut and sago for building materials)				✓	✓	✓	
Cultivated land (gardens)	Food source				✓	✓	✓	
Groundwater wells	Water supply (drinking)	✓	✓					
Lowland swamps	Biodiversity		✓					
	Giant swamp taro, sago – food security	✓	✓					
	Raw materials (e.g. sago)	✓	✓					
Mangroves	Biodiversity			✓				✓
	Food source (fish, molluscs, crustaceans)			✓				✓
Marine (open water)	Food/trade (fish, shark, turtle)			✓		✓	✓	✓
Marine lagoons	Biodiversity			✓		✓	✓	✓
	Food/trade source (fish, molluscs, crustaceans)			✓		✓	✓	✓
	Primary industry – seaweed farming	✓	✓	✓		✓	✓	
Reefs	Biodiversity			✓		✓	✓	✓
	Coastal Protection			✓		✓	✓	✓
	Coral source – coral rock, lime			✓		✓	✓	✓
	Food/trade source (fish, molluscs, crustaceans, turtle)			✓		✓	✓	✓

* Based on the 2030 projections, ecosystem services are likely to be highly vulnerable to sea-level rise and be low to moderately vulnerable to an increase in sea and air temperatures, ocean acidification and an increase in extreme rainfall events.

8 ESRAM outcomes

Wagina Island communities are heavily reliant on ecosystem services for their health and well-being and livelihoods. However, the vulnerability of Wagina Island's social and ecological systems to human threats such as pollution and the over-exploitation of marine resources is likely to be increasing. The growing population will place further pressure on ecosystem services, while the potential mine development will significantly increase the vulnerability of ecosystems and communities. The direct and indirect effects of climate change, specifically sea-level rise and increased sea temperatures, could intensify these pressures. By highlighting these vulnerabilities, opportunities to protect and restore critical ecosystems and their services can be identified to retain and build on the strengths of social systems, in turn increasing the resilience of people and ecosystems.

The following section provides a summary of the vulnerabilities of ecosystem services to climate and non-climate related threats and their effect on the resilience of Wagina's ecosystems and communities. The ESRAM outcomes are presented in three broad ecosystem types: freshwater (rivers, streams, lowland swamps and groundwater); coastal and marine (mangroves, reefs, seagrass, marine lagoons, rocky shores, sandy beaches and islands, and marine waters); and terrestrial (forests, gardens and plantations).

8.1 Resilience of ecosystem services to human-induced and climate change effects

8.1.1 Freshwater ecosystems and services

Freshwater ecosystems provide important ecosystem services to Wagina Island, particularly during times when essential services relied upon daily by residents are limited, e.g. water supply by groundwater wells during prolonged dry periods, and food and habitat provision by lowland swamps which provide swamp taro utilised during food shortages, and streams and rivers which support freshwater fauna used to supplement marine-derived protein (eel fish, fish and stingrays). Existing non-climate threats to freshwater ecosystems include destruction of lowland swamps by pigs, modified river and creek banks and altered riparian vegetation from stream-side gardens, and pollution of groundwater wells, rivers and streams from sanitary uses, domestic animal waste, waste disposal and fuel spills (outboard motor spills into rivers).

Projected effects of climate change are likely to place further stress on freshwater ecosystem services. Sea-level rise presents the greatest threat to groundwater wells, which are already experiencing saltwater intrusion from current sea levels, while lowland swamps are likely to be vulnerable to sea-level rise by 2030. Freshwater ecosystem services likely to be highly vulnerable to human-induced threats and sea-level rise are the provision of drinking water supply by groundwater wells, biodiversity and habitat supported by lowland swamps, and food security and raw material provisions by lowland swamps (swamp taro and sago).

Saltwater intrusion of groundwater wells is currently a critical issue for Wagina Island and is highly likely to worsen with sea-level rise. Existing groundwater wells that are less vulnerable to saltwater intrusion must be protected from other threats such as pollution (from sanitary uses and human and animal waste) and clearing of surrounding vegetation. These groundwater wells are crucial for the community's resilience to increased saltwater intrusion and increased temperatures, and could sustain the drinking water supply for a large proportion of the community. The heavy dependence on rainwater tanks and groundwater wells that are currently vulnerable to climate threats (i.e. drought and sea-level rise), is likely to force communities to seek alternative sources of drinking water for their survival. Potential options may include installing larger rainwater tanks and improving rainwater harvesting systems (collection, storage and distribution of rainwater from roofs), and investigating additional wells and springs throughout the island.

Based on their current condition, rivers and streams are likely to be resilient to the projected effects of climate change due to the relatively intact terrestrial forests and minimal clearing of stream banks. To sustain this key resilience feature, particularly with an increasing population, sustainable clearing practices must be implemented across the island and practices such as clearing on steep slopes and riparian areas must be avoided. By reducing the potential for sediment run-off entering streams, the marine environment will also benefit and strengthen its resilience to the projected increase in extreme rainfall events and associated run-off.

The existing 'back-up' services provided by freshwater ecosystems during current food and water supply shortages are critical for building Wagina's resilience to future climate and non-climate change effects. While residents are reportedly making an increased effort to plant swamp taro further inland, forward planning will need to accommodate both the growing population and lengthy yield times (approximately ten years) to ensure that future yield amounts are sufficient. Groundwater wells that are likely to be less vulnerable to saltwater intrusion must be protected from pollution and vegetation clearing. To continue the provision of food and water security services with the projected increase in temperature, extended dry periods, and overall frequency of natural disasters, while sustaining a growing population, effective management practices must be introduced to protect and enhance these ecosystems services.

8.1.2 Coastal and marine ecosystems and services

Coastal and marine resources play a critical role in sustaining the well-being and livelihood of Wagina Island residents. Marine resources supply daily protein and nutrients, generate cash income, provide building materials, protect communities and the coastline from natural disasters and extreme weather events, and provide cultural identity, status, values and medicinal services. The current condition of the marine environment surrounding Wagina Island is unknown, but threatening processes such as poor sanitary and waste disposal practices, unsustainable harvesting of marine resources, and the direct physical destruction of coral reefs from anchors and the collection of coral products, is likely to be reducing the health of coral reefs, marine lagoons and marine offshore areas. As the population continues to grow, these threats will increase.

Poor waste management and sanitation practices on the island are recognised by local residents as having effects on the surrounding reefs and marine lagoons, particularly adjacent to the sand islands. The large volume of plastic waste entering the inshore marine environment, including both macro- and micro-plastics, is also a concern for marine fauna through consumption and entanglement. Solid waste and human and animal waste affect multiple components of the coastal and marine ecosystem, including water quality, sediment quality, and the structure, composition and condition of flora and fauna communities.

Several anecdotal indications suggest that unsustainable harvesting of marine resources is occurring. Local residents report a reduction in resource abundance of reef fish, so residents are forced to fish further away from villages. In addition, trochus numbers have declined, shark harvesting has increased significantly over the last few years to compensate for the low seaweed prices, and turtle poaching occurs in ACMCA. Site visits to Wagina Island revealed high numbers of harvested sharks and turtles (that were not attributed to feasts or cultural celebrations), which, if frequent, is likely to be at unsustainable levels. Given the high importance of reef resources for food, unsustainable harvesting is a major concern, particularly with population growth and the increasing fishing pressure to supply food. External vessels that visit the in- and off-shore waters are also probably contributing to over-harvesting and physical destruction of coral reefs (from anchors).

Changes to the biodiversity of marine ecosystems can have implications for the stability that enables them to maintain functionality over a range of environmental conditions, and thus provide resilience to a changing climate. Marine ecosystem resilience needs to be enhanced by managing resources sustainably and potentially limiting harvesting for some species that may need to restock and re-build their resilience to shocks and stressors.

The compounding threats of climate change will exacerbate these human-induced effects. Many climate change effects are potentially unavoidable. Marine ecosystems are likely to be highly vulnerable to the projected temperature increase due to coral reefs and lagoons having high sensitivity and low capacity to adapt to changes in sea temperature. The projected 2–4°C increase in sea temperature by 2090, coupled with coral bleaching, over-exploitation and pollution, is likely to result in most provisioning ecosystem services of coral reefs, marine lagoons and open waters becoming highly vulnerable to these changes. These services include: food and trade provision (supplying daily protein and micronutrients through fish, sharks, turtles, molluscs, crustaceans); habitat (essential feeding, breeding, spawning, cleaning and aggregation habitat); and biodiversity; income generation (seaweed farming and fishing); provision of raw materials (coral rock and lime production); and coastal hazard protection (wave attenuation by coral reefs and seabed stabilisation by marine macroalgae).

The projected levels of ocean acidification and the associated decline in aragonite concentrations will further reduce the resilience of coral reefs and all ecosystem services, particularly by 2090 and beyond, when the median aragonite saturation state may continue to strongly decline to values where coral reefs have not historically been found (< 3.0). The effect of acidification on the health of reef and marine ecosystems is likely to be compounded by other stressors, including coral bleaching, storm and anchor damage, water quality, and increased fishing pressure driven by population growth. The people of Wagina Island are likely to be required to adapt to alternative ecosystems for provisional services by 2090.

Wagina Island seaweed farms are solely located in the marine lagoons. While a high proportion of Wagina households are directly dependent on seaweed farming for their livelihoods, it is uncertain how sea temperature rise, ocean acidification and marine pollution will affect seaweed species and the seaweed farming industry. Until further research is completed, marine lagoons must be protected and enhanced to ensure that their vital support of fish and seaweed communities can function at the highest capacity.

Coastal erosion on beaches and sand islands from rising sea levels is also affecting seaweed farming. Sand islands play an important role in supplying land in lagoon areas to service seaweed farming, including land for constructing seaweed drying tables and establishing farming settlements. This land availability is decreasing as a result of coastal erosion, which is likely to have been exacerbated by the removal of shoreline vegetation and the modification of shorelines to make space for drying tables and settlements. This is apparent on several sand islands, including the main seaweed farming island, Benjamin Island, which accommodates most of the seaweed farmers and their families, and enables workers to directly access the seaweed farms and minimises fuel usage in travelling to and from Wagina Island. By 2090, rising sea levels may be close to permanently inundating sand islands, while an increase in cyclone intensity, storm surge and rough seas is likely to erode any remaining shoreline.

The lack of available land for seaweed farmers to be based adjacent to marine lagoons is likely to reduce the viability of seaweed production by increasing fuel costs associated with boat travel between Wagina Island and marine lagoons. The high production costs will affect the income generation and livelihoods of Wagina Island residents and, if adequate measures are not in place, marine resources are likely to be highly vulnerable to over-harvesting as a means for the community to supplement their income (i.e. through fishing, and shark and marine turtle harvesting). In addition to the potential increased harvesting pressures, marine turtles are likely to have a high vulnerability to sea-level rise due to erosion of nesting areas and limited adaptive capacity to nest outside sandy beaches. The potential over-exploitation of marine turtles and the increasing pollution of oceans will further reduce their resilience to rising sea levels and their sensitivity to temperature changes (sexual selection is determined by temperature). The conservation of marine turtles and their nesting areas is paramount to ensure their long-term survival.

Mangrove forests are currently abundant and appear to be in good condition on Wagina Island. However, concentrated clearing for the provision of building materials and fuel without replanting (e.g. Fourth River) may present a future threat to these provisioning services and additional services, including coastal protection and food sources supported by mangrove ecosystems (e.g. mangrove shells, molluscs and crustaceans). Threats are also likely to increase with population growth and expanding settlements. The projected increase in sea temperature and the effect of ocean acidification by 2090 and beyond are likely to increase the vulnerability of mangrove ecosystem services in supporting biodiversity and the provision of food sources, such as molluscs and crustaceans. By sustaining mangrove abundance and health through sustainable harvesting practices (including replanting) in high-use areas and protecting mangrove forests from future developments, mangroves will strengthen the resilience of communities to natural disasters, such as tsunamis and tropical cyclones, and coastal erosion from sea-level rise and storm surge. The sustainable management of mangroves will also continue to provide essential habitat to intertidal fauna communities, in turn contributing to food security for Wagina Island residents.

Marine ecosystems are arguably the most vital ecosystem to the people of Wagina Island, but they are likely to be the most vulnerable to both human and climate-induced effects of climate change.

Increasing population growth and overharvesting of marine resources will continue to push the local marine ecosystem threshold, which may be exceeded and resources may become exhausted.

In terms of economic valuations, the value of fisheries is estimated to be USD 5,173 (2015) and SBD 40,446 (2015) per person each year (Albert *et al.* 2015). Based on the estimated population of Wagina Island (2,000 people), total fisheries are valued at USD 10,346,000 (2015) and SBD 80,892,000 (2015) per annum. The heavy reliance on marine resources for the health, well-being and livelihood of Wagina communities, coupled with the high economic value of fisheries, strongly point to the need for sustainable harvesting of marine resources and protection and effective management of marine ecosystems.

8.1.3 Terrestrial ecosystems and services

The terrestrial forests of Wagina Island appear to be in good condition with disturbance limited to village edges, cultivated land, timber milling and walking tracks. Terrestrial forests provide important ecosystem services for the local community, including the provision of food, fibre, timber and fuel, as well as regulating and supporting services, such as climate regulation, prevention of soil erosion, habitat provision, primary productivity and maintenance of stream water quality. The key non-climate threat to terrestrial forest ecosystem services is land clearing and over-harvesting of timber. The growing population is likely to place further pressure on forest resources, including an increase in clearing for settlements and cultivated land, and harvesting timber and fuelwood. It is unclear whether current hunting rates of terrestrial fauna are sustainable, but the small size of the island, combined with the growing population and the need to meet food supply demands, may increase the vulnerability of terrestrial fauna to hunting threats.

Gardens and plantations are essential for food provision for the local community. Gardens provide the staple vegetation and fruit crops (e.g. sweet potato, cassava and taro), while plantations provide tree crops (e.g. pandanus, coconut and sago) that are highly versatile and are heavily relied upon by the community for food, building and medicinal provisions. Key non-climate threats to both gardens and plantations are: (i) unsustainable harvesting (e.g. excessive cutting of sago leaves, excessive cutting of pandanus roots and tall trees for medicine purposes, and cutting of young coconuts) which undermines plant health, stability and yield; (ii) destruction by feral animals and pests; (iii) encroachment from expanding villages from an increasing population; (iv) excessive weed growth; and (v) theft of garden produce.

In terms of food, building and medicinal provisions, terrestrial forests and gardens are essential to the survival of Wagina Island residents, particularly if marine food resources are limited, income generation is low and the population continues to increase. In such cases, crop yield may need to increase to meet the need of a growing population, coupled with a changing climate. Due to the disturbed state of gardens and plantations, the projected increase in air temperature of 2–4°C by 2090 and beyond is expected to expose gardens, trees and crops to pests and diseases and unsuitable growing conditions, such as reduced soil moisture content and heat stress. Wagina's terrestrial forest is likely to be highly resilient to the projected increases in temperature, due to its high level of intactness, which sustains cooler temperatures within the forest ecosystem.

The projected increase in extreme rainfall events by 2090 is likely to affect gardens and plantations due to their modified state. The provision of food and raw materials is likely to be highly vulnerable to an increase in extreme rainfall events, due to the potential loss of plants and tree crops to localised flooding, loss of topsoil from erosion, and water logging of soils, all contributing to the potential reduction in crop yields. An increase in garden areas and extreme rainfall events may also reduce the resilience of streams to sediment run-off. New plant species with tolerance to high temperature and fluctuating rainfall may need to be explored to build crop resilience to the projected increase in temperature and extreme rainfall events, and strengthen Wagina's food security.

Similar to the projected temperature increases, terrestrial forests are likely to be resilient to an increase in extreme weather events due to their intactness and stable soils that reduce the potential for soil erosion. To maintain the resilience of forest ecosystem services to future climate and non-climate effects, management measures will need to be implemented (e.g. replanting programmes, allocation of protected areas, and sustainable clearing, harvesting and cultivation practices). Sustaining the high level of resilience by terrestrial forests will have positive flow-on effects to other ecosystem services, such as supporting terrestrial fauna and biodiversity and therefore strengthening Wagina's food security, and providing regulating services, such as climate regulation, prevention of soil erosion, primary productivity and maintaining stream water quality (which in turn enhances the water supply for Wagina Island residents).

8.2 Ecosystem-based adaptation options for Wagina Island

Through sustainable natural resource management, EbA integrates biodiversity and ecosystem services into an adaptation strategy. EbA contributes to reducing vulnerability and increasing resilience to both climate and non-climate risks, while enhancing ecosystems and services that continue to provide benefits to communities.

While Wagina Island is highly vulnerable to a changing climate, and is already experiencing adverse effects of climate change, human-induced threats may present a greater risk to the livelihoods of local communities and ecosystem health. In order to reduce the rate of environmental damage to the local and surrounding area and rebuild ecosystem health, a change in the current mindset and behaviour of Wagina residents towards sustainable harvesting and fishing is needed, as is also better management of sanitation and waste and water resources.

By highlighting ecosystem service vulnerabilities, opportunities can be identified that protect and restore critical ecosystems and their services and that retain and build on the strengths of existing community structures. Based on the ecosystem services and threats identified in the sections above, Table 8-1 outlines high level EbA options to help the communities of Wagina Island maintain healthy and well-functioning ecosystems that will be crucial to building community resilience and reducing vulnerability to the effects of climate change.

EbA at Wagina must be a community-led process to empower residents to plan for and adapt to the effects of climate change. Adaptation options must involve all sectors of the community to ensure that individuals feel a sense of ownership, provide direction for implementation, and build new skills that can be transferred to future challenges. For EbA options to be successful on Wagina Island, community environmental education and awareness on the value of ecosystems and ecosystems services is also critical.

Table 8-1 Suggested EbA options to increase the adaptive capacity and resilience of Wagina Island ecosystems

High Level Ecosystem Type	Most Vulnerable Ecosystem Services to Climate and Non-Climate Impacts	Anthropogenic and Non-Climate Stressors	Potential Climate Change Related Impact	Adaptation and Ecosystem Resilience Options	Key Stakeholders to Support EbA Option Implementation
Freshwater (groundwater, urban springs, rivers and streams)	• Drinking water supply • Habitat and biodiversity (lowland swamps) • Food provision (swamp taro during food shortages, and sago) • Raw material provision (sago leaves)	• Population growth • Modified river and creek banks and altered riparian vegetation from stream-side gardens • Clearing of vegetation in proximity to groundwater wells • Pollution from poor sanitation and waste management (including solid waste and domestic animal waste) and fuel spills • Habitat destruction by wild pigs (lowland swamps)	• Saltwater intrusion of groundwater wells from sea-level rise	• Land-use planning restrictions on steep and unstable soils • Food and water security programme (protection of food provisions that support the community in times of food and water shortages) • Clean Water Protection Program - Protection of wells with low exposure to saltwater intrusion - Replanting in proximity to groundwater wells - Pollution control and management of groundwater wells - Vegetation protection and riparian revegetation programme - Water quality testing and monitoring - Increasing and sustaining water storage capacity • Develop a wild pig control programme to protect garden resources, lowland swamps and forest resources	• Ministry of Environment, Climate Change, Disaster Management and Meteorology • Ministry of Education and Human Resources Development • Ministry of Women, Children and Youth • Ministry of Infrastructure and Development • The Nature Conservancy • World Wildlife Fund • Church • Women's groups • Schools • R-WASH • NPA Provincial member • Rural Development Program (RDP) • SPREP
Coastal and marine (mangroves, reefs, seagrass, marine lagoons, rocky shores, sandy beaches and islands, and	• Marine resources as a source of food, trade and income (turtle, shark, fish, molluscs, crustaceans) • Habitat and biodiversity (mangroves, marine lagoons, coral reefs, marine waters) • Raw materials (lime, coral rock)	• Population growth • Depletion of marine resources and loss of biodiversity from over-harvesting and poaching in protected areas • Physical destruction of reefs from anchorage and coral collection • Pollution from poor sanitation and waste management (including	Decline in reef ecosystem condition and coral dieback due to coral bleaching (rising temperature), ocean acidification, poor water quality (sedimentation due to extreme rainfall events). Exacerbated by	• Designation of coastal and marine protection areas • Implementation of species management plans (turtles, sharks) • Sustainable fisheries management • Sand island protection programme • Supporting seaweed farmers to build climate resilience • Coastal vegetation protection and revegetation	• Ministry of Fisheries and Marine Resources • Choiseul Provincial Fisheries • Ministry of Environment, Climate Change, Disaster Management and Meteorology • Ministry of Education and Human Resources Development • Ministry of Women, Children and Youth

High Level Ecosystem Type	Most Vulnerable Ecosystem Services to Climate and Non-Climate Impacts	Anthropogenic and Non-Climate Stressors	Potential Climate Change Related Impact	Adaptation and Ecosystem Resilience Options	Key Stakeholders to Support EbA Option Implementation
marine waters)	• Income generation (seaweed farming) • Coastal protection (attenuation and buffering of wave and storm energy by reefs) • *Kastom* medicine (seagrass) • Land (housing, services)	solid waste and domestic animal waste) and fuel spills • Clearing of coastal vegetation	more intense tropical cyclones. • Shift in marine ecosystem structure due to rise in sea temperature • Altered capacity for oceans to regulate climate from increased sea temperatures • Coastal erosion of sand islands and beaches from sea-level rise, storm surge and tropical cyclones • Permanent inundation of sand islands	• Land-use planning restrictions on coastal fringe • Installation of fish aggregating devices (FAD) • Environmental awareness and education programmes on the value of coral reefs for ecosystem services and sustainable fishing • Environmental awareness and education programmes on the purpose of the local MPAs with a large focus on over-harvesting, especially turtles, sharks and keystone species, e.g. parrotfish • Coral and seagrass transplanting trials at coral reefs and marine lagoons • Development of a coastal and intertidal rehabilitation programme - Educational programme on sustainable natural resource harvesting, including the consequences of over-harvesting and concentrated vegetation clearing (with no replanting) - Mangrove and coastal revegetation programme, including the creation of vegetation buffers - Educational signage - Assign 'Reveg Champions' (potentially a focus on high school students) – develop an understanding of the value of coastal vegetation and mangroves, key threats and adaptation protection measures • Development of a marine lagoon management programme - Education programme on the value of marine lagoons, effects of over-harvesting, and examples of sustainable fishing practices	• Ministry of Infrastructure and Development • The Nature Conservancy • World Wildlife Fund • Church • Women's group • Schools • R-WASH • NPA Provincial member • Rural Development Program (RDP) • SPREP

High Level Ecosystem Type	Most Vulnerable Ecosystem Services to Climate and Non-Climate Impacts	Anthropogenic and Non-Climate Stressors	Potential Climate Change Related Impact	Adaptation and Ecosystem Resilience Options	Key Stakeholders to Support EbA Option Implementation
				- Strengthening management and deterrence of visiting vessels contributing to over-harvesting - Education programme on pollution inputs from poor waste and sanitation practices from informal settlements located directly in the lagoons • Development of a mangrove rehabilitation programme for area located around Fourth River - Education programme on sustainable mangrove harvesting and the effects of concentrated clearing (with no replanting of mangroves) - Educational signage - Assign 'Mangrove Champions' – develop an understanding of the value of mangroves, key threats and protection measures.	
Terrestrial (forests, plantation and gardens)	• Provision of food (gardens and plantations) • Habitat and biodiversity • Provision of building materials (sago) • Supports timber milling • Provision of fuelwood • Provision of medicinal plants and trees	• Population growth • Forest clearing for expanding settlements and cultivation • Unsustainable harvesting for timber, fuelwood and medicine • Encroachment of gardens from expanding settlements • Excessive weed growth, destruction by feral animals • Theft of garden produce	• Soil erosion, sedimentation and landslip from extreme rainfall events. Exacerbated by more intense tropical cyclones. • Reduction in crop yield and soil cohesion and stability, and an increase in invasive species due to increase in temperature	• Designation of protected areas • Vegetation protection and catchment and riparian revegetation programme • Land-use planning restrictions on steep and unstable soils	• Ministry of Environment, Climate Change, Disaster Management and Meteorology • Ministry of Forests and Research • Ministry of Education and Human Resources Development • Ministry of Women, Children and Youth • Solomon Islands Water Authority • Ministry of Infrastructure and Development • The Nature Conservancy

High Level Ecosystem Type	Most Vulnerable Ecosystem Services to Climate and Non-Climate Impacts	Anthropogenic and Non-Climate Stressors	Potential Climate Change Related Impact	Adaptation and Ecosystem Resilience Options	Key Stakeholders to Support EbA Option Implementation
					• World Wildlife Fund • Church • Women's groups • Schools • NPA Provincial member • Rural Development Program (RDP) • SPREP

Glossary

Adaptation (to climate change)	Making changes in order to reduce the vulnerability of a community, society or system to the negative effects of climate change
Adaptive capacity	Capacity of a system to adapt if the environment where the system exists is changing
Biodiversity	Diversity within species, between species and of ecosystems; the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part
Climate change	Changes in the Earth's climate, due to human activities (anthropogenic climate change) or natural processes, which are already occurring or predicted to occur. Anthropogenic climate change is expected to happen much more rapidly than natural changes in the climate, posing an enormous challenge to both natural and human systems.
Ecosystem	A complex set of relationships of living organisms functioning as a unit and interacting with their physical environment
Ecosystem services	The benefits that an ecosystem provides to humans
Resilience	The capacity of a community, society or natural system to maintain its structure and functioning through stress or change
Risk	The effect of uncertainty on objectives (AS 5334:2013)
Sensitivity (to climate change)	The degree to which a system is affected, adversely or beneficially, by climate related stimuli (AS 5334:2013)
Vulnerability (to climate change)	The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (AS 5334:2013)

9 References and Bibliography

9.1 References

Abbott, I.A., (1999) Marine Red Algae of the Hawaiian Islands. Bishop Museum Press, Honolulu, Hawai'i.

Australian Bureau of Meteorology and CSIRO (2014a). Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report, Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation, Melbourne, Australia.

Australian Bureau of Meteorology and CSIRO (2014b). Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report, Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation, Melbourne, Australia.

BMT WBM (2017a) Solomon Islands ESRAM: Volume 1 – ESRAM Introduction and National Assessment. Prepared for the Secretariat of the Pacific Regional Environment Programme by BMT WBM, Brisbane.

BMT WBM (2017c) Solomon Islands ESRAM: Volume 3 Honiara. Prepared for the Secretariat of the Pacific Regional Environment Programme by BMT WBM, Brisbane.

Boseto, D., Morrison, C., Pikacha, P., Pitakia, T. (2007) Biodiversity and conservation of freshwater fishes in selected rivers on Choiseul Island, Solomon Islands. The South Pacific Journal of Natural Science 3: 16-21.

Boseto, D., Sirikolo, M. (2009) A report on the freshwater fishes and other fauna biodiversity of two proposed protected areas on southwest Choiseul Island, Solomon Islands. Report to World Wide Fund For Nature, 69pp.

Boseto, D., Pikacha, P. (2016) .A report on baseline biodiversity inventory of Mount Maetambe to Kolobangara river corridor, Choiseul Island, Solomon Islands. Melanesian Geo, Honiara.

BMT WBM (2014) Integrated Climate Change Risk and Adaptation Assessment to Inform Settlement Planning in Choiseul Bay, Solomon Islands Hazards Assessment. Prepared for the Australian Government Department of Environment by BMYT WBM, Brisbane.

BMT WBM (2016) Solomon Islands ESRAM: Volume 1 – ESRAM Introduction and National Assessment. Prepared for the Secretariat of the Pacific Regional Environment programme (SPREP) by BMT WBM, Brisbane.

Choiseul Province (2008) Choiseul Province Medium Term Development Plan, 2009-2011. Choiseul Provincial Government, Solomon Islands.

Department for Environment, Food and Rural Affairs (DEFRA) 2007 An introductory guide to valuing ecosystem services. DEFRA Publications.

Filardi, C., Boseto, D., Filardi, C. (2007) A preliminary desk study identifying important bird areas (IBAs) in the Solomon Islands. Birdlife International.

Flannery, T. (1995) Mammals of the South-west Pacific and Moluccan Islands. Reed Books, Chatswood.

Game, E., Lip-sett-Moore, G., Hamilton, R., Perterson, N., Kereseka, J., Atu, W., Watts, M., Possingham, H. (2010) Informed opportunism for conservation planning in the Solomon Islands. Conservation Letters 4:38-46.

Green, A., Lokani, P., Atu, W., Ramohia, P., Thomas, P., Almany, J. (eds.) (2006) Solomon Islands Marine Assessment: Technical report of a survey conducted May 13 to June 17, 2004. The Nature Conservancy – Pacific Island Countries, Report No. 1/06.

Groot, R. de, Brander, L., Ploeg, S. van der, Costanza, R., Bernard, F., Braat, L., Christie, M., Crossman, N., Ghermandi, A., Hein, L.G., Hussain, S., Kumar, P., McVittie, A., Portela, R., Rodriguez, L.C., Brink, P., Beukering, P., van (2012) Global estimates of the value of ecosystems and their services in monetary units. Ecosystem Services 1 ISSN 2212-0416 p.50-61.

Iacovino, C., Donohoe, P., Carruthers, T., Chape, S. (2013) Ecosystem-based adaptation and climate change vulnerability for Choiseul Province, Solomon Islands – a Synthesis Report. Secretariat of the Pacific Regional Environment Programme (in collaboration with SPC and GIZ), Apia, Samoa.

Keppel, G., Buckley Y., Possingham H. (2010) Drivers of lowland rain forest community assembly, species diversity and forest structure on islands in the tropical South Pacific. Journal of Ecology 98: 87–95.

Kronen (2010) Socio-economic Dimensions of Seaweed Farming in Solomon Islands. Prepared for the UN Food and Agriculture Organisation (FAO) and the Secretariat of the Pacific Community (SPC).

Lipsett-Moore, G., Hamilton, R., Peterson, N., Game, E., Atu, W., Kereseka, J., Pita, J., Ramohia, P., Siota, C. (2010). Ridges to Reefs Conservation Plan for Choiseul Province, Solomon Islands. The Nature Conservancy: TNC Pacific Islands Countries Report No. 2/10. 53 pp.

Mayr, E. & J. Diamond (2001). The Birds of Northern Melanesia: speciation, ecology, and biogeography. OUP, Oxford.

McClatchey, W.C., Sirikolo, M.Q., Boe, H., Biliki, E., Votboc, F. (2005) A proposed PABITRA study area on Lauru Island, Western Solomon islands. Pacific Science 59: 213-40.

McCoy, M. (2006) Reptiles of the Solomon Islands. CD-ROM Available from filmsolomons@gmail.com.

MDPAC (2011) National Development Strategy 2011 to 2020. Ministry of Development Planning and Aid Coordination, Honiara, Solomon Islands.

Mataki, M., Solo, G., Donohoe, P., Alele, D., Sikajajaka, L. (2013) Choiseul Province Climate Change Vulnerability and Adaptation Assessment Report. Prepared for Secretariat of the Pacific Community (SPC), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and Secretariat of the Pacific Regional Environment Programme (SPREP).

Menazza, S., Balasinorwala, T. (2012) Assessing ecosystem services for Lauru Protected Area Network (LPAN), Choiseul, Solomon Islands. The Economics of Ecosystems and Biodiversity, January 2012 (www. teebweb.org).

Morrison, C., Pikacha, P., Pitakia, T., Boseto, D, (2007) Herpetofauna, community education and logging on Choiseul Island, Solomon Islands: implications for conservation. Pacific Conservation Biology 13: 250-58.

National Statistical Office (2009) 2009 Population and Housing Census – Report on Economic Activity and Labour Force. Solomon Islands National Statistical Office, Ministry of Finance and Treasury, Honiara.

Pauku, R., Lapo, W, (2009) National Biodiversity Strategy and Action Plan for Solomon Islands. Solomon Islands Ministry of Environment, Conservation and Meteorology, Honiara.

Pauku, R, (2009) Solomon Islands Forestry Outlook Study. Working Paper Series – Working Paper No. APFSOS II/WP/2009/31. Prepared for the Solomon Islands Government.

Pikacha, P. (2008) Distribution, habitat preference and conservation status of the endemic giant rats Solomys ponceleti and S. salebrosus on Choiseul Island, Solomon Islands. Final Report (Project no. 700305) to BP Conservation Programme. 25pp.

Pikacha, P., Sirikolo, M. (2009) A report on the biodiversity of three proposed protected areas on southwest Choiseul island, Solomon Islands. Prepared for WWF (Solomon Islands) and Melanesian Geo (Solomon Islands) by Ecological Solutions Solomon Islands.

Ridgway, J., Coulson, F. I. E., Arthurs, J. W., & British Geological Survey. (1987). The geology of Choiseul and the Shortland Islands, Solomon Islands. London: H.M.S.O.

Solomon Islands Historical Encyclopaedia, (2013) Solomon Islands Historical Encyclopaedia, 1893-1978, accessed online at http://www.solomonencyclopaedia.net/biogs/E000118b.htm, September 2016.

Southwest Pacific Bauxite, 2014. Southwest Pacific Bauxite - Vaghena Island Bauxite Project, accessed online at http://www.swpbauxite.com/projects December 2016.

Tabe, T. (2011) Sapon Riki Ba Kain Toromon: A Study of the I-Kiribati Community in Solomon Islands. Masters Thesis, Univresity of Hawai'I at Mānoa.

TNC (2016) The Conservancy helped three communities come together to protect the Arnavon Islands, The Nature Conservancy, accessed online September 2016: http://www.nature.org/ourinitiatives/regions/asiaandthepacific/solomonislands/placesweprotect/arnavon-islands.xml

Turak, E. (2006) Coral Communities and Reef Health. In: Green, A., P. Lokani, W. Atu, P. Ramohia, P. Thomas and J. Almany (eds.) (2006) Solomon Islands Marine Assessment: Technical report of survey conducted May 13 to June 17, 2004. TNC Pacific Island Countries Report No. 1/06.

Wickham, F., Clarke, J., Yee, D., Pauku, R. (2012) National Climate Change Policy 2012-2017. Prepared for the Solomon Islands Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM).

9.2 Bibliography

Albert, S., Udy, J. and Tibbetts, I. (2008) Responses of algal communities to gradients in herbivore biomass and water quality in Marovo Lagoon, Solomon Islands. Coral Reefs. 27:73-82.

Albert, S., Udy, J., Tibbetts, I. (2013) Solomon Islands Marine Life – information on biology and management of marine resources. The University of Queensland, Brisbane.

BMT WBM (2014) Integrated Climate Change Risk and Adaptation Assessment to Inform Settlement Planning in Choiseul Bay, Solomon Islands Hazards Assessment. Prepared for the Australian Government Department of Environment by BMYT WBM, Brisbane.

Envi-Green Pacific (2012) Proposed project for Solomon Bauxite Limited (SBL) – Environmental Impact Assessment (EIA), Final Report. Prepared for Greenpac by Envi-Green Pacific Consultancy Limited, Fiji.

Envi-Green Pacific (2013) Environmental Impact Statement Supplementary Report: Proposed Bauxite mining, Vaghena, Choiseul, Solomon. Prepared for Greenpac and Solomon Bauxite Limited by Envi-Green Pacific Consultancy Limited, Fiji.

Feinberg, R. (2010) Marine resource conservation and prospects for environmental sustainability in Anuta, Solomon Islands. Singapore Journal of Tropical Geography 31:41-54.

Golder Associates (2014) Jejevo/Isabel B Project Environmental and Social Impact Assessment – Volume 3, Ecology Appendix B: Terrestrial Baseline Ecology Report. Prepared for Sumitomo Metal Mining, Solomon Islands Nickel Project.

Govan, H., Maeda, T., Warakohia, D., Atitete, T., Boso, D., Masu, R., Orirana, G., Schwarz, A., Vave-Karamui, A. (2015) From Village to village: local approaches to promoting spread of community based resource management: Lessons from Mararo Community Based Organisation, East ‘Are’are, Malaita Province, Solomon Islands. Report to IUCN Oceania Learning Component.

Jenkins, A., Allen, G., Boseto, D. (2008) *Lentipes solomonensis*, a new species of freshwater goby (Teleostei: Gobioidei: Sicydiinae) from the Solomon Islands. International Journal of Ichthyology (aqua) 14(4): 165-174.

Lavery, T., Pikacha, P., Fisher, D. (2016) Solomon Islands Forest Life – information on biology and management of forest resources. The University of Queensland, Brisbane.

Mueller-Dombois, D., Fosberg, R. (1998) Vegetation of the tropical Pacific Islands. New York, Springer-Verlag. 733 pp.

Pollard, E., Brodie, G., Thaman, R., Morrison, C. (2014) The use of herpetofauna and cultural values to identify priority conservation forests on Malaita, Solomon Islands. Pacific Conservation Biology 20(4): 354-362.

Appendix A Wagina Island Workshop Participants

a)

b)

c)

d)

Figure A-1 Participants at Nikumaroro Workshop, 18 September 2016

Figure A-2 Participants at Arariki Workshop, 19 September 2016

a) b)

c) d)

Figure A-3 Participants at Tekaranga Workshop, 20 September 2016

Figure A-4 Participants at Tengangea Workshop, 21 September 2016

Appendix B Ecosystem service values by biome

Summary of monetary values for each service per biome (values in Int.$/ha/year, 2007 price levels).

	Marine	Coral reefs	Coastal systems	Coastal wetlands [a]	Inland wetlands	Fresh water (rivers/ lakes)	Tropical forest	Temperate forest	Woodlands	Grasslands
Provisioning services	102	55,724	2396	2998	1659	1914	1828	671	253	1305
1 Food	93	677	2384	1111	614	106	200	299	52	1192
2 Water				1217	408	1808	27	191		60
3 Raw materials	8	21,528	12	358	425		84	181	170	53
4 Genetic resources		33,048		10			13			
5 Medicinal resources				301	99		1504			1
6 Ornamental resources		472			114				32	
Regulating services	65	171,478	25,847	171,515	17,364	187	2529	491	51	159
7 Air quality regulation							12			
8 Climate regulation	65	1188	479	65	488		2044	152	7	40
9 Disturbance moderation		16,991		5351	2986		66			
10 Regulation of water flows					5606		342			
11 Waste treatment		85		162,125	3015	187	6	7		75
12Erosion prevention		153,214	25,368	3929	2607		15	5	13	44
13 Nutrient cycling				45	1713		3	93		
14 Pollination							30		31	
15 Biological control					948		11	235		
Habitat services	5	16,210	375	17,138	2455	0	39	862	1277	1214
16 Nursery service		0	194	10,648	1287		16		1273	
17 Genetic diversity	5	16,210	180	6490	1168		23	862	3	1214
Cultural services	319	108,837	300	2193	4203	2166	867	990	7	193
18 Esthetic information		11,390			1292					167
19 Recreation	319	96,302	256	2193	2211	2166	867	989	7	26
20 Inspiration		0			700					
21 Spiritual experience			21							
22 Cognitive development		1145	22					1		
Total economic value	**491**	**352,249**	**28,917**	**193,845**	**25,682**	**4267**	**5264**	**3013**	**1588**	**2,871**

Numbers in the cells are averages of the values found for a particular service and biome. Calculations are based on a total of 665 values. For details see Appendix 1.

[a] Coastal systems include estuaries, continental shelf area and sea grass, but exclude wetlands like tidal marsh, mangroves and salt water wetlands.

Source: de Groot *et al.* 2012, p. 55.

Appendix C Results of well-water quality testing

Electrical conductivity (and pH) testing was conducted at village wells due to concerns about increasing salinity of well-water. Note that this was undertaken as a one-off measurement only and does not provide any indication of temporal variation. The results of this testing are presented graphically in Figure C-1, and spatially for each of the four villages in Figure C-2 to Figure C-5.

Electrical conductivity was compared against the indicative drinking water guidelines listed in Table C-1.

Table C-1 Indicative drinking water guidelines for electrical conductivity and salinity

Electrical conductivity	Palatability
EC < 940 µS/cm	**Good**
EC 940-1400 µS/cm	**Fair**
EC 1400-1875 µS/cm	**Poor**
EC > 1875 µS/cm	**Unacceptable**

Electrical conductivity of well-water at approximately 80% of wells was classed as 'good' (i.e. < 940 µS/cm) and suitable for drinking from a salinity perspective. Approximately 20 % (i.e. one in five) were considered poor to unacceptable for drinking, based on electrical conductivity.

There are no drinking water guidelines for pH, as humans are generally not affected by the pH of drinking water. While the pH of tested groundwater was acidic, ranging from approximately 3.7 to 5.7 (note that neutral pH is around 7), this remains within the pH range of drinks such as fruit juice (i.e. apple and orange juice typically range from 3.3 to 4.2).

Spatial mapping of the water quality data (Figure C-2 to Figure C-5) indicated two things.

- For electrical conductivity, all records for Nikumaroro were classified as good to fair. Poor to unacceptable electrical conductivity was recorded at only the three western villages, and generally only at wells in close proximity to the coastal side of the main road. The maximum distance from the coastline for an 'unacceptable' reading was approximately 100 m.
- The more acidic water quality results tended to be recorded at the two most western villages of Tekaranga and Tengangea. These villages are bounded by rivers (Te Rawa, First and Second Rivers) which are tannin stained (dystrophic) and may have acidic characteristics interacting with the ground water.

While not specifically tested (due to logistics involved in bacterial testing of water samples), of greater concern regarding the suitability of groundwater for drinking is the likely contamination of groundwater. Faecal contamination from poor sanitation practices is a particular concern, which, together with nutrient and chemicals inputs, is assumed to occur and present a serious human health risk. It is noted that the community mentioned that outbreaks of diarrhoea were frequent among the local community.

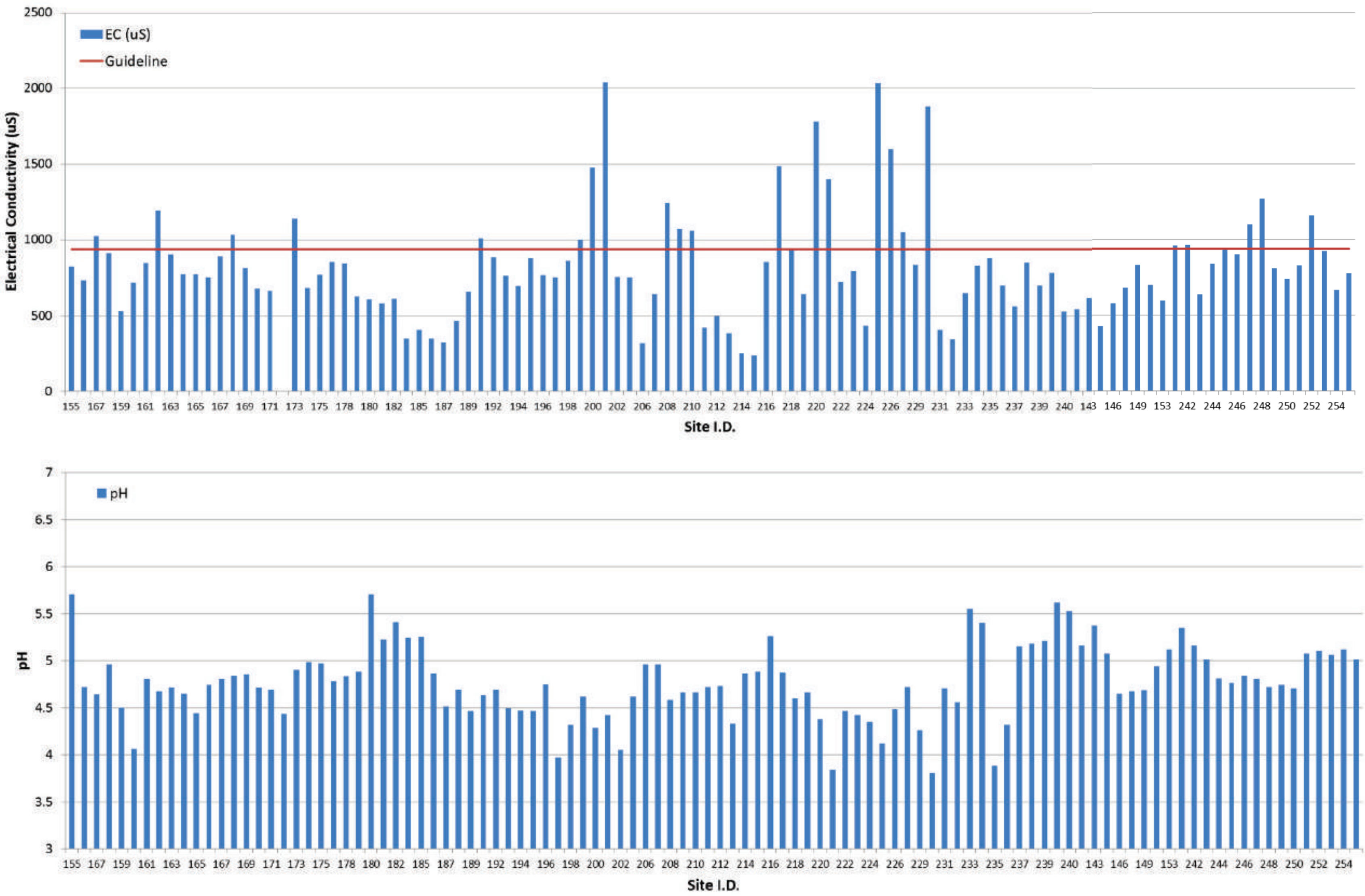


Figure C-1 Electrical conductivity (top) and pH (bottom) recorded at water quality testing sites on Wagina Island

Figure C-2 Spatial representation of the electrical conductivity (top) and pH (bottom) of well/spring waters at Nikumaroro village, September 2016

Figure C-3 Spatial representation of the electrical conductivity (top) and pH (bottom) of well-waters at Arariki village, September 2016

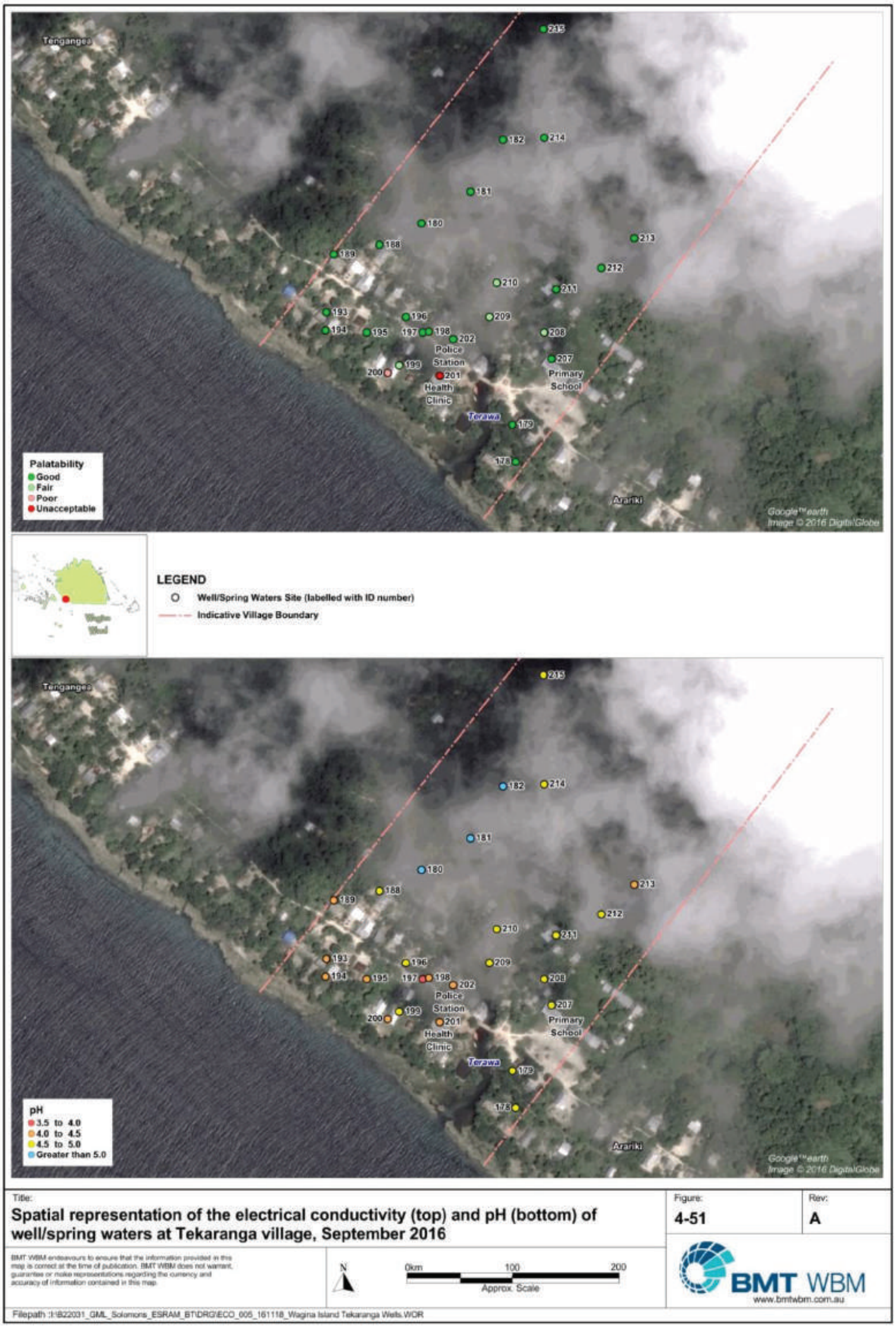


Figure C-4 Spatial representation of the electrical conductivity (top) and pH (bottom) of well/spring waters at Tekaranga village, September 2016

Figure C-5 Spatial representation of the electrical conductivity (top) and pH (bottom) of well/spring waters at Tengangea village, September 2016

Appendix D Wagina Island vulnerability assessment results

	Climate Variable	SLR										Increasing sea temperature										Extreme rainfall event									
	Time Slice and Scenario	2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5				
	Projection	- SLR of between approx. 7–18cm (very similar values for different RCPs) - Mean change: 13cm - Confidence level is medium					- SLR of between approx. 40–89 cm - Mean change: 63cm - Confidence level is medium					- Under all RCPs, the warming is up to 1.0°C relative to 1995 - Mean change: 0.7°C - Confidence level is very high					- Under all RCP8.5, the warming is up to 2 - 4°C - Mean change: 2.8°C - Confidence level is very high					- The current 1-in-20-year daily rainfall amount is projected to increase by approx. 9 mm - 3% increase in annual rainfall - Confidence level for frequency and intensity of extreme rainfall events is high					- Rainfall to increase by approx. 43 mm - current 1-in-20-year daily rainfall event will become, on average, a 1-in-4- year event - 6% increase in annual rainfall - Confidence level for frequency and intensity of extreme rainfall events is high				
Ecosystem	Ecosystem Service	SLR 2030	SLR 2030	SLR 2030	SLR 2030	SLR 2030	SLR 2090	SLR 2090	SLR 2090	SLR 2090	SLR 2090	Sea temp 2030	Sea temp 2030	Sea temp 2030	Sea temp 2030	Sea temp 2030	Sea temp 2090	Sea temp 2090	Sea temp 2090	Sea temp 2090	Sea temp 2090	Extreme rainfall	Extreme rainfall	Extreme rainfall	Extreme rainfall	Extreme rainfall	Extreme rainfall	Extreme rainfall	Extreme rainfall	Extreme rainfall	Extreme rainfall
		E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V
Terrestrial forest	Food (hunting)	0	1	0	1	0	1	1	1	1	1	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Terrestrial forest	Timber source - raw materials	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Terrestrial forest	Timber source - fuel / firewood	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Terrestrial forest	Toilet place	0	3	0	1	0	1	3	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Terrestrial forest	Fresh water filtration	0	3	0	2	0	1	3	3	2	6	0	0	0	1	0	0	0	0	1	0	3	1	3	2	6	3	2	6	2	12
Terrestrial forest	Biodiversity	0	3	0	2	0	1	3	3	2	6	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Terrestrial forest	Fresh groundwater replenishment	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Terrestrial forest	Erosion control	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	2	18
Lowland swamps	Raw materials (e.g. sago)	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	1	3	2	6	3	2	6	2	12
Lowland swamps	Giant swamp taro, sago – food security	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	1	3	2	6	3	2	6	2	12
Lowland swamps	Fresh water filtration	2	2	4	3	12	3	2	6	2	12	0	0	0	1	0	0	0	0	1	0	3	1	3	2	6	3	2	6	2	12
Lowland swamps	Fresh groundwater replenishment	2	2	4	3	12	3	2	6	2	12	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Lowland swamps	Flood control	2	2	4	2	8	3	2	6	2	12	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	2	18
Lowland swamps	Biodiversity	2	3	6	2	12	3	3	9	2	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Cultivated land (gardens)	Food source	1	3	3	1	3	2	3	6	1	6	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	2	18
Beaches and sand islands	Raw materials sources	2	1	2	2	4	3	1	3	2	6	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Beaches and sand islands	Canoe/boat landing	2	1	2	1	2	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Beaches and sand islands	Food source	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Beaches and sand islands	Coastal Protection	2	2	4	2	8	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Beaches and sand islands	Biodiversity	2	2	4	2	8	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Beaches and sand islands	Land source (for housing, transport, services e	3	3	9	3	27	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Rivers, streams and freshwater spring	Canoe landing	1	0	0	1	0	2	0	0	1	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Rivers, streams and freshwater spring	Fresh water source	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	3	18	3	3	9	3	27
Rivers, streams and freshwater spring	Toilet place and waste disposal	1	0	0	1	0	2	0	0	1	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Rivers, streams and freshwater spring	Washing area	1	2	2	2	4	2	2	4	2	8	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Rivers, streams and freshwater spring	Food source (stream side gardens)	1	3	3	2	6	2	3	6	2	12	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	2	18
Rivers, streams and freshwater spring	Food source (aquatic fauna)	1	3	3	2	6	2	3	6	2	12	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Rivers, streams and freshwater spring	Timber source	1	3	3	1	3	2	3	6	1	6	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Rivers, streams and freshwater spring	Fresh water filtration	1	3	3	2	6	2	3	6	2	12	0	0	0	1	0	0	0	0	1	0	3	1	3	2	6	3	2	6	2	12
Rivers, streams and freshwater spring	Biodiversity	1	3	3	2	6	2	3	6	2	12	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Rivers, streams and freshwater spring	Fresh groundwater replenishment	1	3	3	2	6	2	3	6	2	12	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Mangroves	Timber/trade source - raw materials	2	3	6	1	6	3	3	9	1	9	2	1	2	2	4	2	1	2	3	6	3	1	3	1	3	3	2	6	1	6
Mangroves	Timber source - fuel / firewood	2	3	6	1	6	3	3	9	1	9	2	1	2	2	4	2	1	2	3	6	3	1	3	1	3	3	2	6	1	6
Mangroves	Food source (fish, molluscs, crustaceans)	2	1	2	1	2	3	1	3	1	3	2	2	4	2	8	2	2	4	3	12	3	1	3	1	3	3	2	6	1	6
Mangroves	Food source (mangrove fruit)	2	3	6	1	6	3	3	9	1	9	2	1	2	2	4	2	1	2	3	6	3	1	3	1	3	3	2	6	1	6
Mangroves	Coastal protection	2	2	4	2	8	3	2	6	2	12	2	1	2	2	4	2	1	2	3	6	3	1	3	1	3	3	2	6	1	6
Mangroves	Biodiversity	2	3	6	1	6	3	3	9	1	9	2	2	4	2	8	2	2	4	3	12	3	1	3	1	3	3	2	6	1	6
Marine lagoons	Food/trade source (fish, molluscs, crustaceans	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0
Marine lagoons	Primary industry – seaweed farming	3	2	6	3	18	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0
Marine lagoons	Biodiversity	3	1	3	2	6	3	1	3	2	6	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0
Marine lagoons	Medicine (e.g. seagrass)	3	2	6	2	12	3	2	6	2	12	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0
Groundwater	Groundwater dependent ecosystems	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Groundwater	Water supply (human)	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	1	6
Reefs	Food/trade source (fish, molluscs, crustaceans	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0
Reefs	Sand source	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0
Reefs	Biodiversity	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0
Reefs	Coastal protection	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0
Reefs	Coral source – coral rock . lime	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0
Marine (open water)	Food/trade (fish, shark, turtle)	3	0	0	1	0	3	0	0	1	0	3	2	6	2	12	3	3	9	2	18	0	0	0	1	0	0	0	0	1	0
Cultivated land (plantations)	Raw materials	0	3	0	1	0	2	2	4	1	4	0	0	0	1	0	0	0	0	1	0	3	2	6	1	6	3	3	9	1	9
Cultivated land (plantations)	Kastom medicine/costumes	0	3	0	1	0	2	2	4	1	4	0	0	0	1	0	0	0	0	1	0	3	2	6	1	6	3	3	9	1	9
Cultivated land (plantations)	Food source	0	3	0	1	0	2	2	4	1	4	0	0	0	1	0	0	0	0	1	0	3	2	6	1	6	3	3	9	1	9
Cultivated land (plantations)	Betel nut (trade)	0	3	0	1	0	2	2	4	1	4	0	0	0	1	0	0	0	0	1	0	3	2	6	1	6	3	3	9	1	9
Terrestrial (other)	Land source (for housing, transport, services e	0	3	0	2	0	2	3	6	2	12	0	0	0	1	0	0	0	0	1	0	3	2	6	1	6	3	3	9	1	9
Rocky shore	Recreation	1	1	1	1	1	2	1	2	1	2	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Rocky shore	Waste disposal	1	2	2	1	2	2	2	4	1	4	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Rocky shore	Toilet place	1	2	2	1	2	2	2	4	1	4	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Rocky shore	Coastal protection	1	2	2	2	4	2	2	4	2	8	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Rocky shore	Anchorage	1	1	1	1	1	2	1	2	1	2	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0

	Climate Variable	Ocean acidification										Increasing Air Temperature										Extreme Air Temperature									
	Time Slice and Scenario	2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5				
	Projection	- Median aragonite saturation state w ill transition to marginal conditions (3.5) around 2030. - Mean change: -0.4 Ωar - Confidence level is medium					- Median aragonite saturation state w ill continue to strongly decline thereafter to values w here coral reefs have not historically been found (< 3.0). - Mean change: -1.5 Ωar - Confidence level is medium					- Under all RCPs, the w arming is up to 1.0°C, relative to 1995 - Mean change: 0.7'C - Confidence level is very high					- Under all RCP8.5, the w arming is up to 2 - 4°C - Mean change: 2.8'C - Confidence level is very high					- Temp on extremely hot days is projected to increase by about the same amount as average temp - Frequency of extremely hot days is also expected to increase. - Temp of the 1-in-20-year hot day is projected to increase by approx. 0.8°C					- Projected hot day temp increase and frequency is expected to increase as per 2030. - Temp of the 1-in-20-year hot day is projected to increase by approximately 2.9°C - Confidence level is very high				
Ecosystem	Ecosystem Service	Ocean Acidif	Ocean Acidif	Ocean Acidif	Ocean Acidif	Ocean Acidif	Ocean Acidif	Ocean Acidif	Ocean Acidif	Ocean Acidif	Ocean Acidif	Increasing Air	Increasing Air	Increasing Air	Increasing Air	Increasing Air	Increasing Air	Increasing Air	Increasing Air	Increasing Air	Increasing Air	Extreme Air	Extreme Air	Extreme Air	Extreme Air	Extreme Air	Extreme Air	Extreme Air	Extreme Air	Extreme Air	Extreme Air
		E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V
Terrestrial forest	Food (hunting)	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial forest	Timber source - raw materials	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial forest	Timber source - fuel / firew ood	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial forest	Toilet place	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Terrestrial forest	Fresh w ater filtration	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial forest	Biodiversity	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial forest	Fresh groundw ater replenishment	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial forest	Erosion control	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Low land sw amps	Raw materials (e.g. sago)	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Low land sw amps	Giant sw amp taro, sago – food security	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Low land sw amps	Fresh w ater filtration	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Low land sw amps	Fresh groundw ater replenishment	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Low land sw amps	Flood control	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Low land sw amps	Biodiversity	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Cultivated land (gardens)	Food source	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Beaches and sand islands	Raw materials sources	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Beaches and sand islands	Canoe/boat landing	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Beaches and sand islands	Food source	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Beaches and sand islands	Coastal Protection	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Beaches and sand islands	Biodiversity	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Beaches and sand islands	Land source (for housing, transport, services e	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Rivers, streams and freshw ater spring	Canoe landing	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Rivers, streams and freshw ater spring	Fresh w ater source	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Rivers, streams and freshw ater spring	Toilet place and w aste disposal	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Rivers, streams and freshw ater spring	Washing area	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Rivers, streams and freshw ater spring	Food source (stream side gardens)	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams and freshw ater spring	Food source (aquatic fauna)	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams and freshw ater spring	Timber source	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams and freshw ater spring	Fresh w ater filtration	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams and freshw ater spring	Biodiversity	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams and freshw ater spring	Fresh groundw ater replenishment	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Mangroves	Timber/trade source - raw materials	2	0	0	2	0	2	0	0	2	0	2	1	2	1	2	3	2	6	2	12	2	1	2	1	2	3	2	6	2	12
Mangroves	Timber source - fuel / firew ood	2	0	0	2	0	2	0	0	2	0	2	1	2	1	2	3	2	6	2	12	2	1	2	1	2	3	2	6	2	12
Mangroves	Food source (fish, molluscs, crustaceans)	2	2	4	2	8	2	3	6	2	12	2	2	4	1	4	3	3	9	2	18	2	2	4	1	4	3	3	9	2	18
Mangroves	Food source (mangrove fruit)	2	0	0	2	0	2	0	0	2	0	2	1	2	1	2	3	2	6	2	12	2	1	2	1	2	3	2	6	2	12
Mangroves	Coastal protection	2	0	0	2	0	2	0	0	2	0	2	1	2	1	2	3	2	6	2	12	2	1	2	1	2	3	2	6	2	12
Mangroves	Biodiversity	2	1	2	2	4	2	2	4	2	8	2	2	4	1	4	3	3	9	2	18	2	2	4	1	4	3	3	9	2	18
Marine lagoons	Food/trade source (fish, molluscs, crustaceans	3	2	6	2	12	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18
Marine lagoons	Primary industry – seaw eed farming	3	0	0	2	0	3	0	0	2	0	3	2	6	1	6	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18
Marine lagoons	Biodiversity	3	2	6	2	12	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18
Marine lagoons	Medicine (e.g. seagrass)	3	0	0	2	0	3	0	0	2	0	3	2	6	1	6	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18
Groundw ater	Groundw ater dependent ecosystems	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Groundw ater	Water supply (human)	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Reefs	Food/trade source (fish, molluscs, crustaceans	3	2	6	2	12	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18
Reefs	Sand source	3	2	6	2	12	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18
Reefs	Biodiversity	3	2	6	2	12	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18
Reefs	Coastal protection	3	2	6	2	12	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18
Reefs	Coral source – coral rock . lime	3	2	6	2	12	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18
Marine (open w ater)	Food/trade (fish, shark, turtle)	3	0	0	2	0	3	0	0	2	0	3	2	6	1	6	3	3	9	2	18	3	2	6	1	6	3	3	9	2	18
Cultivated land (plantations)	Raw materials	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Cultivated land (plantations)	Kastom medicine/costumes	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Cultivated land (plantations)	Food source	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Cultivated land (plantations)	Betel nut (trade)	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial (other)	Land source (for housing, transport, services e	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Rocky shore	Recreation	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Rocky shore	Waste disposal	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Rocky shore	Toilet place	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Rocky shore	Coastal protection	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0
Rocky shore	Anchorage	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	0	1	0	3	0	0	2	0

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