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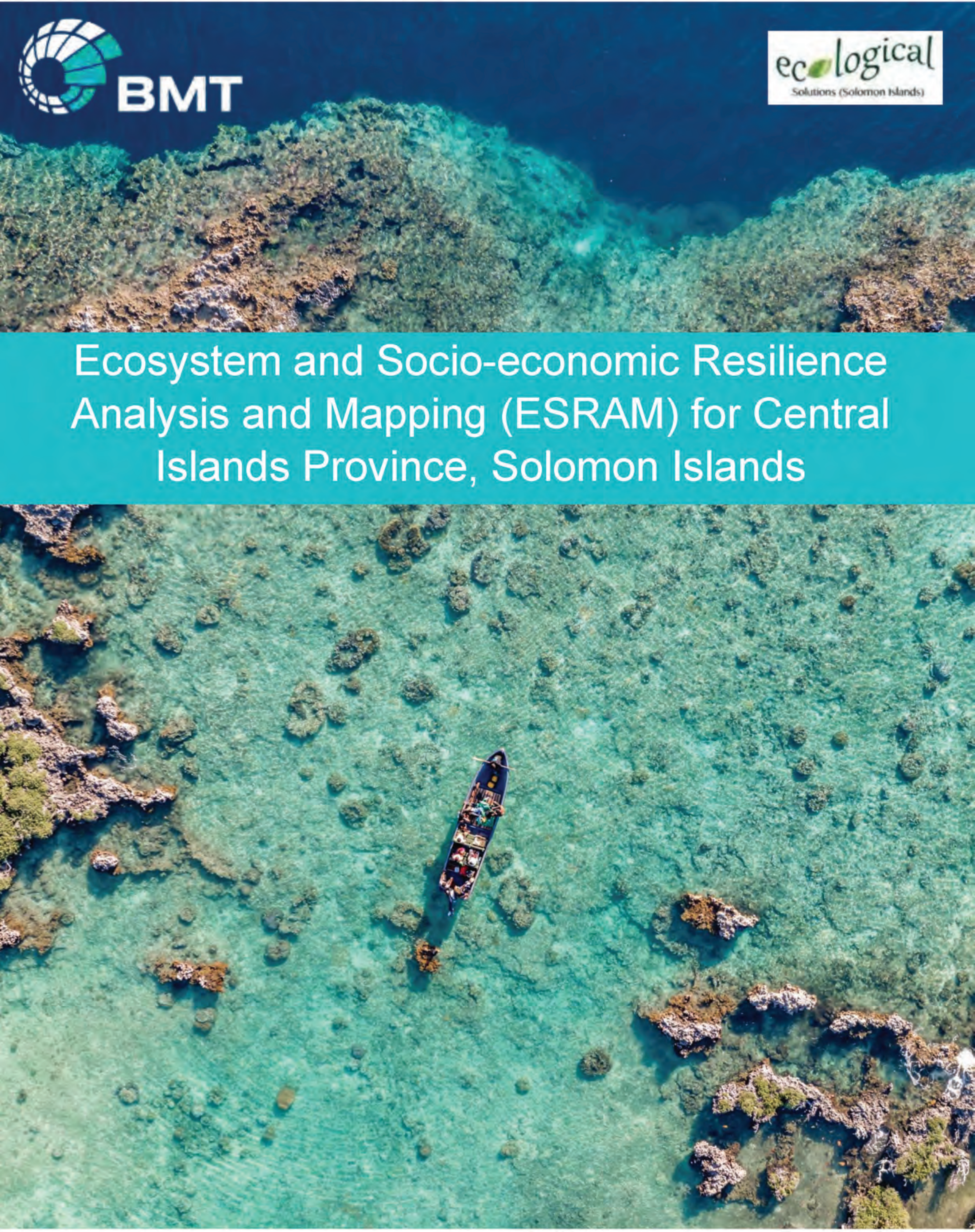

Ecosystem and Socio-economic Resilience Analysis and Mapping (ESRAM) for Central Islands Province, Solomon Islands

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Pacific BioScapes

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Author	Kara Borthwick
Checked By	Dr Beth Toki, Douglas Junior Pikacha (ESSI), Isaac Qoloni (ESSI), David Boseto (ESSI)
Certified By	
Approved By	Dr Beth Toki
Project Manager	Dr Beth Toki

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Cover Photo: the project team in northern Russell Islands, Douglas Junior Pikacha, ESSI

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From left to right: Chris Laore, Sabrina Pania, Thomas Yalu (who assisted WCS on the first week), Isaac Qoloni, Kara Borthwick, and Lucian Muala at Soka

From left to right: Douglas Junior Pikacha, Chris Laore, and Kara Borthwick at Karumulun

List of Acronyms

Acronym	Description
CBRM	Community Based Resource Management
CDD	Consecutive Dry Days
EBSA	Ecologically and Biologically Significant Areas
ENSO	El Niño Southern Oscillation
ESRAM	Ecosystem and Socio-economic Resilience Analysis and Mapping
ESSI	Ecological Solutions Solomon Islands
FAD	Fish Aggregating Device
GIS	Geographic Information Systems
GVP	Global Volcanism Program
IBA	Important Bird Area
IPCC	Intercontinental Panel on Climate Change
IUCN	International Union for Conservation of Nature
KBA	Key Biodiversity Area
LEDS	Low Emissions Development Strategy
LMMA	Locally Managed Marine Area
MACBIO	Marine and Coastal Biodiversity Management in the Pacific Islands
MAR	Mean Annual Rainfall
MECDM	Ministry of Environment, Climate Change, Disaster Management and Meteorology
MFMR	Ministry for Fisheries and Marine Resources
MMA	Marine Managed Area
MPA	Marine Protected Area
NCCP	National Climate Change Policy
OBM	Outboard Motorboat
PACCSAP	Pacific-Australia Climate Change Science and Adaptation Planning program
PEBACC	Pacific Ecosystem-based Adaptation to Climate Change
RIFA	Russell Islands Fisheries Association
SBD	Solomon Islands Dollar
SIBC	Solomon Islands Broadcasting Corporation
SIDS	Small Island Developing States
SLR	Sea Level Rise
SPI	Standard Precipitation Index
SPREP	Secretariat of the Pacific Regional Environment Programme
SSP	Shared Socio-economic Pathways
SST	Sea Surface Temperatures

Acronym	Description
SUMA	Special or Unique Marine Area
TEV	Total Economic Value
UN	United Nations
USD	United States Dollar
VO	Village Organiser
WCMC	World Conservation Monitoring Centre
WCS	Wildlife Conservation Society

Executive Summary

Project Overview

This project forms a component of the broader 'Pacific Biodiversity and Sustainable Land-Seascapes (Pacific BioScapes) Programme' project for the Solomon Islands. The Pacific BioScapes programme is funded by the European Union and is managed and implemented by SPREP. The programme has the overarching goal of contributing to the sustainable development of Pacific SIDS by supporting and improving the management and sustainable use of marine and coastal resources and adapting to climate change through ecosystem-based responses.

SPREP states that the regional initiative for the Solomon Islands is to implement an integrated conservation and development plan for the Solomon Islands Central Province seascape[1]. SPREP will be supported in this endeavour by in-country partner the Wildlife Conservation Society (WCS), who will work in close partnership with the Central Islands Provincial Government, Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM), Ministry of Fisheries and Marine Resources (MFMR) Community Based Resource Management (CBRM) Unit and the Solomon Islands Community Conservation Partnership to design and implement integrated coastal, marine and island conservation and development plans for the seascape.

The Pacific BioScapes programme has four key activities to deliver these outcomes:

1. Ecological and social resilience assessments (ESRAM assessments) completed as a basis for adaptation planning
2. Integrate land and sea management
3. Protect community watersheds
4. Build local capacity and strengthen livelihood opportunities.

Aims and Objectives

The objective of the present project is to deliver the first (of the above four) activities for the Pacific BioScapes programme in Central Province, Solomon Islands. The target area for the ESRAM assessment will focus on the land- and seascape comprising Nggela Islands, Russell Islands and Savo Island. This is largely due to the very high biodiversity values of their terrestrial and marine areas. The marine areas are also critically important for tourism activities, while the terrestrial lands are subject to intense land use pressures, land degradation and the impacts of climate change. The ESRAM assessment will serve as a robust planning information base and mapping tool providing knowledge on the vulnerability and resilience of ecosystems, populations, and the economy to existing and future threats, including the expected impacts of climate change. The assessment will also serve as a planning and decision-making tool for the numerous stakeholders involved (e.g. government, provinces, communities, private sector, civil society etc.).

Central Province ESRAM Outcomes

Central Province's ecosystems are critical to the long-term resilience and prosperity of local communities, and even more so in building community resilience to climate change. However, current anthropogenic pressures, in addition to the existing and future impacts of climate change, are threatening the services these ecosystems provide to local communities. Unsustainable harvesting practices, combined with population increase, is detrimentally impacting upon the health of Central Province's ecosystem values and potentially the health of the local community.

[1] https://www.sprep.org/bioscapes

Freshwater Ecosystems and Services

Freshwater ecosystems provide essential services to Central Province communities, particularly during times when food and water supply is limited. The key non-climatic threats to Central Province's freshwater ecosystem services are modified river and creek banks and altered riparian vegetation from stream side gardens, contamination of rivers and streams by chemicals (such as those used to treat mosquito nets), and increased sedimentation and contamination by illegal logging companies. The key climate threats to freshwater ecosystem services are saltwater intrusion into groundwater wells and lowland swamps from sea level rise, and more extreme wet/dry seasonal cycles reducing the accessibility of safe drinking water from rivers/streams (due to more frequent floods). 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 rivers and streams
- Provision of water for domestic uses (as well as backup drinking water source) provided by groundwater wells
- Provision of food provided by lowland swamps (swamp taro and sago)
- Supporting habitat and biodiversity by lowland swamps
- Raw material provision by lowland swamps (sago leaves)

Saltwater intrusion of groundwater wells is likely to be a critical issue for communities where wells are located in close proximity to the coast (e.g. Vuranimala, Soka, Panueli and Karumulun). Increased frequency of river/stream flooding from more extreme rainfall is most likely to affect Soka, Gumu and Vuranimala which rely on freshwater rivers/streams as their primary source of drinking water. The increased sedimentation and contamination of rivers and streams by illegal logging activities was identified as a critical issue on Nggela Islands, particularly for the communities of Gumu and Haleta, which are located near areas where illegal logging is known to occur.

The provision of food and water by freshwater swamps and groundwater wells are typically utilised during times of food shortages and prolonged dry periods where rainwater tanks and /or streams 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 and overall frequency of natural hazards which may impact on food and water supply. Protecting the ecosystems that provide the back-up services of today will strengthen the resilience of local residents to future impacts of climate change. The expected high vulnerability of freshwater 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 means for house building materials.

Coastal and Marine Ecosystems and Services

Marine and coastal ecosystem services are vital to the livelihoods and well-being of Central Province residents, particularly those in Nggela and Russell Islands. Fishing is the primary source of income for many communities along the Nggela coastline due to their proximity to Honiara and Tulagi markets. Fishing also presents a significant source of income for communities in Russell Islands, while Savo Island residents primarily harvest marine resources for subsistence purposes only.

Marine ecosystem services provide daily protein and nutrients, generate income, provide building materials and protect communities and the coastline from natural hazards and extreme weather events. The key anthropogenic threats to marine and coastal ecosystem services are unsustainable harvesting of marine resources, destructive fishing methods and the physical destruction of coral reefs for the collection of coral products. The increasing population will intensify these threats. Climate change impacts projected to have the most impact on coastal and marine ecosystem services are sea level rise and an increase in sea temperature and associated ocean acidification and coral bleaching. Coastal erosion on beaches and sand islands from the compounding impacts of coastal hazards (storm surges, extreme/king tides etc) and rising sea levels is also a critical issue for many Central Province communities (all except for Gumu). Land availability provided by beaches and sand islands is decreasing across Central Province due to sea level rise, with some communities like Karumulun already experiencing large portions of the island washing away. Projected sea level increases present a critical threat to communities with very little available land capital and low elevations (equating to a very low adaptive capacity).

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

- Provision of food, trade and income generation from local fisheries (fish, molluscs, crustaceans etc) provided by reefs, marine waters, mangroves and beaches
- Provision of habitat and biodiversity provided by reefs, marine waters and mangroves
- Provision of income generation (sale of megapode eggs) provided by sandy beaches on Savo Island
- Provision of raw materials (coral rock and lime production) provided by reefs
- 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 to the health and livelihoods of residents across Central Province, with the most significant being in Nggela Islands. The full extent of climate change impacts on marine resources are complex and may be unable to be avoided. 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. Reports from residents from all eight communities across Nggela, Savo and Russell Islands that some species abundance has declined, suggests that sustainable fisheries management and environmental education is urgently needed in Central Province.

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. Existing efforts to promote environmental awareness and establish protected and conservation areas by communities in the Russell Islands should be supported and encouraged.

Terrestrial Ecosystems and Services

Central Province's terrestrial forests appear to be in good health and provide important ecosystem services for the local community including the provision of food, medicine, timber and fuelwood. Gardens and plantations are essential for food provision and income generation, particularly for communities located further inland (Gumu). Communities on Savo island are also highly reliant on the sale of produce, which is the primary source of income alongside selling megapode eggs. Russell Island communities are especially reliant on coconut plantations for income generation as a result of their extensive history of plantations. The key threats to terrestrial forest ecosystem services are land clearing and overharvesting for timber (including by illegal logging practices), while gardens and plantations are threatened by unsustainable harvesting, destruction by pests and diseases (e.g. African Snail), encroachment from expanding villages from an increasing population, excessive weed growth and theft of garden produce.

The climate change projections likely to have the greatest impact on Central Province'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:

- Provision of food provided by terrestrial forests, gardens and plantations
- Generation of income from the sale of produce/products from terrestrial forests, gardens and plantations
- Provision of raw materials (timber, fuelwood and building materials) provided by terrestrial forests and plantations

In terms of food, building and medicinal provisions, terrestrial forests and gardens are essential to the survival of Central Province residents, particularly if marine food resources (or megapode eggs) are limited, income generation is low and the population continues to increase. 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 high climate fluctuations and a potential increase in pests and diseases, may need to be explored to strengthen Central Province's food security.

Terrestrial forests on Nggela and Savo are likely to be more resilient to the projected increases in temperature and rainfall due to their high level of intactness which sustains cooler temperatures within forest ecosystem and stable soils that reduce the potential for soil erosion. To maintain the resilience of forest ecosystem services to future climate and non-climate impacts, management measures will need to be implemented (e.g. replanting programs, allocation of protected areas, stronger enforcement of logging regulations 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 Central Province's food security, and providing regulating services such as climate regulation, prevention of soil erosion, primary productivity and maintaining stream water quality.

Conclusion

While Central Province is highly vulnerable to a changing climate, and is already experiencing several impacts from climate change, human induced threats may present a greater risk to the livelihoods of some local communities and ecosystem health. There are significant opportunities to improve community practices and promote the sustainable use of ecosystems to reduce environmental degradation and conserve critical ecosystem services for future generations. Findings from this ESRAM assessment indicate that the priority areas in most urgent need of support through ecosystem-based responses, in the context of sustaining ecosystems and ecosystem services, are:

- **Nggela Islands** – reefs and inshore marine areas which have been heavily impacted by destructive fishing methods and intensive overharvesting.
- **Savo Island** – megapode laying fields
- **Russell Islands** – offshore marine areas, coconut plantations, Karumulun Island, and existing MMAs and MPAs (to further strengthen these initiatives).

The BMT study team gratefully acknowledge the support and advice of our project partners, especially:

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1 Introductions

1.1 Background

This ESRAM assessment forms a key component of the *Pacific Biodiversity and Sustainable Land-Seascapes (Pacific BioScapes) Programme* Solomon Islands initiative. The Pacific BioScapes programme is funded by the European Union and contains regional initiatives for 11 Pacific Island nations. The programme has the overarching goal of contributing to the sustainable development of Pacific Small Island Developing States (SIDS) by supporting and improving the management and sustainable use of marine and coastal resources and adapting to climate change through ecosystem-based responses.

In the Solomon Islands context, the Pacific BioScapes initiative aims to implement an integrated conservation and development plan for the Central Province seascape to strengthen and protect key coastal ecosystems. The land- and seascape (comprising Nggela Islands, Savo Island and Russell Islands) was selected due to its very high biodiversity values, importance for tourism, exposure to intense land use pressures and degradation, and potential exposure to climate change impacts. The initiative is managed and implemented by SPREP with support from the Wildlife Conservation Society (WCS). WCS will work in close partnership with the Central Islands Provincial Government, Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM), Ministry of Fisheries and Marine Resources (MFMR) Community Based Resource Management (CBRM) Unit and the Solomon Islands Community Conservation Partnership to design and implement integrated coastal, marine and island conservation and development plans for Central Province.

The Pacific BioScapes initiative for Solomon Islands has four key components to deliver project outcomes:

1. **Ecological and social resilience assessments (ESRAM assessments) completed as a basis for adaptation planning**
2. Integration of fine-scale resource use and management priority information into the National Marine Spatial Plan
3. Formalizing management around priority areas through participatory approaches
4. Development of watershed management plans to prioritise places for investment in ecosystem-based adaptation (EbA).

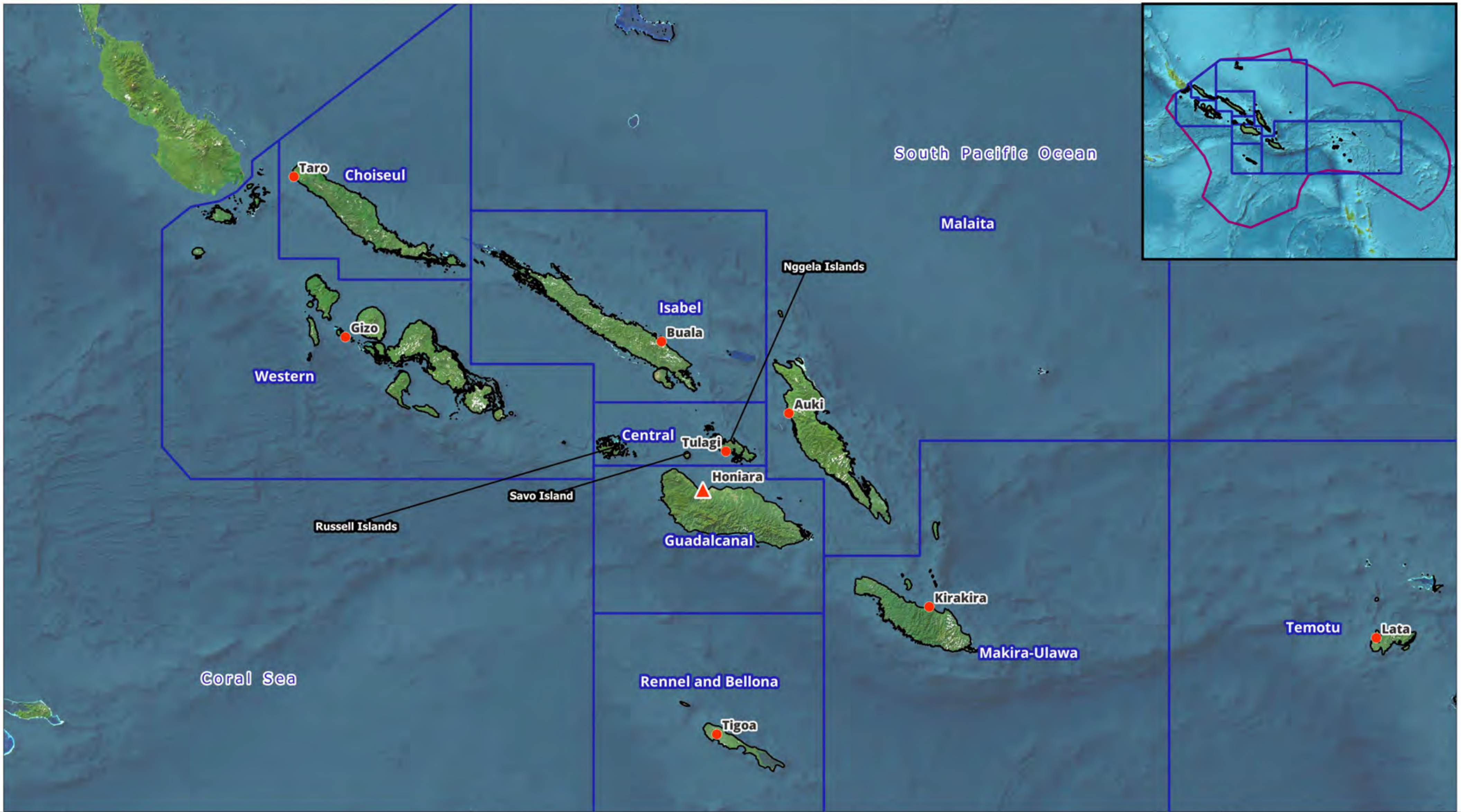
1.2 Aims and Objectives

This ESRAM assessment constitutes one of four key components of the Solomon Islands Pacific BioScapes initiative. The aim of the assessment is to serve as a robust planning information base and mapping tool which provided knowledge on the vulnerability and resilience of ecosystems, populations, and the economy to existing and future threats, including the expected impacts of climate change. The assessment will also serve as a planning and decision-making tool for the numerous stakeholders involved (e.g. government, provinces, communities, private sector, civil society etc.).

The specific objectives of the ESRAM study are to:

1. Identify socio-ecological values, sensitivities and threats in the context of:
    a. Ecosystem types present, in the context of the key ecosystem services
    b. 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

   c. Key ecosystem services in terms of direct community dependencies
   d. Role of ecosystem services in providing socio-ecological resilience
   e. Critical ecosystem linkages or dependencies
   f. Main existing sensitivities and threats to an ecosystem and/or ecosystem service
2. Map the locations of key ecosystems and related ecosystem services, critical environmental processes and associated socio-economic linkages (including high use areas and/or actual and potential future key threats)
3. Describe the natural variability (spatial and temporary), sensitivity and resilience for key values (where known).
4. Assess the vulnerability of ecosystems services to the impacts of climate change based on climate change projections and other existing threats
5. Undertake an economic valuation to define the economic value of key ecosystems and their services relevant to the ESRAM
6. Provide a ranking of key environmental and ecosystem assets and services according to their socio-economic value
7. Provide broad recommendations on how to enhance ecosystem and socio-economic resilience under different plausible future climate scenarios.



LEGEND
- ▲ National Capital
- ● Provincial Capital
- Solomon Islands Coastline
- Solomon islands Province Boundary
- Solomon Island EEZ

Title:
Location of Central Province and Nggela, Russell and Savo Islands

Figure: 1-1

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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2 Methodology

2.1 Study Approach

The Central Province ESRAM approach follows the methodology presented in Figure 2.1. This approach broadly aligns with those employed in previous Solomon Islands ESRAM studies for SPREP, specifically the prior National, Honiara and Choiseul Province / Wagina Island ESRAMs (BMT WBM 2017a, 2017b, 2017c), while also incorporating any improvements and lessons learned. Notably, the 'draft identification of socio-ecological values, sensitivities and threats' and 'community consultation, evaluation and validation' steps are closely linked via feedback loops to highlight the collaborative, non-linear process used to derive outcomes. While BMT collated a preliminary list of socio-ecological values, sensitivities and threats prior to in-country field work via desktop review, the final socio-ecological values, sensitivities and threats were ultimately largely informed by local knowledge sourced directly from each of the eight selected communities (see Section 2.3).

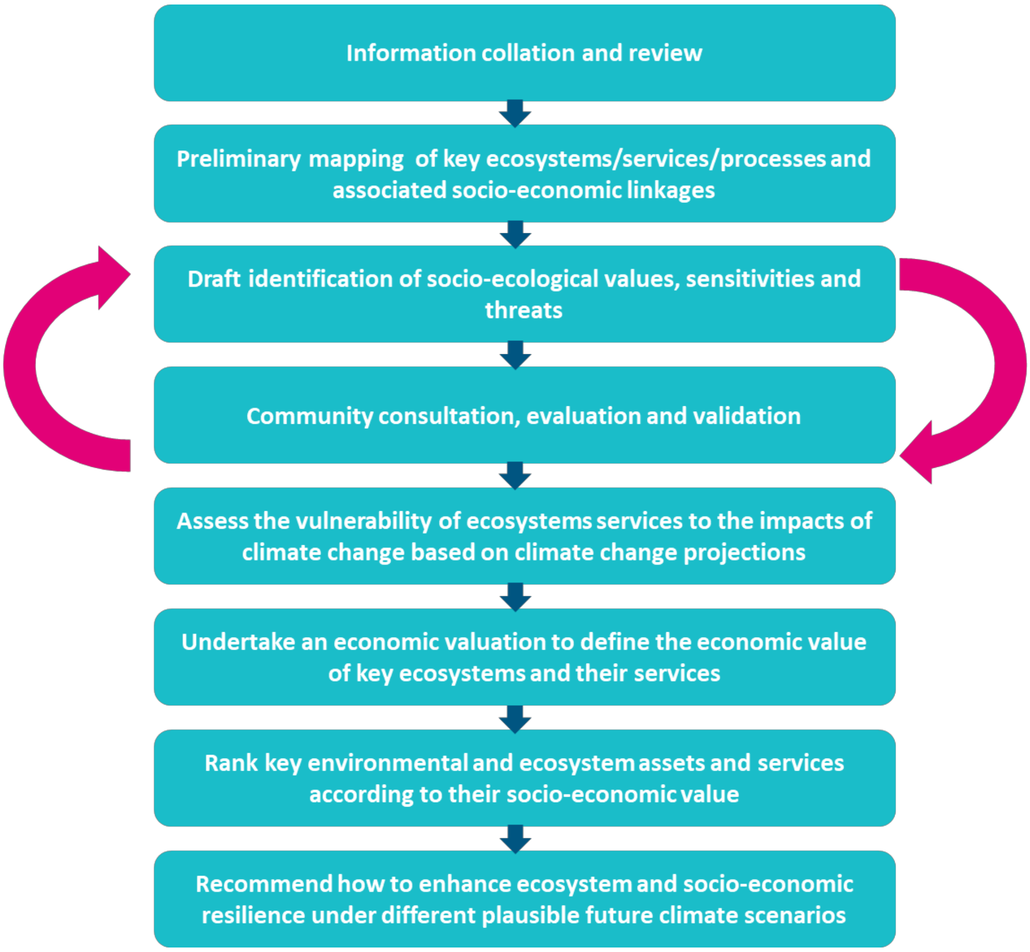

Figure 2.1 Methodology Framework

2.2 Preliminary Information Collation and Review

Table 2.1 provides a summary of the data sources which were reviewed as part of the 'information collation and review' project task. Available literature was grouped into the following key categories: climate change, waste, oceans, forestry, food security, freshwater and natural hazards. Any literature which contained information specific to either the Nggela, Savo or Russell Island groups was also collected.

In the context of the environmental aspects of the ESRAM assessments, there were significant gaps in the available literature. Despite the increase in environmental studies and assessments in recent times, environmental literature for the Solomon Islands remains concentrated on the ecosystems and/or ecosystem components that are deemed to either be of key conservation value (e.g. by having a high presence of endemic fauna, being in pristine condition or having high biodiversity) or direct economic importance (e.g. to fisheries and forestry industries) (BMT WBM, 2017a). Therefore, while some environmental components have been studied on numerous occasions, and in significant detail, the geographic coverage of available environmental information can still be very limited (BMT WBM, 2017a). This is especially true for Solomon Islands' Central Province, which has extensive gaps in knowledge despite the region harbouring high biodiversity values.

Russell Islands, Savo Island and Nggela Islands have all been largely overlooked by environmental literature. Existing available information for the Russell Islands typically comprises historical accounts of coconut plantation establishment on the islands, which provide useful social and cultural context (Davis, 1967; Larson, 1968). There has also been a previous survey conducted by Central Province Fisheries, the Locally Managed Marine Areas (LMMA) Network, MFMR, WorldFish and WCS regarding the impact of COVID-19 on fishing and coastal communities (Wale and LMMA Network, 2020). Savo Island has more recent literature available, particularly regarding food security (Georgeou and Hawksley 2015; 2017) and natural hazards (Petterson *et al.*, 2003). Nggela Islands has the most available information of the three island groups, with most literature focused on fisheries resource management and stock/health of commercially important marine species (e.g. Sulu, 2010; Tafea and Bebeu, 2007; Foale and Macintyre, 2000; Foale and Day, 1997). This aligns with previous observations in BMT WBM (2017a) that environmental literature in the Solomon Islands is typically concentrated on ecosystems and/or ecosystem components which have direct economic importance.

Table 2.1 Preliminary Information Collation Summary

Category		Year
BMT WBM Reports	*Solomon Islands ESRAM: Volume 1 – ESRAM Introduction and National Assessment*	2016
	Solomon Islands ESRAM: Volume 2 – Wagina Island (Choiseul Province)	2016
	GIS data provided by SPREP for *Solomon Islands ESRAM: Volume 1 – ESRAM Introduction and National Assessment* (specific datasets listed below)	2016
MACBIO Reports	*Developing a Marine Spatial Plan: A Toolkit for the Pacific*	2018
	Solomon Islands State of the Environment Report 2019	2021a
	Marine Turtle status report for the Solomon Islands	2024
	Solomon Islands National Ocean Policy 2018	2021b
	Marine Atlas Maximising Benefits for Solomon Islands	2019

Category		Year
	National Marine Ecosystem Service Valuation Solomon Islands	2015
	Biophysically Special, Unique Marine Areas of the Solomon Islands	2021
	Women and Disability in the context of climate mobility	2022
Climate Change	*Climate change adaptation as a development challenge to small Island states: A case study from the Solomon Islands*	2020
	Community-based adaptation to climate change in villages of Western Province, Solomon Islands	2020
	Economic impact of climate change and climate change adaptation strategies for fisheries sector in Solomon Islands: Implication for food security	2016
	Colonial Relocation and Implications for Future Climate Change Induced Migration and Displacement	2020
	Climate Change and Conflict in Solomon Islands	2023
	Solomon Islands National Climate Change Policy 2023 – 2032	2023a
	Pacific Island Mangroves in a Changing Climate and Rising Sea	2006
	Climate Risk Country Profile: Solomon Islands	2021
Waste	*Feasibility Report Solomon Islands: Scoping Study for Landfill Rehabilitation and/or Climate Proofing in Solomon Islands*	2023
	Solid Waste Management Country Profile Solomon Islands	2022
	SWAP Marine Litter Training – Solomon Islands	2023
	Waste Audit Report Solomon Islands	2023
	Project SnapShot Solomon Islands	2021
	Solomon Islands Profile Solid Waste	2018
	National Waste Management and Pollution Control Strategy, 2017 - 2026	2023b
	Solomon Islands National Waste Audit Analysis Report	2023
	PacWastePlus Country Profile: Solomon Islands	2020
Oceans	*Fisheries in the Economies of Pacific Island Countries and Territories: Updated catch reconstructions of Melanesia*	2016
	Preliminary Report on Inshore Fisheries Resources Marketed in Honiara, Solomon Islands	2016
	Status and potential of locally-managed marine areas in the Pacific Island Region: meeting nature conservation and sustainable livelihood targets through wide-spread implementation	2009
	Community Based Resource Management in Solomon Islands: Provincial Snapshots	2022
	Solomon Islands Community Based Coastal and Marine Resource Management Strategy	2021c

Category		Year
	A report on turtle harvest and trade in Solomon Islands	2019
	Coral reef conservation in Solomon Islands: Overcoming the policy implementation gap	2020
Forestry	*5th National Report on the Implementation of the Convention of the Biological Diversity*	2014
	Factors influencing smallholder commercial tree planting in Isabel Province, the Solomon Islands	2017
	Project Overview: The Project on Capacity Development for Sustainable Forest Resource Management in Solomon Islands	2020
	Tropical Rainforest Heritage of Solomon Islands	2008
	Global Forest Resources Assessment	2020
Food Security	*Malnutrition in rural Solomon Islands: An analysis of the problem and its drivers*	2019
Freshwater	*Geographical inequalities in drinking water in the Solomon Islands*	2020
Natural Hazards	*Solomon Islands Historical Encyclopaedia 1893-1978: Seismic Activity in Solomon Islands*	2020a
	Building Community Resilience in the Solomon Islands: Helping communities manage disaster and climate risk	2018
	Solomon Islands Disaster Management Reference Handbook	2023
	Disaster Risk Reduction in the Solomon Islands: Status Report	2023
Nggela Islands	*Multidisciplinary Appraisal of the Effectiveness of Customary Marine Tenure for Coral Reef Finfish Fisheries Management in Nggela (Solomon Islands)*	2010
	Dynamic and Flexible Aspects of Land and Marine Tenure at West Nggela: Implications for Marine Resource Management	2000
	Abundance of commercially important species of invertebrates, fish and the status of coral health in Community Based Marine Protected Areas in Gela, Central Province, Solomon Islands	2007
	Stock assessment of trochus (Trochus niloticus) (Gastropoda: Trochidae) fisheries at West Nggela, Solomon Islands	1997
Russell Islands	*Coconuts in the Russell Islands*	1947
	Tikopian Labour Migration to the Russell Islands	1968
	COVID-19 Impacts on Fishing and Coastal Communities	2020
Savo Island	*Challenges for Sustainable Communities in Solomon Islands: Food Production, Market Sale and Livelihoods on Savo Island*	2017
	Human Security and Livelihoods in Savo Island, Solomon Islands: Engaging with the Market Economy: A Report for Honiara City Council	2015
	The eruptive history and volcanic hazards of Savo, Solomon Islands	2003

2.3 Preliminary mapping

Geographic Information Systems (GIS) was used to map information sourced from the data collation task, as well as any additional relevant spatial data which already exists for Central Province. The preliminary mapping outputs were useful for providing a deeper understanding of the socio-ecological coupling which may take place in the target areas and how this varies spatially. The maps also allowed for clearer identification of data gaps. Preliminary mapping outputs are presented in Annex A and included the following datasets (where relevant):

- Solomon Islands National Government ministries spatial data sets previously provided to BMT by SPREP for the national scale ESRAM work in 2017 as part of the PEBACC project. Datasets included:
  - General administration data (e.g. settlements, health centres, wharves, schools, roads, logging roads, watercourses and ward boundaries)
  - Forest types
  - Swamps
  - White beaches
  - Seaweed farms
  - Plantations
- Special and Unique Marine Areas (SUMA) (Ceccarelli *et al.*, 2021)
- Mangroves (Bunting *et al.*, 2018)
- Coral Reefs (UNEP-WCMC *et al.*, 2021)
- Seagrass (UNEP-WCMC and Short, 2021)
- Saltmarsh (Mcowen *et al.*, 2017)
- Important Bird Areas (IBAs) (Birdlife, n.d.)
- Key Biodiversity Areas (KBAs) (IBAT, n.d.)
- Ecologically and Biologically Significant Areas (EBSAs) (Ecologically or Biologically Significant Marine Areas, 2024)
- Satellite imagery

The preliminary mapping was amended following the ‘community consultation, evaluation and validation’ task to ensure ecosystem extents were reflective of on-the-ground conditions. In addition, the maps were also updated to include the locations of ecosystem services (where possible) and associated socio-economic linkages (including high use areas and threats).

2.4 Draft Socio-Ecological Values, Sensitivities and Threats

As mentioned above, the ESRAM assessment for Central Province was largely informed by local knowledge sourced directly from eight communities through detailed consultation workshops. Insights from the preceding two tasks were used to build a preliminary list of socio-ecological values, sensitivities and threats to inform workshop design and prompt community discussion. However, this list was revised significantly (in part due to the lack of available Central Province-specific literature) following the community consultations.

2.5 Community Consultation, Evaluation and Validation

Community consultations were conducted at eight villages across Central Province. Five of these communities were located in Nggela Islands (Soka, Gumu, Toa, Vuranimala and Haleta), one was located on Savo Island (Panueli) and two were located in Russell Islands (Marulaon and Karumulun). Consultations were undertaken in late November, early December 2024 (25/11/24 – 05/12/24), with all communities (except those in Russell Islands) being consulted on separate days. Objectives of the consultation workshops were to:

- Advise community representatives from each village about the ESRAM study, its part in the Pacific BioScapes Programme, and the community's role in informing the ESRAM study. Explain relationship to existing programme contacts (i.e. BMT as project partners to WCS and the broader Pacific BioScapes team)
- Provide some awareness on ecosystems, ecosystem services and climate change in both the local (Nggela, Savo and Russell) context and that of the ESRAM/Pacific BioScapes projects
- Utilise and document the knowledge of the local community for informing the ESRAM study, with a particular focus on:
  - Identifying the most important local ecosystems as perceived by the community
  - Understanding why particular ecosystems were deemed as important. Documenting ecosystem services in terms of the community's direct dependence on their local land and sea resources, ascertaining the relative value of resources to the community (i.e. which resources are essential and/or valued most).
  - Undertaking interactive mapping exercises to spatially document ecosystem services, with a particular focus on high-use areas.
  - Identifying existing sensitivities and threats to the important local ecosystems and/or ecosystem services, noting that there is often a strong overlap between ecosystem services and existing threats to ecosystems (e.g. overexploitation for income).

Each consultation workshop was held in the respective village meeting house and was attended by approximately 20 active participants (Table 2.2). The only exception to this was Haleta, whereby the original consultation date had to be moved due to a funeral and the new date coincided with the community's graduation celebrations. This resulted in a decreased number of total participants (10) and change in venue (community members were voluntarily brought to the project team's accommodation in Tulagi to participate in the consultations). 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 (44-60%) of active participants at six of the eight villages, and approximately one quarter (29%) of participants at the remaining two villages (Soka and Marulaon).

During the interactive exercises to identify and map important local ecosystems and their services (i.e. why they are important), the participants for each workshop were divided into three groups. These were typically a women group, men group and youth group. At villages where the number of participants was lower, only two groups (one women and one men) were used (Haleta, Panueli and Karumulun). Following the interactive mapping exercise, all groups were brought back together to present their maps and ideas. An open discussion on the threats (often phrased as 'worries and concerns') to these important ecosystems was then facilitated by the project team to gain an understanding of the human and climate change threats perceived by the community to be impacting key ecosystems. The discussions also allowed for a greater understanding of what constituted priority / 'more severe' threats.

The project team conducting the consultations typically comprised of one person from BMT (Kara Borthwick), one person from ESSI (either Isaac Qoloni or Douglas Junior Pikacha) and the team's vessel skipper Laore who generously volunteered to assist in running the activities and explaining instructions in the native Gela dialect. In total, 152 community representatives were actively involved in the consultation workshops, together with the local Village Organiser (VO), the ESRAM project team and additional non-active observers/listeners. Photographs of example groups participating in these exercises are shown in Figure 2.2, while photographs of all participating groups are provided in Annex B.

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.
- Discussions with the broader WCS team who were conducting complementary project work alongside BMT's ESRAM trip. The WCS team had visited all eight communities before and were able to provide helpful insights into community life.
- Field surveys to map critical locations (e.g. in relation to the important local ecosystems and ecosystem services on which the community are directly dependent) and qualitatively assess the current condition of key ecosystems, particularly at high-use areas. GPS points and geolocated photographs were also taken at points of interest for validation.

Table 2.2 Summary of 2024 consultation attendees for each community

Community	Workshop date	Total number of active participants	Male proportion	Female proportion	Additional local observers	Project team
Soka	25th Nov	17	71% (12)	29% (5)	0	2 + VO and venue host
Gumu	26th Nov	21	52% (11)	48% (10)	10-15	3 + VO
Toa	27th Nov	28	57% (16)	43% (11)	12	3
Vuranimala	28th Nov	18	50% (9)	50% (9)	7	3 + VO
Haleta	29th Nov	10	40% (4)	60% (6)	0	3
Panueli	3rd Dec	16	50% (8)	50% (8)	13	3
Marulaon	5th Dec	24	71% (17)	29% (7)	3	3
Karumulun	5th Dec	18	56% (10)	44% (8)	8	3

A)

B)

C)

D)

Figure 2.2 Examples of groups participating at community workshops: a) youth at Soka, b) women at Toa, c) men at Vuranimala, d) women at Karumulun,

2.6 Economic Valuations

The purpose of quantifying values as part of the ESRAM process was to provide insights on the relative extent and magnitude of ecosystems and ecosystem service values across and between different environments (BMT WBM, 2017a). This study employed a similar, more simplified, ecosystem valuation methodology to previous ESRAM works, which were based on the concepts of Total Economic Value (TEV) and benefit transfer (BMT WBM, 2017a; 2017b). The TEV of ecosystem services, includes both use and non-use values and is sometimes also referred to as triple bottom line (TBL), with triple reflecting economic, environmental and social values (BMT WBM, 2017a). By definition, use values refer to the satisfaction that involves a physical encountering while non-use values involve no actual physical involvement (direct or indirect) with an entity (Kareiva *et al.*, 2012).

The calculation of non-use values can be difficult and is therefore typically done using 'benefit transfer' whereby ecosystem values calculated for one locality are used to estimate the values for another (similar) locality (BMT WBM, 2017a). This can be used to leverage previous non-use valuation studies, as well as to substitute for market values where local information is insufficient (e.g. fish prices from a neighbouring province or island could be used as a proxy for the target site).

Based on the methods in BMT WBM (2017a,b,c) the following framework was adopted for the economic valuation process:

1. **Filter and sort ecosystem services for valuation**: aggregate ecosystem services with reference to previous valuation studies (non-market values) and available economic information (market prices and production value).

2. **Establish ecosystem unit values**. Local scale data and information was used for establishing unit values in the first instance (i.e. 'bottom-up') and figures from other locations and were identified for benefit transfer (i.e. 'top-down') to fill any gaps. Values were presented in 2024 dollars, and in two currencies Solomon Island Dollars (SBD) and United States Dollars (USD). Where values were used from previous years, consumer price index figures were used to account for inflation based on government data. Where conversion was required, exchange was based on the December 2024 USD to SBD exchange rate of 1 USD = 8.3837 SBD. Where more localised values could not be identified, global median values were used. These values were sourced from a study by de Groot *et al.* (2012) which builds on over 320 publications and incorporates over 655 value estimates.

3. **Calculate ecosystem services**. Use spatial and socio-economic data to calculate indicative ecosystem service values across desired scale (i.e. Provincial). The values generated are indicative only and provide an estimate of their benefits to society - benefits that would be lost if they were destroyed or gained if they were restored.

It is worth noting that, as in the Wagina Island ESRAM (BMT WBM, 2017b), the most relevant and adaptable local information was found in the MACBIO National Marine Ecosystem Service Valuation, Solomon Islands (2015), which provides detailed data on ecosystem service values across the country. This information was used wherever applicable. It should be noted that while MACBIO provided a number of relatively robust and applicable values, many were quite specific and did not necessarily capture the full range of ecosystem services (BMT WBM, 2017b).

2.7 Climate Change Vulnerability Assessment

The key objective of ecosystem-based adaptation to climate change is to develop solutions that will help decrease vulnerability and increase the resilience of communities and ecosystems to climate change threats (BMT WBM, 2017b). Previous ESRAM studies have conducted Climate Change Vulnerability Assessments for both the national (Solomon Islands) and local (Wagina Island) scales using a quantitative vulnerability approach based on exposure, sensitivity and adaptive capacity (BMT WBM, 2017a; 2017b). Through this approach, the studies identified a key list of ecosystems (and their services) with high to very highly vulnerability to climate change.

This study builds on the results of the previous Climate Change Vulnerability Assessments by incorporating updated climate change projections to verify that the most significant climate threats remain consistent. Additionally, the study integrates qualitative data from Central Province communities to tailor the assessment specifically to Nggela Islands, Savo Island and Russell Islands. Updated climate change projection scenarios adopted for this study are discussed in Section 10.

Following a discussion of the updated climate change projections for the Solomon Islands and identification of the most significant near term and long term climate threats, the vulnerability of ecosystem services was assessed according to the below methodology:

- Additional provisioning, regulating, supporting and cultural ecosystem services which are relevant to the Central Province context, but were not explicitly identified by communities during consultations, were adopted from the National ESRAM report (BMT WBM, 2017a).

- Ecosystem services which are predicted to be vulnerable to various climate change variables for 2040 and 2100 were identified.

- A generic risk rating scale (green/yellow/red for low/medium/high risks) was assigned to each vulnerable ecosystem service based on a qualitative assessment of the predicted severity of expected climate change impacts.

3 Provincial Context

3.1 Central Province Setting

3.1.1 Geographic and Socio-Economic Setting

Central Province is situated in the centre of the Solomon Islands, directly north of Guadalcanal Island and the nation's capital city of Honiara (Figure 1.1). The province comprises three primary island groups: Nggela Islands, Savo Island and Russell Islands, which are divided into various wards (Figure 3.1). Nggela Islands are the largest island group in the province, occupying approximately 418.5 sq km and located between 8.883°S – 9.1962°S and 160.0008°E – 160.4146°E. The island group is comprised of four main islands: Buena Vista Island, Sandfly Island, Big Nggela (Nggela Sule) and Small Nggela (Nggela Pile). Big Nggela and Small Nggela are separated by the narrow Mboli Passage.

Russell Islands are the second largest island group in the province, occupying approximately 200 sq km and located between 8.9586°S – 9.1668°S and 159.0303°E – 159.3703°E. The island group is comprised of two main islands: Pavuvu and Mbanika, as well as numerous smaller islets. Savo Island is the smallest island in the province occupying approximately 29.5 sq km and located between 9.0999°S – 9.1648°S and 159.7843°E – 159.839°E. It is comprised entirely of an active forested stratavolcano with its peak at 485 m (Solomon Islands Historical Encyclopaedia, 2020a). Further detail on the geography of Nggela, Savo and Russell Islands are provided in the subsequent sections.

Central Province has a total population size of 30,326 according to the 2019 census, with an annual growth rate of 1.5% from 2009 – 2019 (MFMR/WorldFish, 2022). Approximately 5.6% of the population lives below the basic needs poverty line, which places it above the national average (MFMR/WorldFish, 2022). In Central Province, like most of the Solomon Islands, the majority of land is classified as 'Customary Land', with land rights being inherited via a unilineal inheritance (often matrilineally) (Foale and Macintyre, 2000). People also typically regard reefs as an extension of the land, with both being owned and managed by traditional genealogical groups, allowing rural communities to have autonomy over their natural resources and the right to open or close resource access (Abernathy et al. 2014, Furusawa et al. 2014).

There are a substantial number of rural communities in Central Province, with most occurring close to the coast and along major rivers. These communities are heavily dependent on natural resources, with most people conducting subsistence activities to sustain livelihoods and generate income. Most communities are only accessible via outboard motor boat (OBM) and rely on sea travel for transporting goods and services (Georgeou and Hawksley, 2015; 2017; MFMR/WorldFish, 2022; Tafea and Babeu, 2007; Wale and LMMA Network, 2020). In this rural, isolated setting, income for Central Province's communities is typically generated through small scale copra production, harvesting of marine products, agricultural production (i.e. fruit, vegetables and nuts), tourism revenue and small-scale timber export (Georgeou and Hawksley, 2015; 2017; MFMR/WorldFish, 2022; Tafea and Babeu, 2007; Wale and LMMA Network, 2020). A 2016 study of inshore fisheries resources marketed in Honiara found that Central Province was the largest supplier of inshore fisheries resources (Rhodes and Tua, 2016).

Crucially, the province is exposed to a wide variety of natural hazards such as earthquakes, landslides, extreme wet/dry seasons and potential volcanic eruptions from Savo Volcano which has experienced recent increases in seismic activity.

LEGEND

- ESRAM Communities
- Watercourses
- Roads
- Savo Ward Boundaries
- Nggela Ward Boundaries

Russell Ward Boundaries

- Lovukol
- Mbanika
- Pavuvu

Title:

Central Province

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3.1.2 Existing Climate

The climate of Central Province 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. Similar to most of the Solomon Islands, Central Province experiences a wetter season between November to April and a drier season between May to October. Temperature patterns remain largely consistent throughout the year, fluctuating between higher wet season temperatures of 30-32°C and lower dry season temperatures of 23-24°C (Weather Atlas, 2024a). Annual maximum and minimum temperatures have increased in Honiara since 1951 with maximum temperatures increasing at a rate of 0.15°C per decade (BMT WBM, 2017a).

Rainfall in the Solomon Islands is affected by the South Pacific Convergence Zone and the Intertropical Convergence Zone which bring bands of heavy rainfall and thunderstorm activity (BMT WBM, 2017a). The West Pacific Monsoon also influences rainfall in the Solomon Islands (BMT WBM, 2017a). The Solomon Islands typically has two distinct seasons, a wet season from November to April and a dry season from May to October (BMT WBM, 2017a).

While the islands of Central Province are all located at a similar latitude, there are variations in rainfall patterns from west to east. Data for the Provincial capital, Tulagi (located in Nggela Islands), indicate that mean annual rainfall (MAR) at Tulagi is approximately 1700 mm, with the highest monthly totals occurring in February and the lowest occurring in August (Figure 3.2). The National capital of Honiara, which is located further west closer to Savo Island, experiences slightly lower rainfall totals than Tulagi (1550 mm) but follows a similar pattern (Figure 3.2). In contrast, the climate of Russell Islands (located further west again) is typically much wetter than that of Honiara and Tulagi. Data for Yandina, the principal town on Mbanika in Russell Islands, showcases monthly average rainfall as high as 612 mm in some wet season months (e.g. March) (Weather Atlas, 2024b). The lowest monthly average rainfall is approximately 114 mm which is typically experienced in the dry season (June) (Weather Atlas, 2024b). This demonstrates the consistent exposure of Yandina, and Russell Islands more broadly, to heavy, frequent rainfall (Weather Atlas, 2024b).

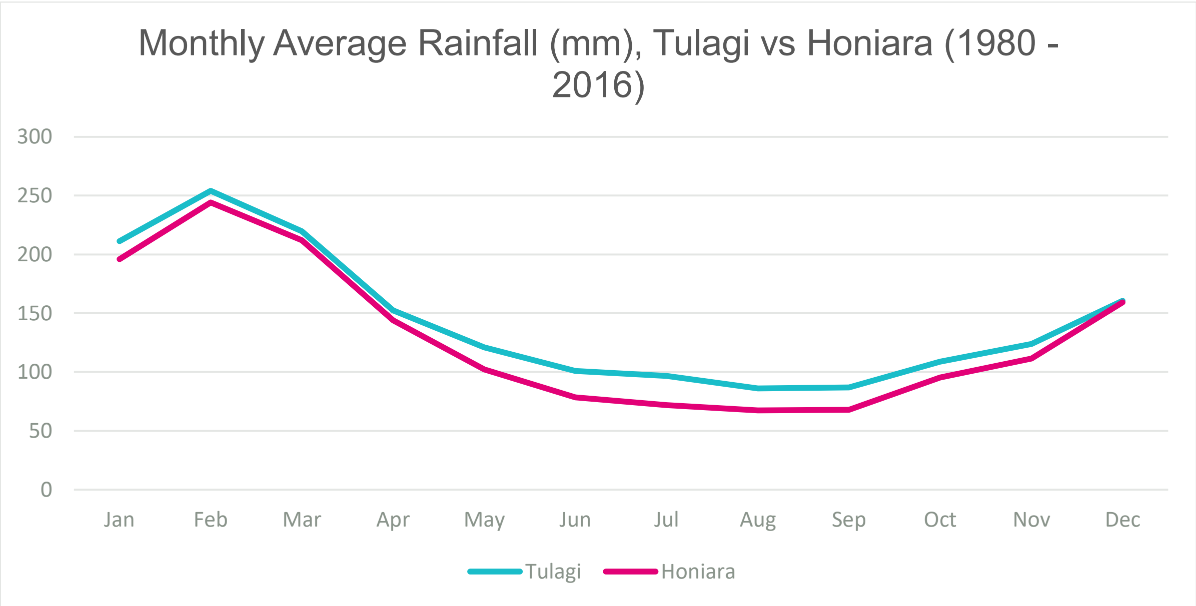


Figure 3.2 Monthly average rainfall comparison between Tulagi and Honiara (based on data from Weather Spark, 2025a; 2025b).

The wind-wave climate for the Solomon Islands shows strong interannual variability associated with the ENSO, as well as strong spatial variation across the region (BMT WBM, 2017a). Seasonally, they are primarily influenced by the trade winds, cyclone activity and the West Pacific Monsoon (CSIRO, 2014). During the wet season (December to March), the waves are from the north, while in the dry season (April to November) waves are from the east and northeast (CSIRO, 2014). Small waves (mean height around 0.15 m) occur around Honiara, which is sheltered from easterly trade winds, and larger waves occur on the outlying easterly islands. The height of a 1-in-50 year wave event on the north coast of Santa Cruz is 8.0 m (BMT WBM, 2017a).

Based on the 1969 to 2011 seasons, tropical cyclones occur mainly between November and April (wet season) with an average of 29 cyclones per decade (BMT WBM, 2017a). Cyclones were more frequent in El Niño years than in La Niña and neutral years (BMT WBM, 2017a). Of all the cyclones between 1981 and 2011, 27% were severe events (Category 3 or stronger), with the most intense events occurring during an El Niño (BMT WBM, 2017a).

3.1.3 Existing Ocean State

Sea levels have risen in the Solomon Islands by approximately 8 mm per year since 1993 (CSIRO, 2014). However, more recent data suggests that they are now rising at approximately 8 – 10 mm per year (compared to the global average of approximately 3.4 mm/yr) (The World Bank Group, 2021). The higher rate of rise may be related to natural fluctuations caused by the ENSO (BMT WBM, 2017a). The Solomon Islands are also experiencing ocean acidification, which affects corals by decreasing the carbonate ion concentration of seawater, making it harder for them to grow (BMT WBM, 2017a). A metastable form of calcium carbonate, aragonite, is used by hard reef building corals to build skeletons (BMT WBM, 2017a). For coral growth, saturation states above 4 are optimal, between 3 and 4 are marginal, with no corals historically found below 3 (Guinotte *et al.,* 2003). Aragonite saturation state has declined in the Solomon Islands region from approximately 4.5 in the late 18th century to an observed value of about 3.9 ± 0.1 by 2000.

3.1.4 Climate Change Governance

An updated National Climate Change Policy (NCCP) for the Solomon Islands was launched by MECDM in 2023 to build on the work of the first policy developed in 2012. The updated policy is intended to serve as an overarching policy instrument to address present and future risks from climate change, with a particular focus on turning climate change response into an opportunity (Government of the Solomon Islands, 2023). It is anticipated that interactions between climate change and various development actions will allow the Solomon Islands to capitalise on opportunities to strengthen its low emission status while supporting economic growth and strengthening resilience (Government of the Solomon Islands, 2023).

The first NCCP covered a period of 2012-2017 and had the primary focus of mainstreaming climate change across sectors. However, most of the policy objectives contained in the first NCCP were not implemented. This is in part due to the significant changes in regional, national and international climate change contexts which have occurred since the policy's inception (e.g. the establishment of the Paris Agreement, Sustainable Development Goals, Sendai Framework etc.) (Government of the Solomon Islands, 2023). Many of the policy objectives contained in the first NCCP therefore remain relevant and have been carried over into the updated NCCP outcomes, directives and strategies (Government of the Solomon Islands, 2023) The updated NCCP aligns with existing national, regional and international policies (Figure 3.3).

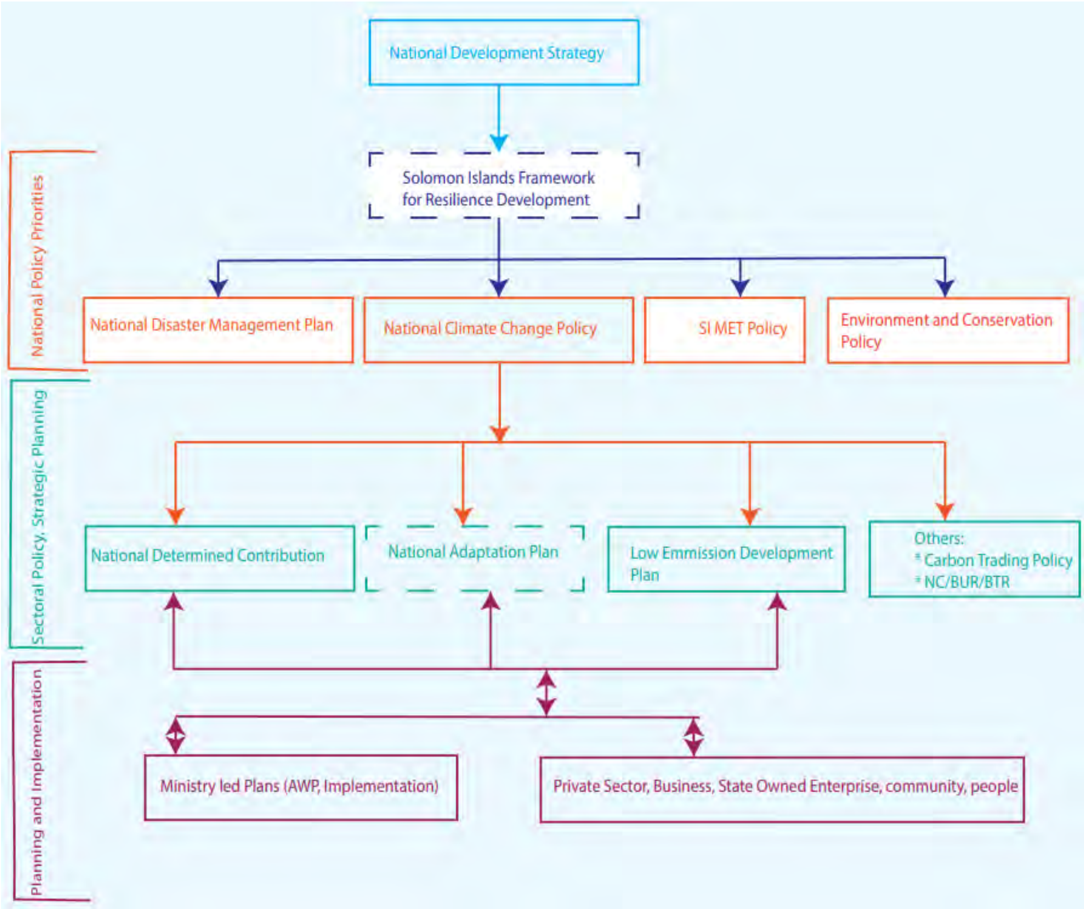


Figure 3.3 Climate change linkages (MEDCM, 2023 page 14).

3.2 Biodiversity Values, Ecosystem Threats and Conservation

3.2.1 Biodiversity values

Central Province is recognised for its high biodiversity values, with Nggela Islands (excluding Buena Vista Island) and western Russell Islands (Pavuvu) both classed as Key Biodiversity Areas (KBAs). However, there remains a paucity of environmental literature for Central Province, except for areas recognised as having direct economic importance. For example, most of the existing literature for Nggela Islands focuses on fisheries at West Nggela due to the presence of commercially important marine species. In addition, West Nggela contains the highest concentration of Nggela's local Marine Protected Areas (MPAs) which could contribute to its dominance in the literature. The Solomon Islands Rapid Marine Assessment also identified Russell Islands as having some of the highest biomasses of key fisheries species in the Solomon Islands (snappers, surgeonfishes, emperors, and parrotfishes) (Green *et al.*, 2006). At the provincial level, the catch from Central Province was represented by the second most diverse range of species (299 species) in the Solomon Islands, behind only Western Province (Rhodes and Tua, 2016).

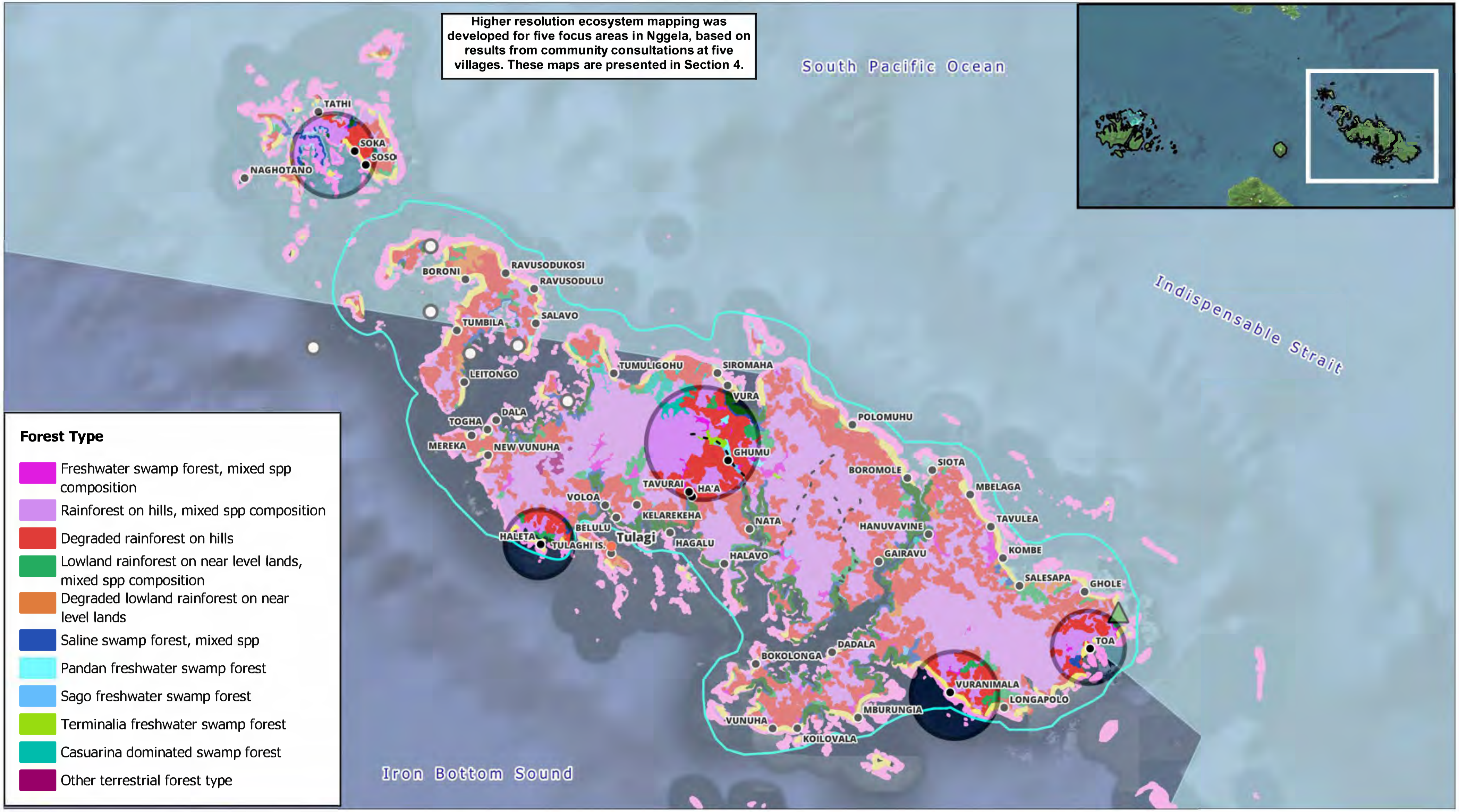
Both Nggella and Russell Islands are surrounded by fringing reefs and contain patch reef networks within their small lagoons (Green *et al.*, 2006). Savo Island is not surrounded by reefs, however, it is home to important spinner dolphin resting and breeding areas (Kahn, 2007). The preferred dolphin habitats are suspected to have remained stable for exceptionally long periods of time and often have been known to villagers for over five generations (Kahn, 2007). Indispensable Straight (east of Nggela) has also been identified as an important migratory corridor for large marine life (including blue whales) and is classified as a Special and Unique Marine Area (SUMA) (Kahn, 2007).

Figures 3.4 – 3.6 present ecosystem and land use mapping for Nggella, Savo and Russell Islands respectively. Most of the interior of Nggela Islands (excluding Buena Vista Island) is classified as mixed rainforest on hills that is either in good or degraded condition. Buena Vista Island is dominated by degraded mixed rainforest on hills, degraded lowland rainforests and saline swamp forests. The coastal fringe of Nggela, as well as areas bordering major rivers, support a greater diversity of forest types (e.g. various swamp forest types, lowland rainforest and mangroves). The largest stands of mangroves occur along the entire length of Mboli (Utaha) Passage separating the islands Nggela Sule and Nggela Pile, with fourteen recorded species (Ramohia and da Wheya, n.d.). It should be noted that Sandfly Island is largely dominated by degraded rainforest forest types.

Higher resolution forest data could not be obtained for Savo Island. However, it is anticipated that the island is dominated by mixed rainforest on hills in good condition. In addition, coral reef data from the WCMC (2021) shows coral reefs occurring around the perimeter of the island (Figure 3.5). No coral reefs were observed during the in-country consultations and the literature indicates an absence of coral reefs in the region due to the island's unique geology (e.g. Green *et al.*, 2006). UN WCMC data should therefore be treated as indicative only.

The eastern Russell Islands (Mbanika Island) is mainly classified as degraded rainforest on hills or degraded lowland rainforest and is dominated by coconut plantations. Some rainforest on hills in good condition is mapped towards the centre of Mbanika furthest from the coast. The western Russell Islands (Pavuvu Island) supports a greater diversity of forest types, including good condition rainforest on hills, lowland rainforest and upland forest on hills. Pavuvu also supports various swamp forest communities and significant stretches of mangroves along its northeastern coastline. Based on early mapping of the Russell Islands in Davis (1947), it is likely that the areas classified as degraded lowland rainforests on Pavuvu represent historic coconut plantations.

Very little information is available on the biodiversity of terrestrial fauna and avifauna in Central Province. However, Savo Island is particularly renowned for its population of megapode birds. The Melanesian megapode (*Megapodius eremita*) occurs on a few islands across the Solomon Islands but Savo Island is the most popular. It is thought that the heat from the volcanic sand incubates the eggs and makes the area attractive for megapode laying. Megapode eggs are the primary source of protein for Savo communities and their consumption and trade is critical for food security. The megapode bird is also very important culturally to the people of Savo Island.



Title:

Terrestrial vegetation and marine reefs for Nggela Islands

Figure: 3-4

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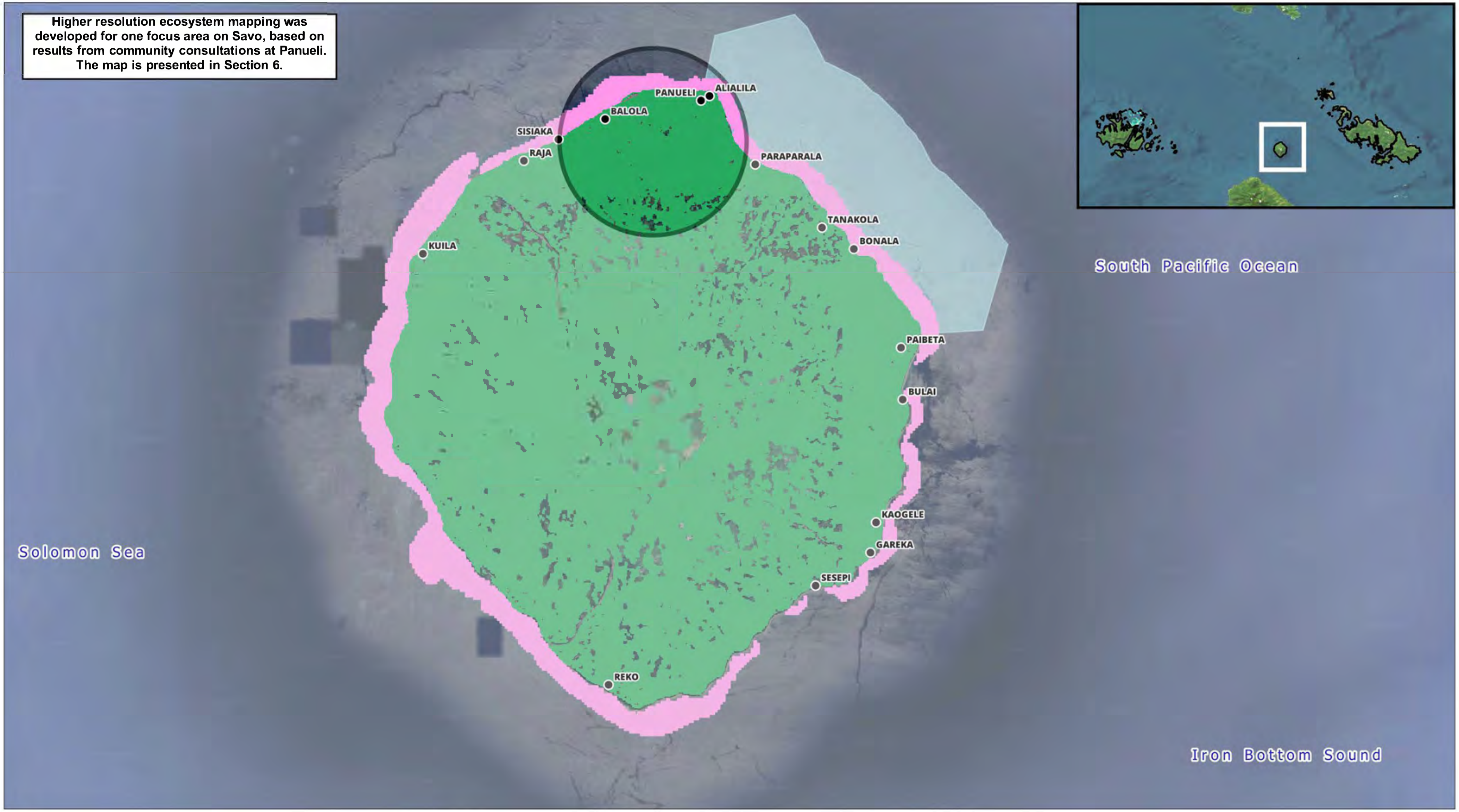

LEGEND

- Settlement
- Terrestrial forest (Brandt et al., 2023)
- Coral reef (WCMC, 2021)
- Special and Unique Marine Areas

Title:

Terrestrial vegetation and marine reefs for Savo Island

Figure: **3-5**

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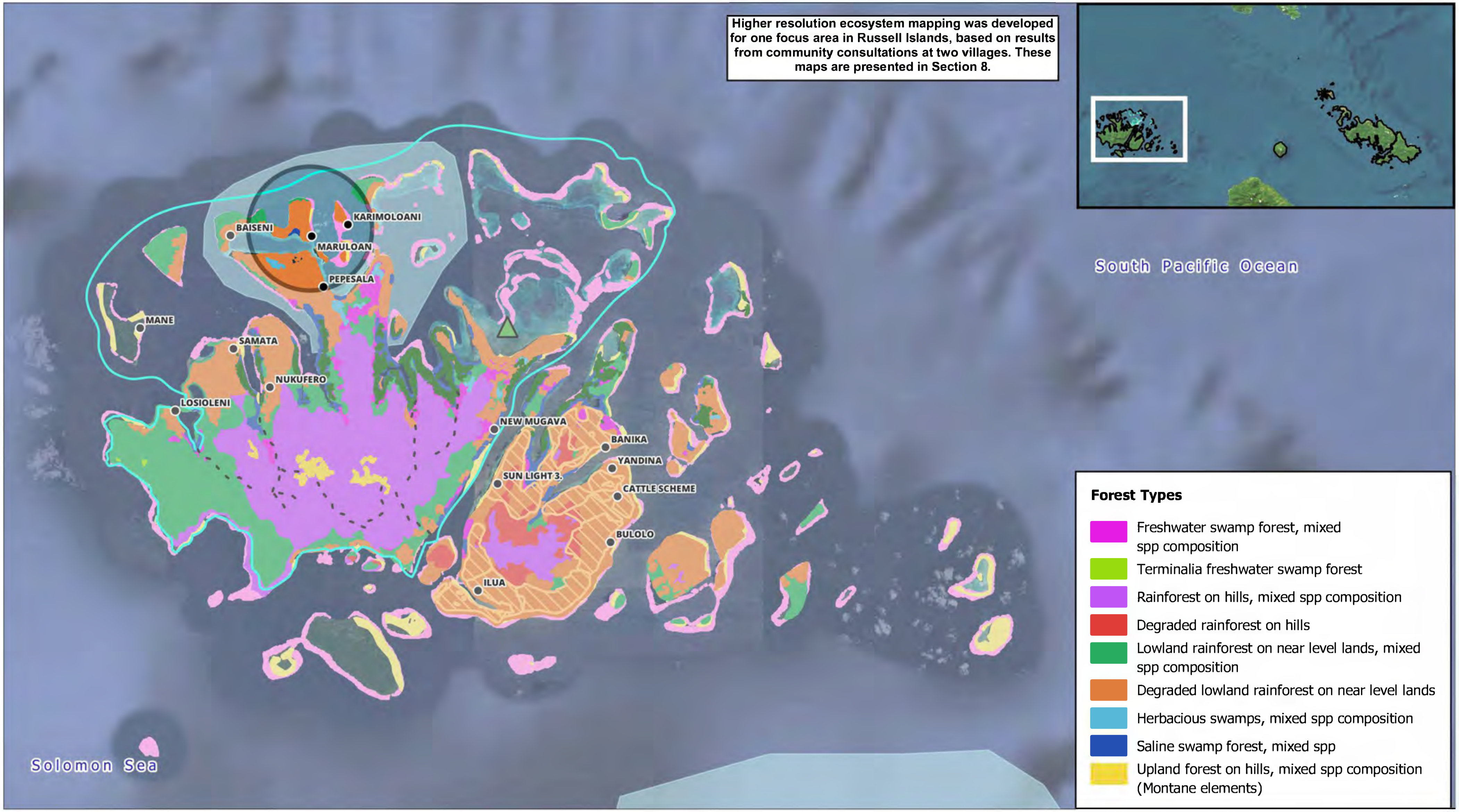

LEGEND

- Settlement
- Logging road
- Seaweed farm
- Key Biodiversity Area
- Mangroves (GMW, 2020)
- Plantation
- Special and Unique Marine Areas
- White beaches (approx.)
- Coral reefs (WCMC, 2021)

Title:

Terrestrial vegetation and marine reefs for Russell Islands

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3.2.2 Existing Ecosystem Threats

As mentioned in Section 3.1.1, the local economy and community livelihoods are dependent on natural resources. Overexploitation and/or unsustainable harvesting practices are therefore the major existing threat to local ecosystems. In Nggela and Russell Islands, overharvesting has specifically been recognised as a key threat to inshore reefs where substantial reductions in marine resources have been observed (MFMR/WorldFish, 2022; Tafea and Babeu, 2007). This has resulted in a shift towards fishing in offshore subtidal reefs where stocks are higher (Sulu, 2010). As previously mentioned, Central Province is among the largest suppliers of inshore fisheries resources to Honiara, signifying very high demands (Rhodes and Tua, 2016). In Savo Island, overharvesting of megapode eggs has become the primary area of concern (Georgeou and Hawksley, 2015; 2017). There are currently no formal resource management strategies in place to protect the megapode eggs from overharvesting and any eggs which are not harvested are typically because they have been missed (MECDM, 2014). Hunting pressures combined with destruction of suitable habitat may be causing the Savo Island megapode populations to become locally extinct. Overharvesting threats will be discussed in more detail in each Islands' respective sections (Sections 4 – 9).

Despite the Provincial government refusing to grant any new business licenses to logging and mining operations since 2019, logging still takes place on some islands illegally (Cannon, 2019). This is most notable on Nggela Islands, which have approximately 16 km of logging roads across the northwest and east Gela Wards. Logging roads open sensitive habitats on Nggela to the damaging environmental effects of logging, such as large-scale deforestation, soil erosion, sedimentation, soil compaction, extensive erosion and sediment runoff, increased suspended solids in waterways, and the resultant degradation of estuarine and marine environments through sedimentation (BMT WBM, 2017a). Global Witness estimates that the Solomon Islands export nearly twenty times the annual sustainable harvest, with much of this timber being harvested illegally (i.e. logging occurring outside areas allocated on licenses, or on private land without landowner approval) (Forest Trends, 2021).

Feral animals, or introduced pests such as rats, cats, cane toads and dogs, are an additional threat that cause habitat degradation and directly impact terrestrial ecosystems (BMT WBM 2017). This is also now considered a high risk for aquatic ecosystems due to the increasing number of local aquaculture ventures farming Tilapia (Boseto and Sirikolo, 2009).

3.2.3 Conservation

Formal conservation and environmental management approaches for Central Province's ecosystems remain largely under-developed. Conservation efforts for marine ecosystems typically consist of establishing locally implemented and managed protected areas, noting that almost all land and inshore areas are owned under customary tenure (MFMR/WorldFish, 2022; Foale and Macintyre, 2000). The establishment of such initiatives are largely facilitated by various local and regional conservation networks (e.g. West Lavukal Conservation Network, Russell Fisheries Network and Gela Russell Savo (GERUSA) Natural Resource Management Network), in partnership with the Central Province Fisheries Office. According to the Coral Triangle Marine Protected Area database, there are 26 active marine protected areas in Central Province (Figure 3.7) (Coral Triangle Atlas, 2015; Govan, 2009). Most of these protected areas occur in Nggela Islands (16), followed by Russell Islands (7) and then Savo Island (3). Of the 26 active marine protected areas, the vast majority (22) are voluntary locally managed marine areas (LMMAs) and 4 are voluntary marine protected areas / 'tabu' (taboo) areas.

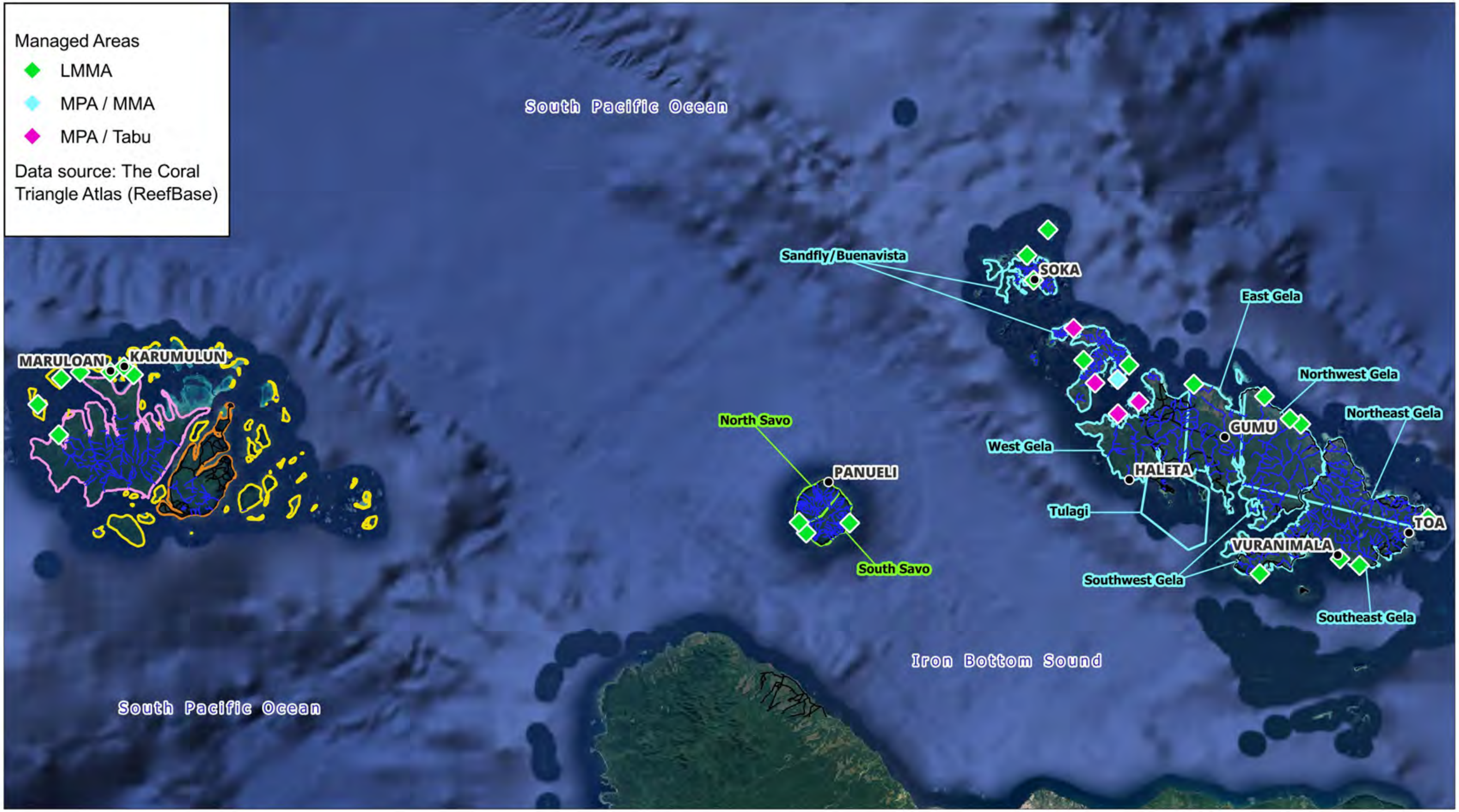
It should be noted that the Coral Triangle Marine Protected Area database may not capture all LMMAs which have been established in Central Province. For example, a recent report by the MFMR and WorldFish investigating community-based resource management in the Solomon Islands noted that the West Lavukal Conservation had worked with the Central Province Fisheries Office to establish nine community based marine managed areas within the Lavukal ward of the Russell Islands (MFMR/WorldFish, 2022). The Coral Triangle Marine Protected Area data from 2015 only shows 7

MPAs within this region. Additionally, during the in-country consultations, the project team was advised that the communities of Marulaon and Karumulun have a Marine Protected Area (MPA) agreement with the Fisheries Office around Kusuvau Island, which is not explicitly included in Coral Triangle mapping (Figure 3.7). The community based protected areas (Figure 3.7) are strict no-take areas, with harvest prohibition managed entirely by the customary owners of the sites.

LMMAs have reported numerous key benefits such as recovery of natural resources, improved food and tenure security, increased economic opportunities, improved governance, strengthened community organisation and cultural recovery (Govan, 2009). However, the LMMAs established on traditional reefs around Nggela Islands have had mixed results (Sulu, 2010; Tafea and Bebeu, 2007; Foale and Macintyre, 2000). At the time of writing there have been no studies undertaken on the effectiveness of LMMAs established around Savo Island or in the Russell Islands.

Formal protected areas for terrestrial ecosystems in Central Province are generally yet to be established, with the exception of some small scale locally managed areas (Figure 3.7). These are typically established by individual communities over a set period of time to ease the pressures of overharvesting. For example, during the in-country consultations, the project team was informed that Karumulun has banned all harvesting of coconut crabs, possums and shells from the island for five years, and Marulaon has no-take forest areas which the community want to preserve for future generations. These are discussed in more detail in Section 9.

As mentioned in the previous section, Central Province has also blocked all new logging and mining operations in the region to reduce ecosystem degradation. While these actions do not directly constitute conservation efforts, they are an important first step towards ecosystem preservation.



Title:

Central Province Managed Areas

Figure: 3-7

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4 Nggela Islands Context

4.1 Nggela Islands Setting

4.1.1 Geographic

Nggela Islands are located at the eastern extent of Central Province and house the provincial capital of Tulagi near the west coast of Nggela Sule (Big Nggela). The island group consists of 50 islands in total, with the largest being Nggela Sule, followed by Nggela Pile (Small Nggela), Sandfly Island and Buena Vista Island (Solomon Islands Historical Encyclopaedia, 2020b). Nggela Sule and Nggela Pile are separated by the narrow Mboli (or Utuha) Passage which provides an easy passage from Tulagi and Honiara to Malaita. The islands are composed of dense tropical rainforests on varying terrain, with elevations reaching up to 350m in some places. Coastlines are dominated by white coral beaches, as well as mangroves where the coastline is protected from the open ocean by smaller islets. Variations in terrain also manifest along the coastlines, with some communities bordered by steep rocky cliffs constraining them close to the sea. This project focuses on the following five Nggela communities: Soka (Buena Vista Island), Gumu (Big Nggela), Toa (Small Nggela), Vuranimala (Small Nggela) and Haleta (Big Nggela).

4.1.2 Cultural Context

In line with Central Province more broadly, the majority of Nggela land and inshore areas are owned under customary tenure. Any assessment of Nggela therefore needs to give due consideration to the underlying land tenure/rights and associated issues or conflicts. As discussed in Section 3.1.3, community-based resource management initiatives such as LMMAs have had mixed results in Nggela (Sulu, 2010; Tafea and Bebeu, 2007; Foale and Macintyre, 2000). Some studies have suggested that the dynamics of personal power and local level politics have hindered local management initiatives, particularly in West Gela (Foale and Macintyre, 2000). For example, Foale and Macintyre (2000) found that people who achieved influential social status within the community would often attempt to abuse the local land court system to acquire more marine access rights. Crucially, there has also been an observed cultural shift away from traditional regulatory systems which helped to curb exploitation drivers in the past, such as taboos (‘tabu’), prohibitions, belief systems, traditional ecological knowledge and traditional leadership/governance systems (Sulu, 2010). As a result, many communities across Nggela are believed to be losing respect for taboos enacted by chiefs and preferring to engage in more destructive, unsanctioned harvesting practices (Wairiu and Tabo, 2003 in Sulu, 2010). Refer to Sulu (2010) for further socio-cultural background on community-based resource management in Nggela Islands.

Nggela’s direct historical involvement in World War II military campaigns has also influenced many of the region’s communities. For example, communities on Buena Vista Island temporarily migrated to Sandfly Island since there was more places to shelter from bombings. In addition, the most common destructive fishing method employed in Nggela is ‘dynamite fishing’, which uses explosives constructed from leftover WWII ammunitions (Sulu, 2010). Tulagi was the seat of the administration of the British Solomon Islands prior to the 1942 Japanese invasion, and the island group subsequently became a key base of operations for the US, Australian and New Zealand war effort. At its peak, approximately 6,500 US troops were stationed in the Nggela group, outnumbering the indigenous population (Solomon Islands Historical Encyclopaedia, 2020b). Following the end of the war, the British administration and the Anglican Church relocated to the now-capital Honiara. Ultimately the European importance of the Nggela area declined and Tulagi was left in a state of post-war disrepair from which it never recovered (Solomon Islands Historical Encyclopaedia, 2020b).

4.1.3 Socio-Economic Profile

Nggela Islands are unique in that they were among the first islands to be exposed to European markets (Solomon Islands Historical Encyclopaedia, 2020b). This was due to early interactions with the Melanesian Mission in the late 1800s who developed a strong presence in the islands and built a series of permanent churches and schools on the islands (Solomon Islands Historical Encyclopaedia, 2020b). This allowed the population to access modern education and meant they were well placed to become the centre of both the Protectorate administration and the Melanesian Mission post 1920 (Solomon Islands Historical Encyclopaedia, 2020b). Once Tulagi and the attached commercial bases became better established in the late 1900s, the islands became the primary provider of food for the European and Chinese communities there (Solomon Islands Historical Encyclopaedia, 2020b). The significant foreign presence in the islands gave the Nggela communities access to large quantities of European goods (easily traded for local produce) and enhanced their dependence on the market economy (Solomon Islands Historical Encyclopaedia, 2020b). Further European trade benefits were experienced during the war as a result of significant foreign troop presence.

Today, Nggela Islands have some of the richest inshore fishing grounds in the Solomon Islands, however, overexploitation has led to perceived reductions in marine resources at inshore reefs (MFMR/WorldFish, 2022; Tafea and Babeu, 2007). Population growth has been a key driver of this overexploitation by increasing the number of people utilising marine resources for both subsistence and income generation (Sulu, 2010). It has also increased the competition for resources around Nggela, promoting the uptake of improved fishing technology and destructive fishing gear by fishermen (Sulu, 2010). There has therefore been a shift towards fishing in offshore sub tidal reefs (Sulu, 2010). The below figure from Sulu (2010) illustrates the extent of the fishing grounds belonging to 10 selected communities (Figure 4.1). Even among 10 communities, significant fishing ground overlaps are observed.

Fishing is the primary source of income for many communities along the Nggela coastline, particularly given the close proximity to Honiara and Tulagi markets (MFMR/WorldFish, 2022; Sulu, 2010; Tafea and Babeu, 2007). This proximity also attracts fishermen from neighbouring provinces who use destructive fishing techniques to increase their catches for market (Tafea and Babeu, 2007). The increased influence of the market economy has shifted livelihood patterns away from the traditional subsistence economy by increasing the reliance on externally produced products (e.g. clothes, tobacco, alcohol etc.) (Sulu, 2010). The dominance of the market economy further exacerbates existing overharvesting pressures and increases both intra-island and inter-island competition. This is especially true for islands in close proximity to major markets, such as Nggela.

It is common for fishermen to engage in more than one livelihood activity, which typically takes the form of subsistence gardening (Sulu, 2010). As a result, selling gardening produce at the markets is also a large component of income for many communities, particularly those situated on rivers. Fishing, and associated reliance on marine resources for income, is generally higher in the western zone of the islands (west of Tulagi) due to the smaller natural land capital and, subsequently, less space for subsistence gardening (Sulu, 2010). The islands also engage heavily in the trade of lime from corals for chewing betel nut, which has led to greater destruction of some reefs (MFMR/WorldFish, 2022). The lack of political will, as well as financial and human resources to enforce provincial ordinances (to protect coral reefs) have been identified as key barriers to effective fisheries management at Nggela (Sulu, 2010).

Recent discussions around conservation and food security have also prompted communities to request aquaculture projects to breed species such as Tilapia and Prawns for income and livelihood options (MFMR and WorldFish, 2022). Other initiatives to enhance food security within Nggela Islands include the installation of Fish Aggregating Devices (FADs) and establishment of seaweed farms, although funds for these projects are limited (MFMR and WorldFish, 2022).

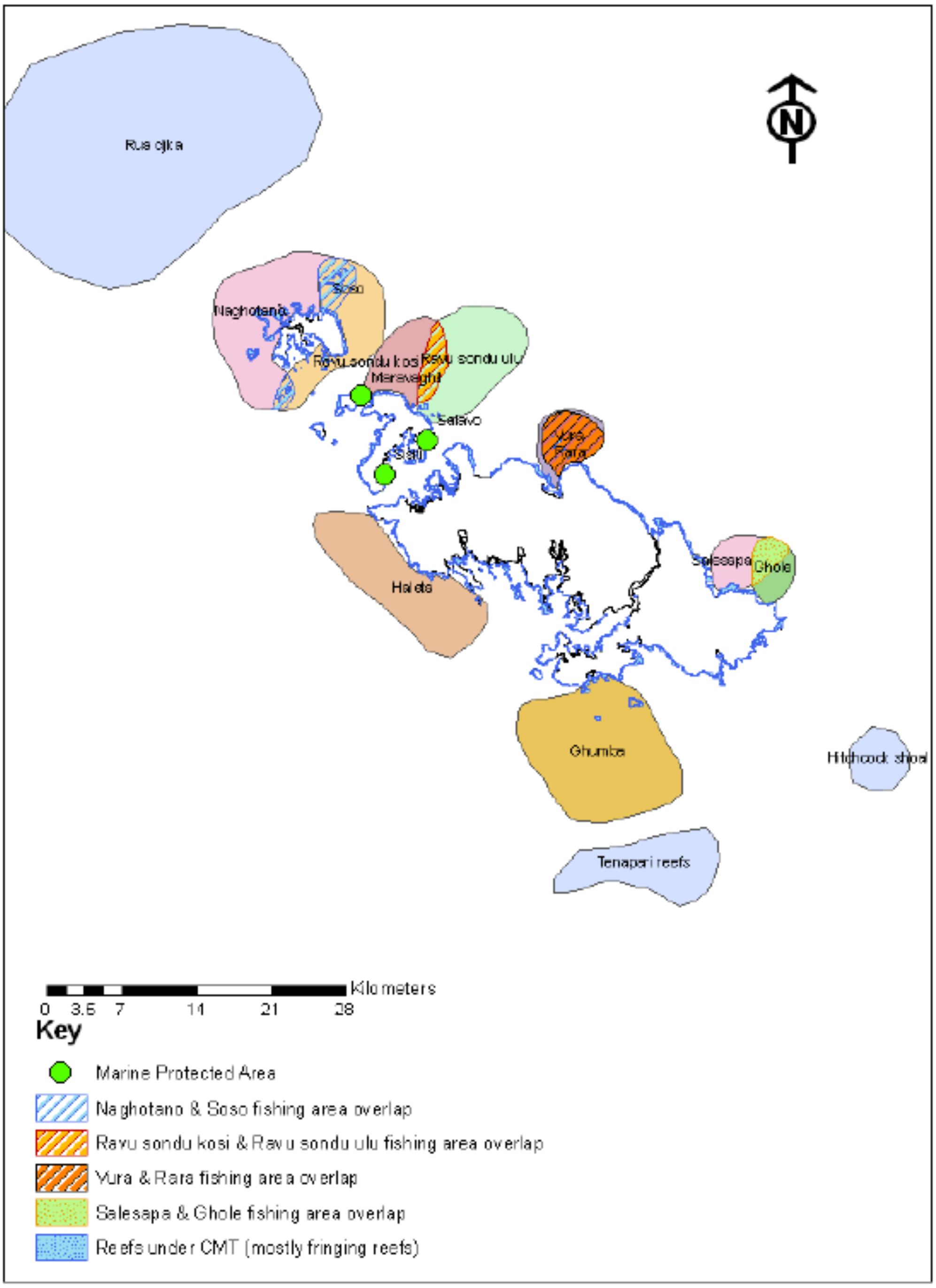


Figure 4.1 Map showing the spatial range of fishing activity for 10 study villages and overlaps in fishing space (from Sulu, 2010 page 113)

5 Nggela Islands Socio-Ecological Values, Sensitivities and Threats

Nggela communities are almost entirely dependent on their surrounding ecosystems to sustain their livelihoods and earn an income. The social, cultural and economic values of each community are therefore directly intertwined with the surrounding ecosystem values. While the ecosystems have intrinsic values, they are more often regarded by the communities as having instrumental value in the form of provision of ecosystem services.

This section provides a description of the key ecosystems directly utilised by the five Nggela communities and the associated ecosystem services which constitute their value for each community. The section also includes a summary of the human and climate threats ('worries and concerns') to each ecosystem (and its services) identified by the local community. Sensitivities of ecosystems and their services to human and climate change threats are briefly discussed, however, sensitivities to climate change-related threats will be discussed in more detail in the Climate Change Vulnerability Assessment (Section 11).

In order to accurately document and convey the concepts and values communicated to us by the communities, we have attempted to retain a similar differentiation of different '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.

We first provide an overview (Section 5.1) of the key ecosystems and ecosystem services which form the socio-ecological values for each community, followed by a more detailed examination of each ecosystem / service in the subsequent sections (Sections 5.3 to 5.13)

5.1 Overview – Socio-Ecological Values

5.1.1 Community-Derived Identification

The Nggela communities consistently recognised 11 main ecosystems on which they were directly dependent, including:

1. Terrestrial forest
2. Freshwater swamp (wild taro area)
3. Mangroves
4. Reefs
5. Rivers, streams and groundwater springs
6. Sandy beaches, islands and coastal areas
7. Cultivated land – gardens
8. Cultivated land – plantations
9. Conservation or Tabu areas
10. Marine (Other)
11. Other (Village)

Other ecosystems and or services derived from elsewhere (e.g. drinking water from rainfall to rainwater tanks, wharves allowing tourist ships to dock and bat caves) were also occasionally recognised and have been documented in the ‘Other (village)’ category.

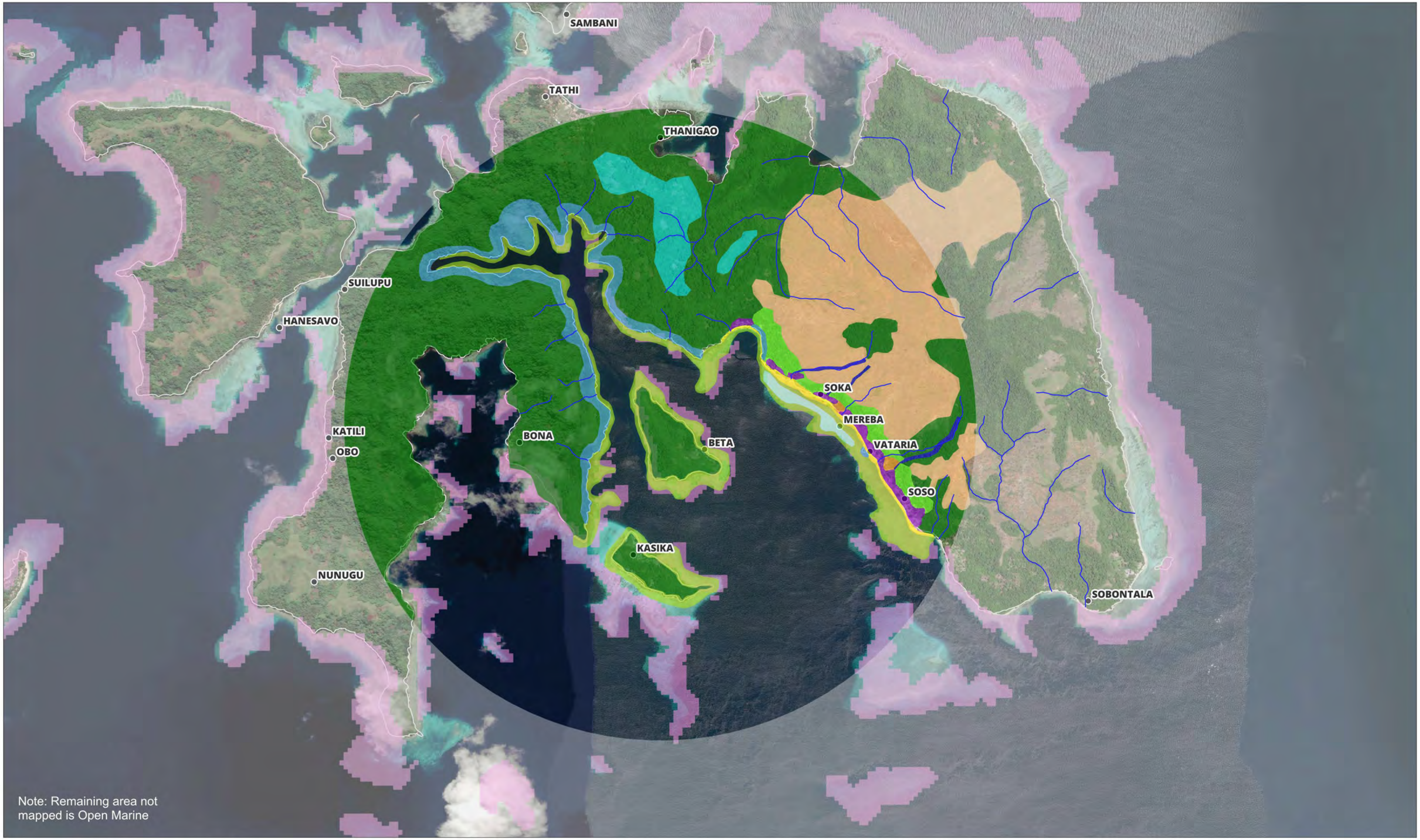
A map showing the spatial distribution and extent of these ecosystems are provided in Figures 5.1 – 5.5. Note that this mapping is to be considered indicative only, and has been derived from existing GIS data, discernment of ecosystems through remote sensing, community-derived information, and rapid field mapping (in close proximity to villages). Extensive and/or detailed ground works to verify and validate ecosystem maps were not undertaken as part of this project. Freshwater swamps and groundwater springs, in particular, are not well represented in the mapping as they are difficult to detect remotely.

Table 5.1 lists the respective ecosystem services for each ecosystem, as identified by the Nggela communities. 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 communities were most reliant include:

- Ecosystems providing timber and other building or house materials, as well as fuelwood/firewood (i.e. timber from mangroves and forests).
- Forests as an area which could be cleared for gardens (the importance of this largely stems from the limited, narrower natural land capital in some parts of Nggela).
- Mangrove areas for food security (mainly via collection of mangrove shells and mud crabs), as well as recognition of their importance as fish breeding areas.
- Fishing grounds around coral reefs for the provision of food (for both domestic consumption and small-scale commercial trade – particularly fish and shells).
- Cultivated gardens as a key food source and source of income.
- Water sources for the provision of water for drinking and domestic uses (includes groundwater, freshwater springs and streams).
- Coconut plantations for the provision of multiple products for both domestic consumption and small-scale commercial trade (mainly copra).
- Conservation or Tabu Areas for tourism (an important source of income in some communities).

It can be seen in Table 5.2 that some broad ecosystem services (e.g. building materials or food) are sourced from a variety of ecosystems. In contrast, some ecosystem services are more specialised and may only be associated with one or two ecosystems (e.g. drinking water sources, coastline protection, clam shells). This is important in the context of climate change resilience, since there may be limited alternative sources for some essential ecosystem services if the original source is undermined.

Areas of direct community utilisation of land and sea resources, as well as key threats, are shown spatially in Figures 5.6 – 5.10. Generally, the community accesses and uses the full range of ecosystems with and immediately surrounding their village, occasionally venturing further afield (typically for offshore fishing grounds).



LEGEND

- Rivers and streams (desktop)
- Coral Reefs (WCMC, 2021)

Community Ecosystem Classifications

- Seagrass
- Forest
- Grassland
- Mangroves
- Reef
- Stream
- Freshwater swamp
- Built settlement
- Sandy beaches
- Gardens
- Plantation
- Coastline

Title:

Distribution of key ecosystems in Soka focus area, Buena Vista Island, Nggela Islands

Figure: 5-1

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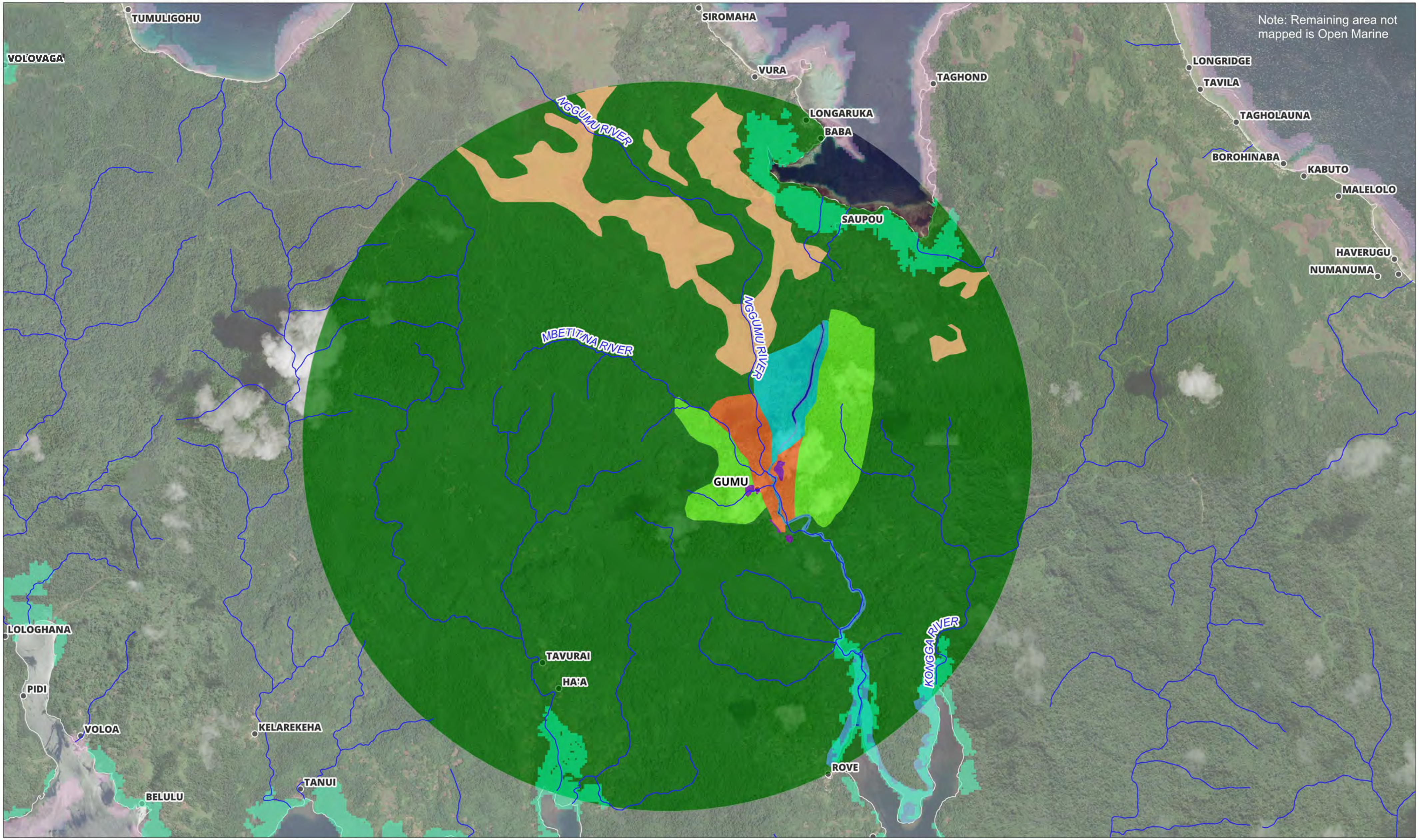

LEGEND

- Rivers and streams (desktop)
- Coral Reefs (WCMC, 2021)
- Mangroves (GMW, 2020)

Community Ecosystem Classifications

- Forest
- Grassland
- Mangroves
- Stream
- Freshwater swamp
- Built settlement
- Gardens
- Plantation
- Coastline

Title:

Distribution of key ecosystems in Gumu focus area, Nggela Islands

Figure: **5-2**

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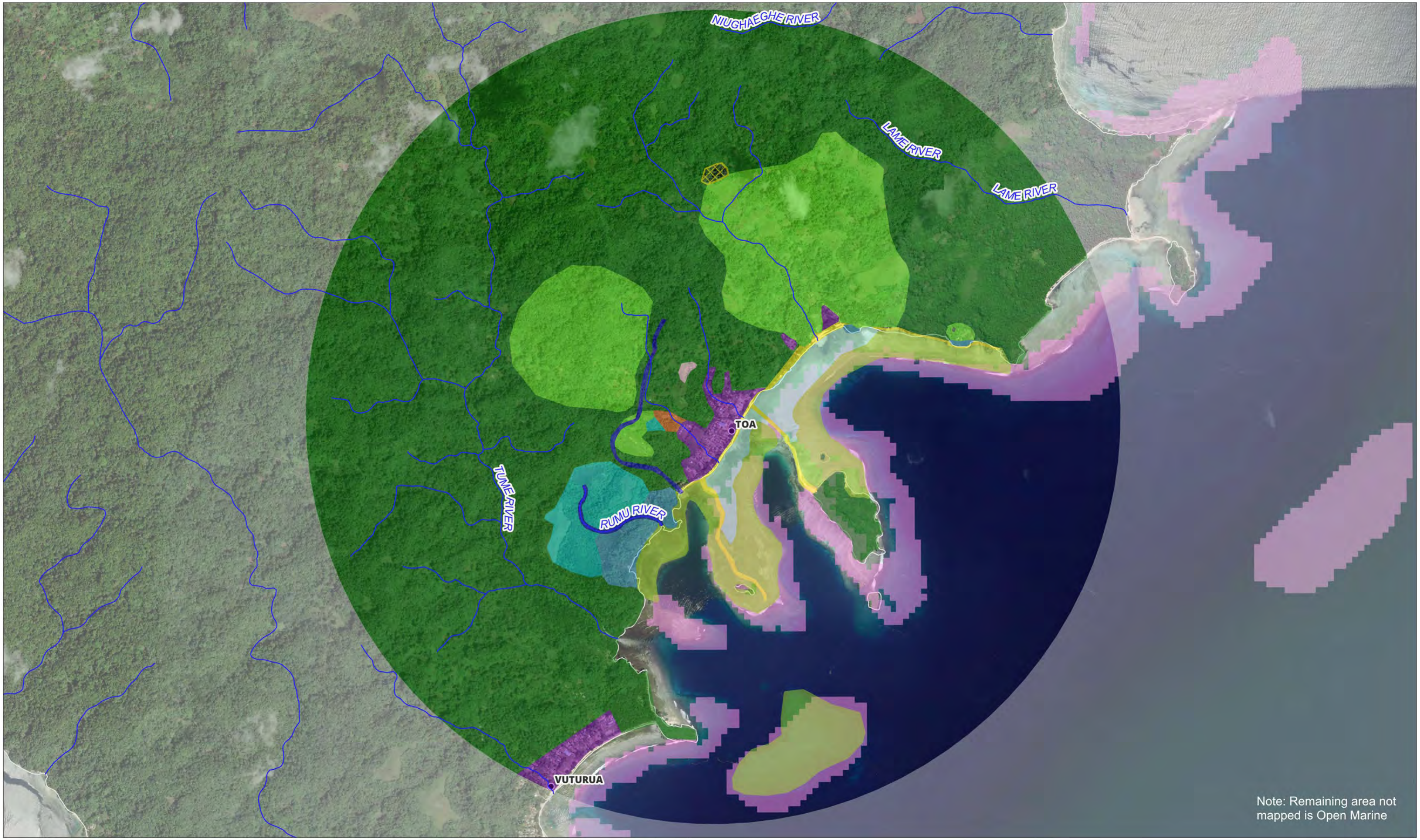

Title:

Distribution of key ecosystems in Toa focus area, Nggela Islands

Figure: 5-3

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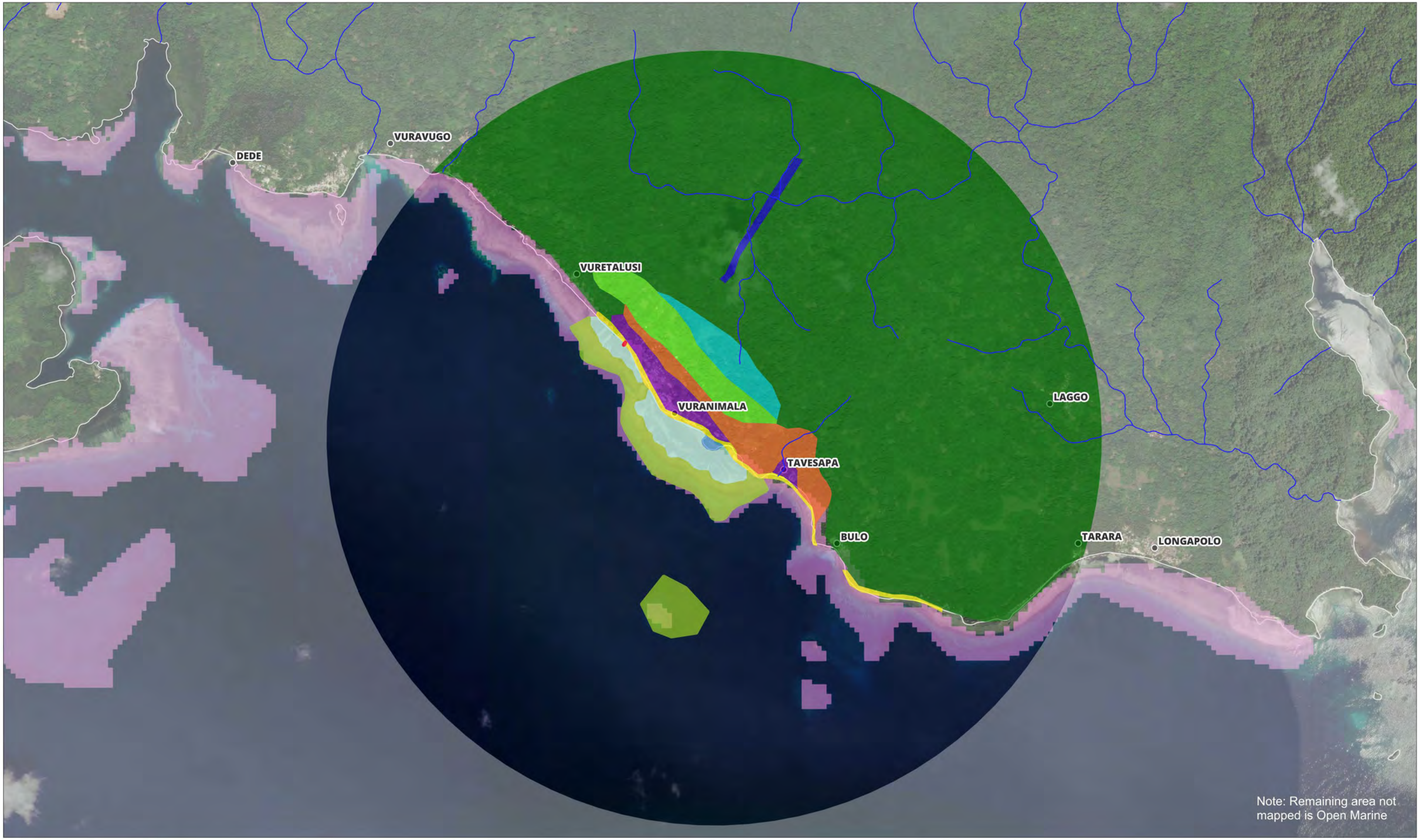

LEGEND

- Rivers and streams (desktop)
- Coral Reefs (WCMC, 2021)

Community Ecosystem Classifications

- Seagrass
- Forest
- Mangroves
- Reef
- Stream
- Built settlement
- Sandy beaches
- Gardens
- Plantation
- Freshwater Swamp (Sago Palm Site)
- Newly Planted Mangroves
- Coastline

Title:

Distribution of key ecosystems in Vuranimala focus area, Nggela Islands

Figure: 5-4

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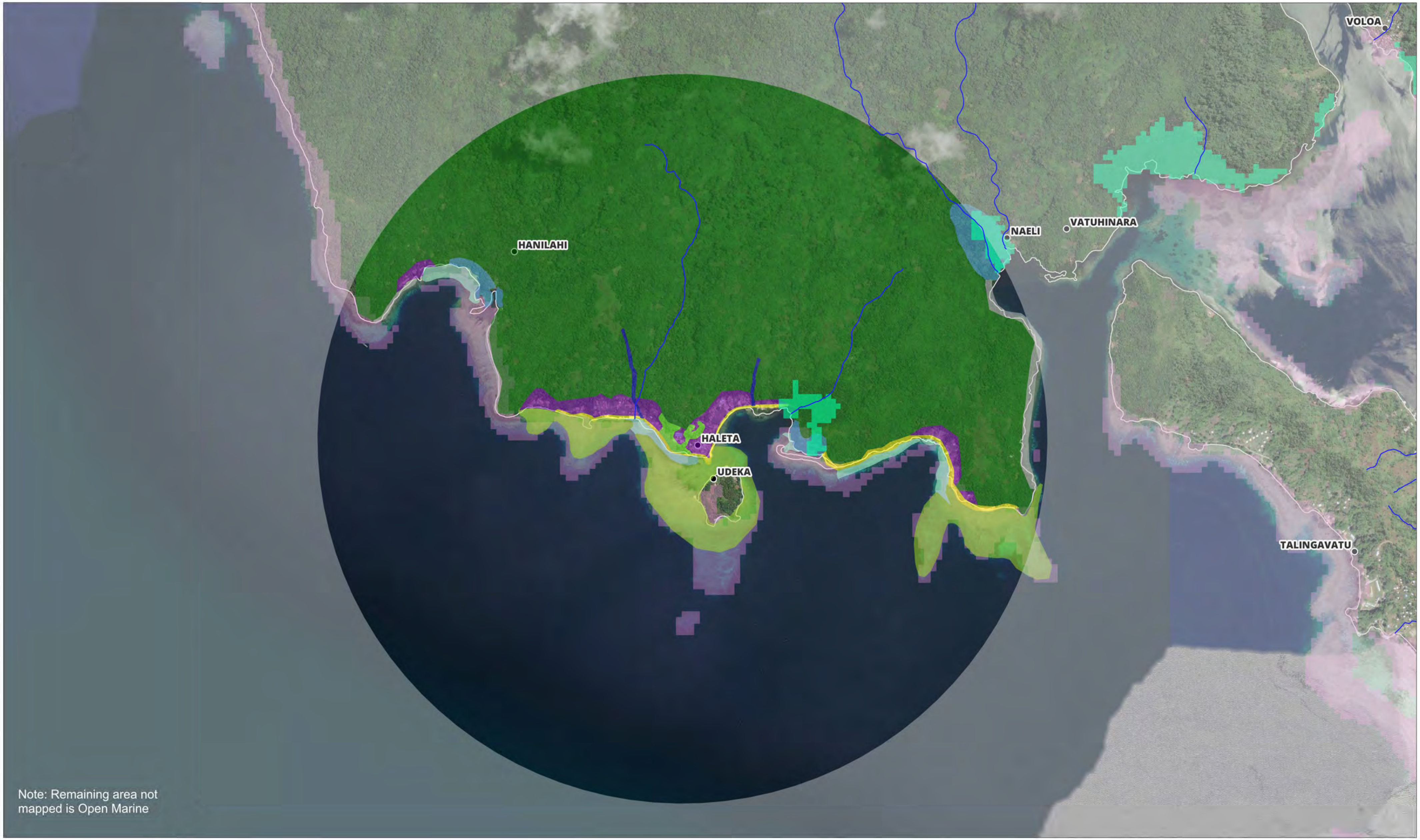

LEGEND

- Rivers and streams (desktop)
- Coral Reefs (WCMC, 2021)
- Mangroves (GMW, 2020)

Community Ecosystem Classification

- Seagrass
- Forest
- Mangroves
- Reef
- Stream
- Built settlement
- Sandy beaches
- Gardens / Plantation
- Rocky Shores
- Coastline

Title:

Distribution of key ecosystems in Haleta focus area, Nggela Islands

Figure: 5-5

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Table 5.1 Inventory of ecosystems and ecosystem services identified by Nggela communities (✓ denotes the frequency of each ecosystem service identified at each village). Higher frequencies are highlighted in pink, medium frequencies in yellow and lower frequencies in blue.

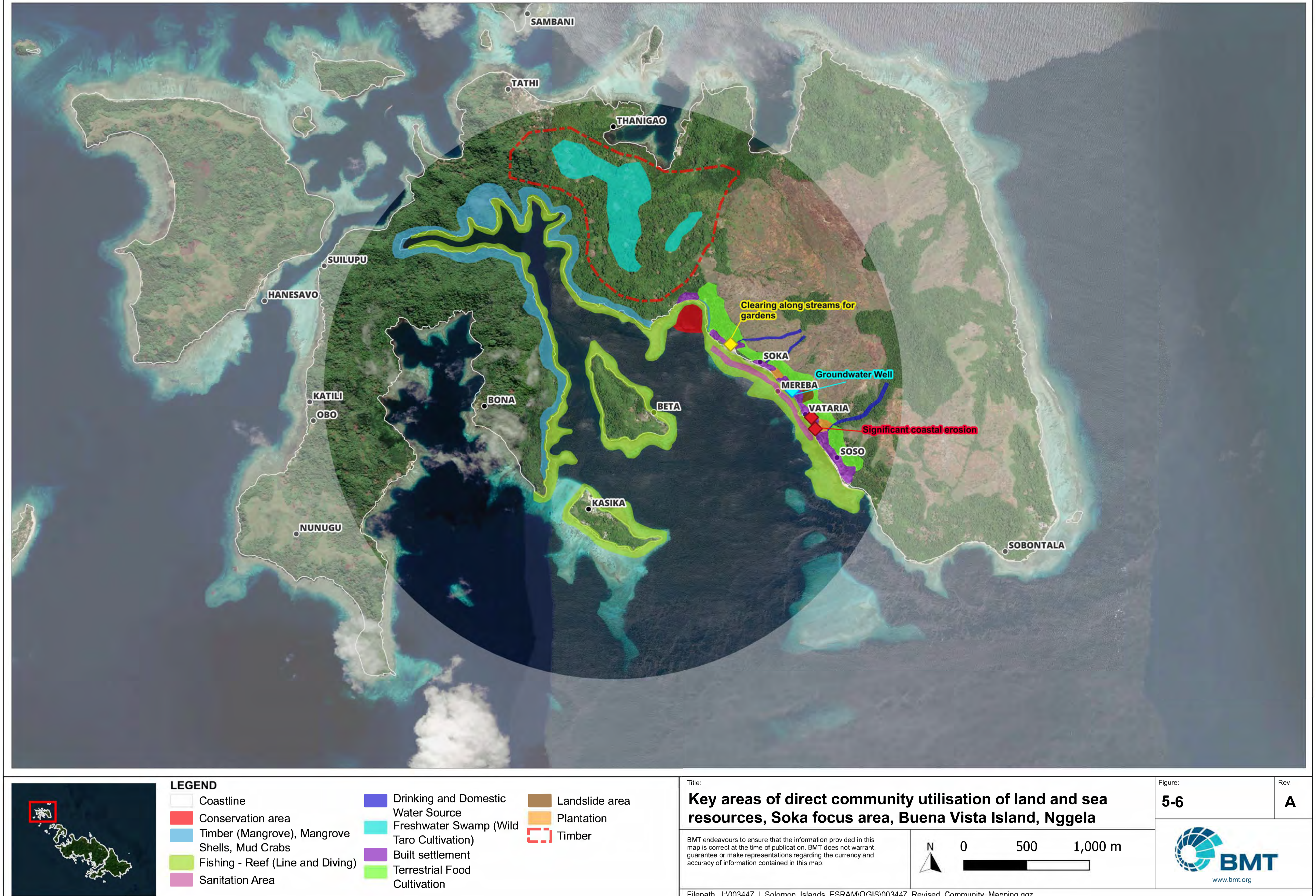
Ecosystems	Key Ecosystem Services identified by Nggela communities	Frequency of Identification by Each Community (three groups per community, except for Haleta which had two)				
		Soka	Gumu	Toa	Vuranimala	Haleta
Forest	Hunting ground for food (pigs, possum and other terrestrial fauna)		✓✓✓			✓
	Timber source - building materials and canoes	✓✓	✓✓✓	✓✓	✓✓	✓✓
	Timber source - fuelwood / firewood					
	Timber milling area – for selling (export to Honiara)			✓	✓	
	Biodiversity – *intrinsic ecosystem value (e.g. butterfly breeding)*	✓			✓	✓
	Medicine		✓		✓	
	Clearing for gardening	✓		✓	✓✓	✓✓
Freshwater swamp (wild taro area)	Collecting mushrooms				✓	
	Kangkung (water spinach)			✓		
	Kakake (*Cyrtosperma chamissonis* or giant swamp taro – food security)	✓✓	✓	✓		
Mangroves	Timber – building materials, fuelwood / firewood	✓	✓	✓✓		✓✓
	Mangrove shells (bivalve molluscs – food source)	✓✓✓	✓✓	✓		✓✓
	Fish breeding area			✓	✓✓✓	✓
	Fishing	✓✓				
	Other food (mud crabs, fruit)	✓✓✓		✓✓		
	Coastline protection		✓			

Ecosystems	Key Ecosystem Services identified by Nggela communities	Frequency of Identification by Each Community (three groups per community, except for Haleta which had two)				
		Soka	Gumu	Toa	Vuranimala	Haleta
Reefs	Fishing, food source and small-scale commercial trade	✓✓✓	✓	✓✓	✓✓✓	✓✓
	Coral source – lime (for chewing betel nut) and coral rock harvest for building material	✓✓✓				✓
	Species protection			✓		
	Shells (e.g. clam shells)	✓✓✓		✓✓	✓	✓✓
	Seaweed and beche de mer (when not banned)	✓		✓	✓✓	
Rivers, streams, groundwater	Water source (drinking, washing, cooking, bathing, other)	✓✓	✓✓✓	✓✓	✓✓✓	✓✓
	Crops – food security (sago palm and wild taro, kakake)		✓✓	✓	✓	
	Fishing – food source (prawns, eels, tilapia fish etc.)		✓	✓	✓	✓
	Fish breeding ground				✓	
Sandy beaches, islands and coastal areas	Sanitation area	✓✓				
	Groundwater springs			✓		
	Crab area – seasonal and used for food security and income			✓	✓✓	
	Collecting rubble, gravel and sand for building materials				✓✓✓	
Gardens	Food and income source (fruit and vegetable crops for domestic and commercial use, e.g. banana, cassava, sweet potato, taro, yam, pana, melon, corn, peanuts etc.)		✓✓✓	✓✓✓	✓✓	
	Solving family issues – *social value*		✓			
Plantations	Coconuts (copra) – small scale commercial, food security		✓✓		✓✓✓	

Ecosystems	Key Ecosystem Services identified by Nggela communities	Frequency of Identification by Each Community (three groups per community, except for Haleta which had two)				
		Soka	Gumu	Toa	Vuranimala	Haleta
	Cocoa – small scale commercial		✓			
	Betel nut – small scale commercial		✓✓			
	Sago palm plantation				✓✓	
	Increase community development - *social value*		✓			
Conservation or Tabu Area	Tourism – source of income (e.g. marine areas, terrestrial caves)	✓✓			✓✓	✓
	Sacred, cultural significance (kastom)		✓		✓	
	Protection of resources (e.g. virgin forest)				✓	
Marine (other)	Deep sea fishing grounds for food security and income, fishing and diving			✓	✓✓	
Other	Rainwater tanks (drinking water)			✓		
	Bat cave – manure?			✓		
	Old settlement and previous gardens / plantation			✓		
	Wharf – allows ships to dock for tourism and trade					✓
	Village (school, church, clinic etc.)		✓	✓✓	✓✓	

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	Income (market)	Biodiversity and species protection	Medicine	Land for gardening	Fish breeding	Coastline protection	Sanitation	Clam Shells (cultural)	Income (tourism)	Cultural significance
Forest	✓				✓	✓	✓	✓	✓	✓						
Freshwater swamp (wild taro area)	✓															
Mangroves	✓	✓			✓						✓	✓				
Reefs		✓			✓		✓							✓		
Rivers, streams, groundwater	✓	✓	✓	✓							✓					
Sandy beaches, islands and coastal areas	✓			✓	✓								✓			
Gardens	✓						✓									
Plantations	✓						✓									
Conservation or Tabu Area								✓							✓	✓
Marine (other)		✓					✓									
Other (rainfall)			✓													
Other (bat caves and wharves etc.)															✓	



Title:

Key areas of direct community utilisation of land and sea resources, Soka focus area, Buena Vista Island, Nggela

Figure: 5-6

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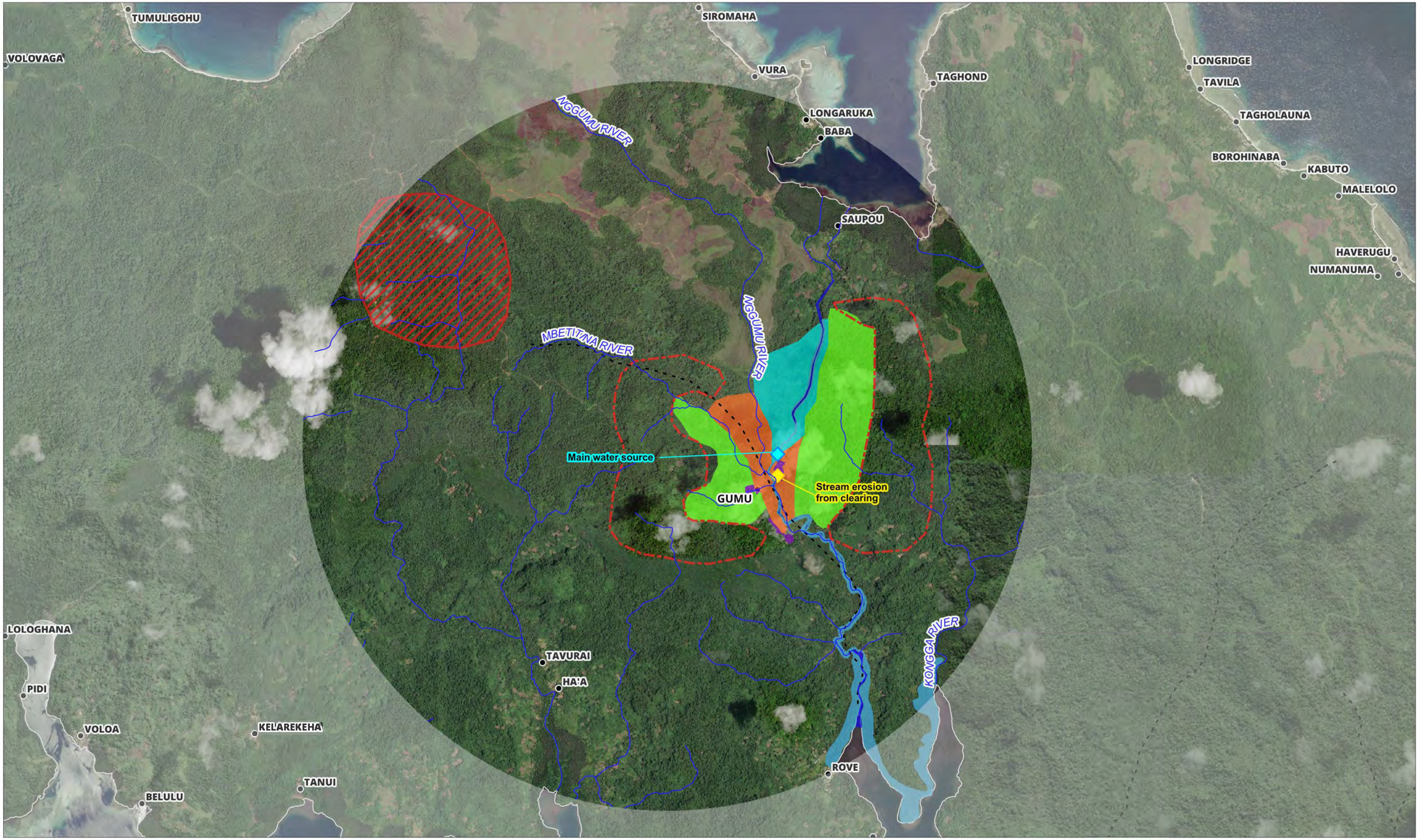

LEGEND

- Coastline
- Timber (Mangrove), Mangrove Shells, Coastline Protection
- Drinking and Domestic Water Source, Food (Fishing)
- Freshwater Swamp (Wild Taro and Sago Palm Cultivation)
- Built settlement
- Terrestrial Food Cultivation
- Plantation
- Illegal Logging Observed
- Timber, Hunting, Medicine
- Logging Roads (desktop)

Title:

Distribution of key ecosystems in Gumu focus area, Nggela Islands

Figure: **5-7**

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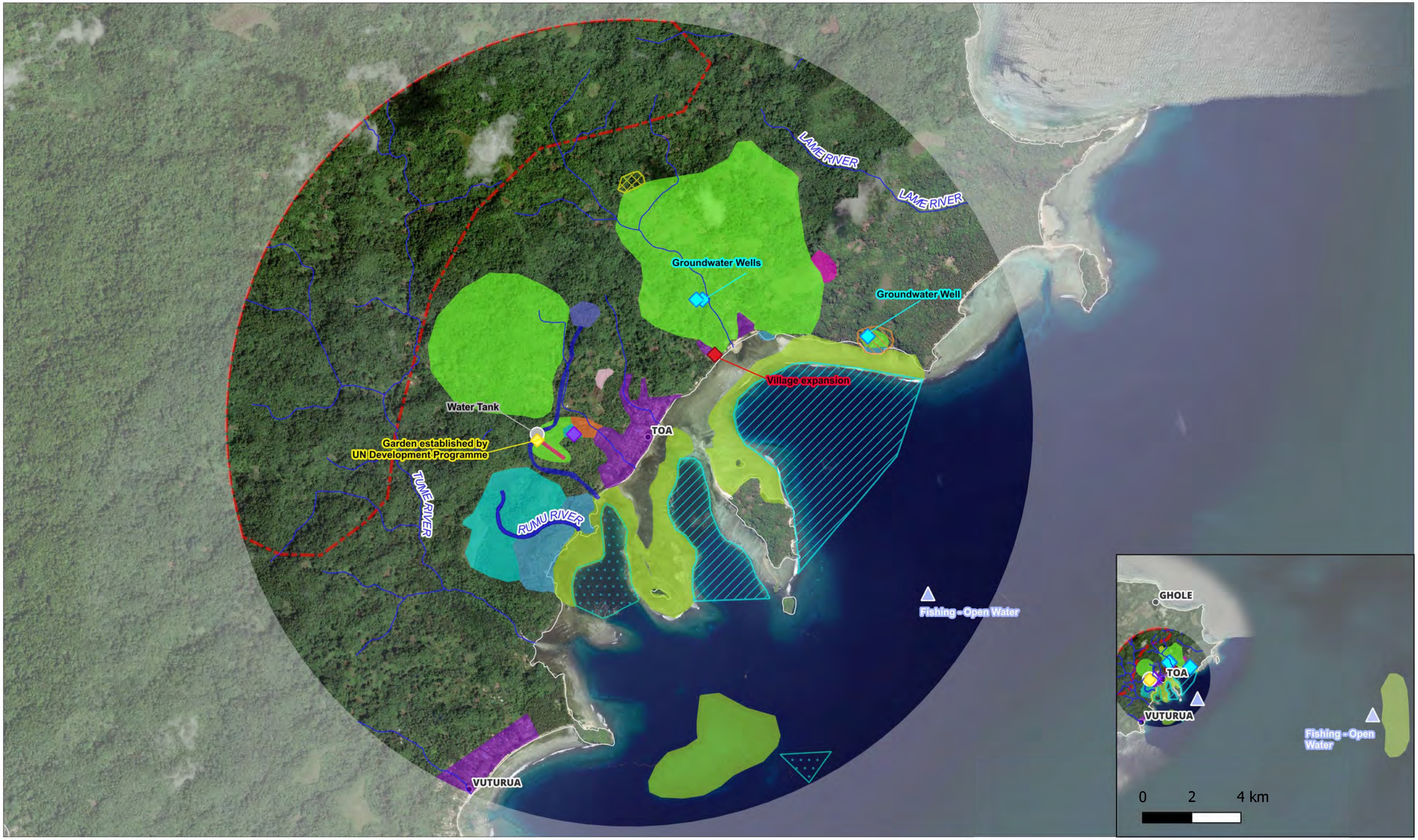

LEGEND

- Coastline
- Timber (Mangrove), Mangrove Shells, Mud Crabs, Nursery
- Fishing - Reef (Line and Diving)
- Drinking and Domestic Water Source, Food (Fishing), Irrigation (Crops)
- Wild Taro Cultivation and Creeping Cabbage
- Built settlement
- Terrestrial Food Cultivation
- Plantation
- Aquaculture (Tilapia)
- Passage
- Burial site
- Dam
- Bat cave
- Old settlement
- Timber
- Fishing and diving
- Crab area
- Swamp taro area

Title:

Key areas of direct community utilisation of land and sea resources, Toa focus area, Nggela

Figure: 5-8

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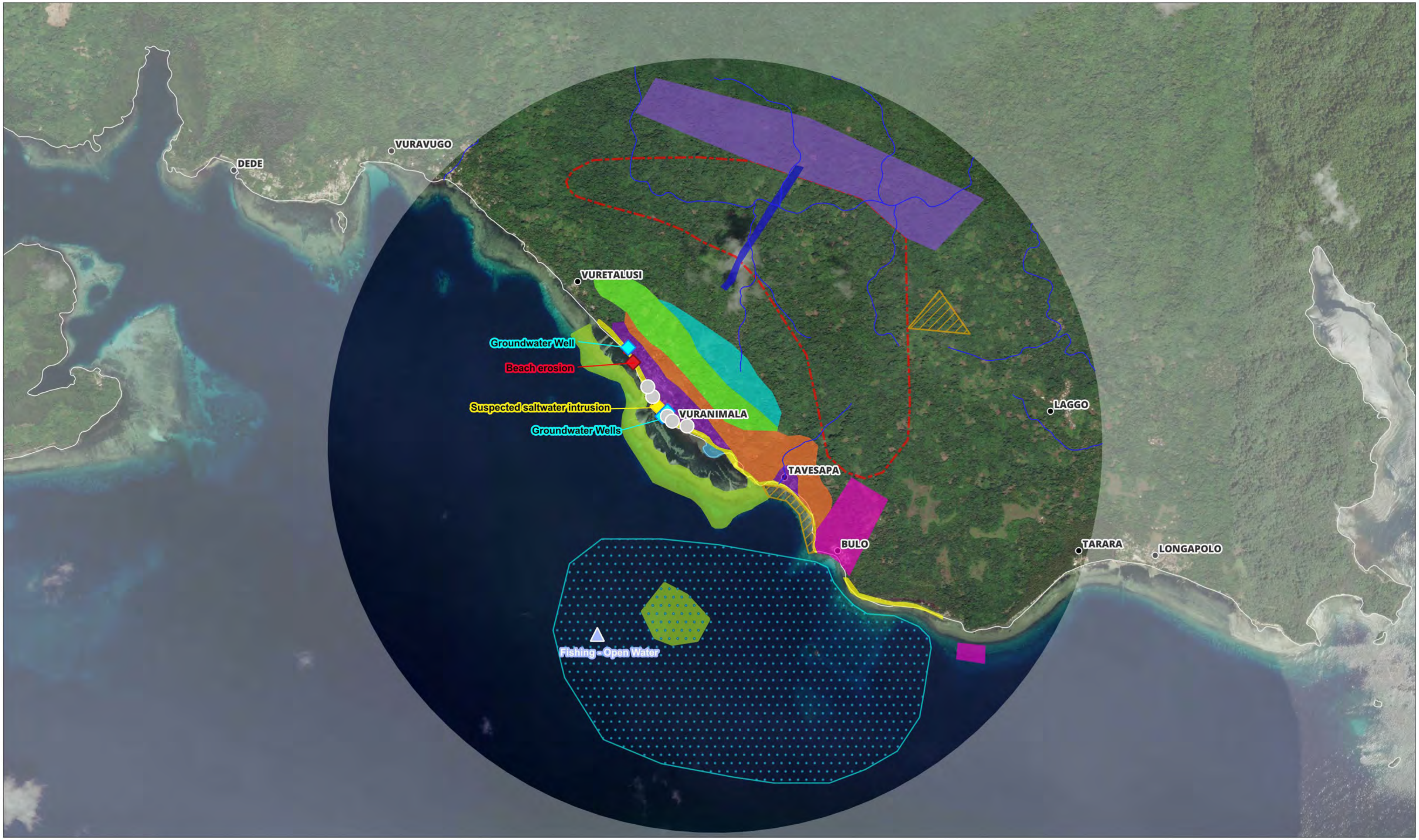

LEGEND

- Coastline
- Fish Breeding Area (Mangroves)
- Fishing - Reef (Line and Diving)
- Drinking and Domestic Water Source, Food (Fishing), Irrigation, Nursery
- Built settlement
- Sand, Gravel, Rubble (Building Materials)
- Terrestrial Food Cultivation
- Plantation
- Timber Milling Area
- Sago Palm Site
- Crab area
- Fishing and diving
- Virgin forest - Tabu
- Cultural Tabu Site
- Newly Planted Mangroves
- Sea Defences (e.g. around burial ground)

Title:

Key areas of direct community utilisation of land and sea resources, Vuranimala focus area, Nggela

Figure: **5-9**

Rev: **A**

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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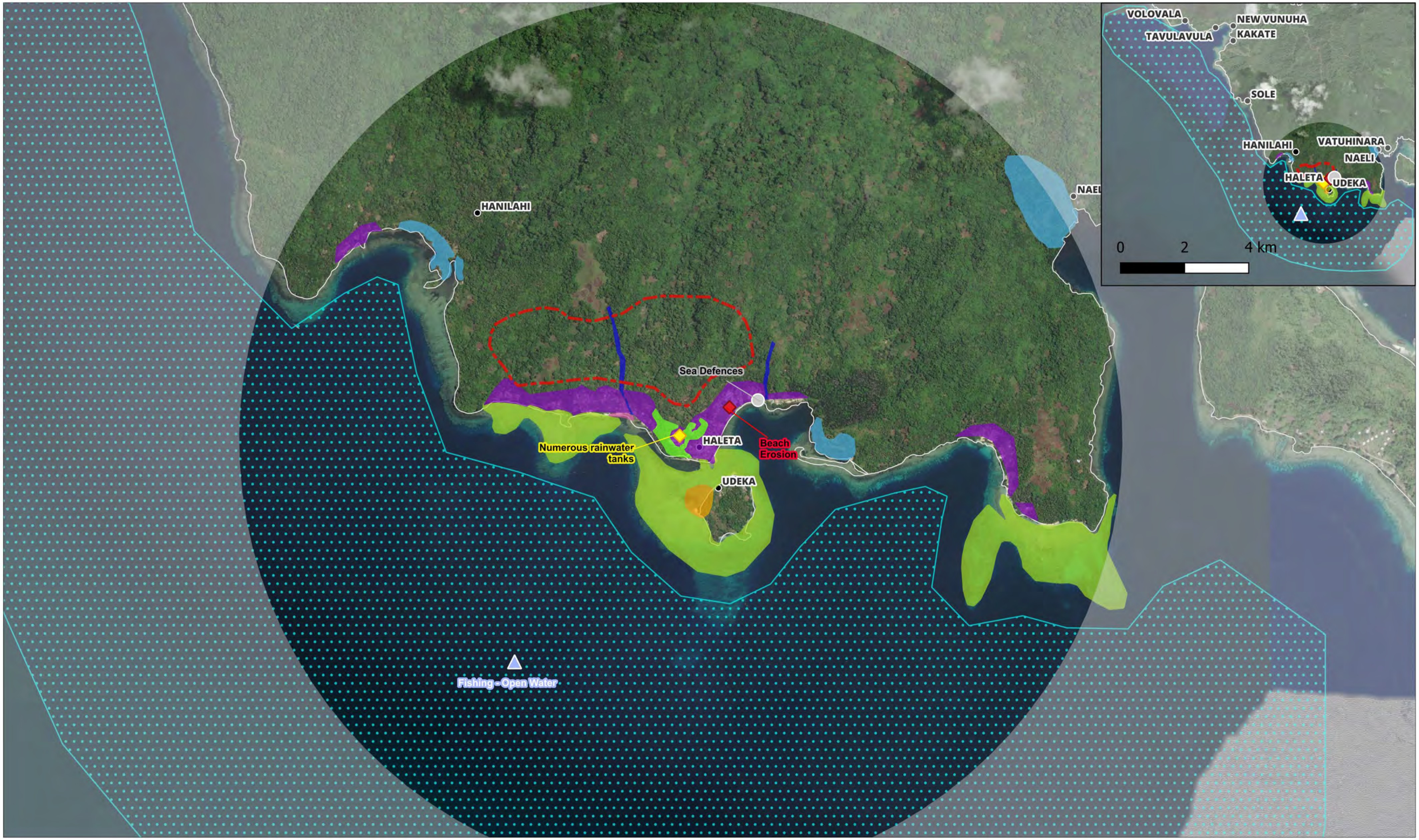

LEGEND

Coastline
Timber (Mangrove), Mangrove Shells, Fish Nursery
Fishing - Reef (Line and Diving)
Sanitation
Drinking and Domestic Water Source, Food (Fishing)
Built settlement
Terrestrial Food Cultivation
Tourism Area
Timber, Food (Hunting)
Fishing and diving (approximate area based on Sulu 2010)

Title:

Key areas of direct community utilisation of land and sea resources, Haleta focus area, Nggela Islands

Figure: 5-10

Rev: A

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5.1.2 Additional Ecosystem Services Identification

Most of the ecosystem services recognised by the Nggela communities would be classified as provisioning services (i.e. the provision of food, water and raw materials). However, some communities identified ecosystem services classified as regulating services (e.g. coastline protection), habitat services (e.g. biodiversity, fish breeding areas) and cultural services (e.g. kastom significance). In addition to these services, there were a number of additional services not accounted for. The complete list of regulating, habitat and cultural services (based on a study by de Groot et al. (2012)) are listed in general terms in Table 5.3. 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 (BMT WBM, 2017b). Ecosystems that provide multiple ecosystem services, especially critical services (i.e. provision of water and food), are considered crucial for community resilience on Nggela.

The list of services in Table 5.3 was applied across the different ecosystems (where relevant) as part of the economic valuations (Section 10) in order to fill gaps where services were not identified by the local community. Similar to the previous Wagina Island ESRAM study, this approach was taken to (1) prioritise the local community's description and understanding of ecosystem services, (2) minimise gaps in the ecosystems services for economic valuation, and (3) avoid duplication.

Table 5.3 General ecosystem services (adapted from BMT WBM, 2017a; de Groot *et al.*, 2012)

Provisioning Services	Regulating Services
Food	Air quality regulation
Water	Climate regulation
Raw materials	Disturbance moderation
Genetic resources	Regulation of water flows
Medicinal resources	Waste treatment
Ornamental resources	Erosion prevention
Supporting industry	Nutrient cycling
	Pollination
	Biological control
Habitat Services	**Cultural Services**
Biodiversity	Aesthetic information
Nursery service	Education
Habitat connectivity	Recreation
	Inspiration
	Spiritual experience
	Cognitive development

In order to make an assessment of the effects of climate change (or other changes/threats) to ecosystem services, it is necessary to go beyond the initial identification phase to recognise the ecosystem components and processes that underpin a particular ecosystem service (BMT WBM, 2017a). For example, with regards to garden crops, considering the effects of climate change on other non-provisioning ecosystem services (e.g. nutrient cycling, pollination, soil erosion prevention), and other environmental processes (e.g. water flows, biological competition between cultivated and weed species etc.) (BMT WBM, 2017b).

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, sea level rise
- Geology and geomorphology – including both fluvial and land-based geomorphology. Volcanic processes are likely to have significantly contributed to the formation of Nggela Islands, with the channels between the islands thought to be created by past eruptions. The islands remain subject to volcanic activity from the nearby active Savo Volcano and various submarine volcanoes. Studies on the contribution of these volcanoes to current geological processes on the islands are lacking, however, their contributions appear to be restricted to occasional earthquakes and associated landslides.
- Sediment loads
- 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 and marine waters)
- Biological processes (e.g. primary productivity, carbon cycling by bacteria, zooplankton grazing, bioturbation and other fauna interactions).

Ecosystem services are therefore often dependent on complex interactions between biological, physical and chemical ecosystem processes. These services are then assigned particular social, cultural and economic values depending on their relationship with human society. This creates a complex interconnected web of socio-ecological values. Furthermore, 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) (BMT WBM, 2017b).

5.2 Overview – Sensitivities and Threats

5.2.1 Community-Derived Identification

Consultations at the five Nggela communities included an open discussion on threats which were perceived to be affecting the key ecosystems (and associated services) described above. Community members were encouraged to share their worries and concerns regarding specific ecosystems, as well as any changes in the ecosystems they have observed over the years. Table 5.4 presents a summary of the ecosystem threats identified by the Nggela communities and therefore demonstrates the biggest threats as perceived by the local community. Initial threat prioritisation has been undertaken based on community attitudes, with more severe perceived threats highlighted in red and less severe threats highlighted in orange.

Threats for 'Conservation or Tabu Areas' are reflected in the threats to each individual ecosystem type which constitute those conserved/tabu areas. Notably, the following ecosystems have been combined, since communities often grouped these ecosystems together when discussing threats:

- 'Freshwater swamp' and 'rivers, streams and freshwater springs'
- 'Reefs' and 'Marine (other)'.

Based on the summary information in Table 5.4, the greatest perceived threats to the communities within Nggela were:

- Overharvesting of forest resources due to increases in population and substantial market demand (primarily from Honiara). Most communities also noted that they have been finding it harder to source larger trees.
- Overharvesting of mangroves (all resources), including timber, shells, fish and crabs. This was also linked to population growth within the communities.
- Overharvesting of fishing reefs due to increases in population and substantial market demand. Communities also noted that destructive fishing habits could be influencing this.
- Overharvesting of shells in reefs due to increases in population and substantial market demand.
- Sea level rise inundation and beach erosion were consistently cited as major concerns among coastal communities.
- Sanitation and water security (i.e. not enough rainwater tanks) were consistently raised as major overarching threats to community livelihoods.

Table 5.5 provides a summary of the key threats to Nggela Islands' ecosystems and services broken down into human (non-climate) and climate related threats. 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 the human resilience, ecosystems are subject to significant anthropogenic threats such as pollution and overharvesting of marine resources (BMT WBM, 2017b). Furthermore, these threats are exacerbated by the current and projected adverse impacts of climate change (to be explored further in Section 11).

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 Nggela Islands to future climate change impacts (BMT WBM, 2017b).

Table 5.4 Inventory of ecosystem threats identified by Nggela communities (✓ denotes identification of threat by community). Red cells indicate more severe threats as perceived by the local communities, orange cells indicate less severe threats.

Ecosystem	Key Threats ('worries') identified by Nggela communities	Frequency of Identification by Each Community				
		Soka	Gumu	Toa	Vuranimala	Haleta
Forest	Stream levels decreasing as people cut down trees for gardening, soil dries out	✓				✓
	Overharvesting of forest resources (harder to find big trees) – population increase and market demand	✓	✓	✓	✓	✓
	Less animals if forest becomes uninhabitable	✓				✓
	Soil drying out as trees are cleared					✓
	Illegal logging		✓			✓
Mangroves	Overharvesting of mangrove resources timber (e.g. no small mangroves left since used for rafters and beams in houses) – increasing population	✓	✓	✓		✓
	Overharvesting of mangrove resources (e.g. shells, fish and crabs), impacting fish breeding areas	✓	✓	✓	✓	✓
	Oil spills from oil companies		✓			
	Sanitation				✓	
Reefs	Pollution from Honiara (reefs no longer clean)	✓				
Marine (other)	Overharvesting, diving for fish occurring at all times (night etc.) (bigger fish declining) – population increase and market demand	✓	✓	✓	✓	✓
	Destructive fishing methods (e.g. dynamite fishing) – only recently stopped			✓	✓	
	Destruction of corals for lime extraction	✓			✓	
	Destruction of corals for rubble and stones to export to Honiara	✓				
	Coral bleaching			✓	✓	
	Overharvesting of shells, no seashells in closest reefs	✓		✓	✓	✓
	Competing fisherman (e.g. from Malaita and Honiara) / stealing from other communities	✓		✓		

Ecosystem	Key Threats ('worries') identified by Nggela communities	Frequency of Identification by Each Community				
		Soka	Gumu	Toa	Vuranimala	Haleta
	Oil spills from ships					✓
	Illegal logging impacting water quality – sediment being discharged to the sea		✓			✓
Freshwater swamp (wild taro area)	Clearing land for gardening adjacent to streams (stream levels decreasing)	✓			✓	
	Illegal logging impacting water quality		✓			✓
Rivers, streams, dams and groundwater	Extreme wet periods - flooding means stream can't be used for drinking water	✓	✓			
	Extreme dry periods – streams drying up		✓	✓	✓	
	Landslides		✓			
	Sanitation starting to impact water quality		✓			
	Overharvesting of freshwater fish (e.g. eels, tilapia, prawns)				✓	
	Overharvesting of sago palm				✓	
	Chemical used for treating mosquito nets impacting water quality and is toxic to some aquatic life				✓	
	Sea water intrusion (into groundwater)			✓		
Sandy beaches, islands and coastal areas	Sanitation starting to impact water quality	✓		✓		
	Climate change affecting seasonal cycles of crab area				✓	
	Overharvesting of crabs (but tend to recover by following season)				✓	
	Storms				✓	
	Sea level rise inundation	✓		✓	✓	✓
	Beach erosion	✓		✓	✓	✓
Gardens	Population increase – running out of space	✓				✓

Ecosystem	Key Threats ('worries') identified by Nggela communities	Frequency of Identification by Each Community				
		Soka	Gumu	Toa	Vuranimala	Haleta
	Insects/pests (wild pigs, caterpillars etc.) and disease	✓	✓	✓	✓	✓
	Soil fertility – intensive gardening with no fallow	✓		✓		✓
	Longer periods of sun/dry rather than quick wet/dry cycles	✓				
	Other communities stealing		✓	✓		
	Landslides	✓	✓	✓	✓	
Plantation	Insects/pests (e.g. Rhinoceros beetle threat to coconut trees, birds eating fruit)		✓		✓	
	Landslides		✓			
	Overharvesting plantation resources – decreasing yields and no replanting (population increase)				✓	
	Other communities stealing		✓			
Other (e.g. village)	Sea level rise	✓		✓	✓	✓
	Beach erosion	✓		✓	✓	✓
	Salt intrusion into the ground, salt erosion			✓		
	Cyclones and tsunamis (nowhere to shelter/hide)			✓	✓	
	Food security	✓	✓	✓	✓	✓
	Sanitation	✓	✓	✓	✓	✓
	Not enough rainwater tanks	✓	✓	✓	✓	
	Lack of rural electrification			✓		
	Not enough medical areas/clinics				✓	

Table 5.5 Summary of key threats to each ecosystem service (services and threats identified by communities)

Ecosystems	Key Ecosystem Services identified by Nggela communities	Climate Related Threats									Non-Climate Related Threats												
		Sea level rise, saline intrusion	Drought / dry periods	Flooding / wet periods	Coastal / beach erosion	Landslide	Cyclones and storms	Invasives / pests / disease	Ocean acidification	Changing seasonal cycles (e.g. crabs)	Pollution & contam. (water)	Tsunamis	Sanitation (solid waste mgmt.)	Land clearing and modification	Population growth	Overharvesting - economic	Inadequate resource management	Competing fishermen	Oil spills	Destructive harvesting	Illegal logging	Lower soil fertility	Stealing
Forest	Food (hunting)														✓		✓						
	Timber source - building materials													✓	✓	✓	✓				✓		
	Timber source - fuelwood / firewood													✓	✓	✓	✓				✓		
	Timber milling area – for selling (export to Honiara)													✓	✓	✓	✓				✓		
	Biodiversity													✓	✓	✓	✓				✓		
	Medicine													✓	✓	✓	✓						
	Clearing for gardening														✓		✓						
Mangroves	Timber – building materials, fuelwood / firewood						✓					✓		✓	✓		✓						
	Food (fish, shells/molluscs, crabs, fruit)						✓					✓	✓						✓				
	Fish breeding area						✓					✓	✓						✓				
	Coastline protection						✓					✓											
Reefs	Food/trade source (fish, seaweed etc)						✓		✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		
	Coral source – lime (for chewing betel nut) and coral rock harvest for building material								✓		✓	✓				✓	✓		✓	✓	✓		
	Species protection						✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		
	Shells (e.g. clam shells)						✓		✓		✓	✓			✓	✓	✓	✓					
Freshwater swamp, rivers, streams, groundwater	Water source	✓	✓	✓		✓	✓				✓	✓	✓	✓							✓		
	Food source (stream side gardens)	✓	✓			✓	✓	✓			✓	✓		✓	✓	✓	✓				✓	✓	✓
	Food source (aquatic fauna)							✓			✓			✓	✓	✓	✓				✓		
	Fish breeding ground		✓	✓				✓						✓	✓	✓	✓				✓		
Sandy beaches, islands and coastal areas	Sanitation area	✓			✓		✓								✓								
	Food/trade source (crabs)						✓			✓		✓			✓	✓							
	Building materials	✓			✓		✓								✓		✓						
Gardens	Food and income source		✓	✓	✓	✓	✓	✓				✓			✓	✓	✓					✓	✓

Ecosystems	Key Ecosystem Services identified by Nggela communities	Climate Related Threats									Non-Climate Related Threats												
		Sea level rise, saline intrusion	Drought / dry periods	Flooding / wet periods	Coastal / beach erosion	Landslide	Cyclones and storms	Invasives / pests / disease	Ocean acidification	Changing seasonal cycles (e.g. crabs)	Pollution & contam. (water)	Tsunamis	Sanitation (solid waste mgmt.)	Land clearing and modification	Population growth	Overharvesting - economic	Inadequate resource management	Competing fishermen	Oil spills	Destructive harvesting	Illegal logging	Lower soil fertility	Stealing
Plantations	Coconuts (copra) – small scale commercial, food security		✓		✓	✓	✓	✓				✓			✓	✓	✓					✓	✓
	Cocoa – small scale commercial		✓		✓	✓	✓	✓				✓			✓	✓	✓					✓	✓
	Betel nut – small scale commercial		✓		✓	✓	✓	✓				✓			✓	✓	✓					✓	✓
	Sago palm plantation (building materials)		✓		✓	✓	✓	✓				✓			✓	✓	✓					✓	✓
Conservation or Tabu Area	Tourism income (e.g. marine areas, terrestrial caves)								✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		
	Sacred, cultural significance (kastom)								✓			✓	✓		✓	✓	✓	✓	✓	✓	✓		✓
	Protection of resources (e.g. virgin forest)					✓									✓	✓	✓				✓		✓
Marine (other)	Food/trade source (fishing and diving)						✓		✓		✓		✓		✓	✓	✓	✓	✓	✓			
Other (Village)	Built settlement (school, church, clinic etc.)	✓			✓		✓						✓		✓								
	Wharf to allow ships to dock				✓		✓																
	Rainwater tanks – water provision		✓							✓													
	Old settlement and previous gardens	✓	✓		✓		✓	✓							✓	✓							

5.3 Terrestrial Forest

5.3.1 Description of Socio-Ecological Values

Nggela Islands are heavily vegetated, with tropical forest covering the bulk of the interior of Nggela Sule and Nggela Pile. The remaining land is primarily comprised of mangroves, freshwater swamps, sandy beaches, cultivated land and built village areas. Buena Vista and Sandfly Islands also contain significant areas of grassland; however, the communities did not recognise this ecosystem type as providing any useful services. The forests provide important ecosystem services for the local community including the provision of food, medicine, timber and fuel. The ecosystem services were identified by the local communities as necessary for daily life, and include:

- Timber for housing and canoe making
- Timber milling areas for small-scale export to Honiara (income source)
- Food provision, primarily as a habitat for hunting land-based animals, which are important for supplementing sea-derived protein sources
- Fuel wood (for cooking)
- Medicine.

Three communities (Soka, Vuranimala and Haleta) also recognised the habitat services of the forests (rather than just their provisioning services) by highlighting ‘biodiversity’ as a key ecosystem service. For example, some parts of the forests near Vuranimala were reserved for butterfly breeding. Another ecosystem service which was consistently recognised by the communities was the land capital provided by forests (i.e. they represented lands that could be cleared for gardens). Crucially, in addition to those services identified by workshop participants, 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.

The terrestrial forests surrounding Soka, Gumu, Toa and Vuranimala were typically in very good condition (Figure 5.11). Unfortunately, constraints at Haleta (Section 2) meant that no site visit of the surrounding terrestrial forest could be undertaken. 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 (e.g. illegal logging area identified by Gumu community nearby existing logging tracks). Some wider spread clearing occurs from time to time, usually for the purposes of creating land for cultivation. The land capital provided by forests is an important ecosystem service for the communities on Nggela, particularly Toa, Vuranimala and Haleta, which are typically constrained against the coastline by steep elevations. In terms of food provision and hunting, pigs and possums are usually the primary targets.

Figure 5.11 Terrestrial vegetation communities around A) Soka, B) Gumu, C) Toa and D) Vuranimala

5.3.2 Sensitivities and 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, reductions in stream levels) they consider to be essential resources. The primary threat is forest clearing (in some cases via illegal logging) and the risk of overharvesting timber, particularly as growing populations place an increased demand on forest and land resources. Note that no specific management measures are in place (e.g. replanting, formal protected areas), however some communities have tabu areas within the forest that are traditionally protected for cultural reasons.

There was a strong awareness across all five communities that some target forest trees (especially bigger, more mature trees) are getting harder to find and that the current practices may be unsustainable. Some communities had started making changes to harvesting practices to alleviate some of the pressures of overharvesting. For example, in Vuranimala, the Honiara demand for timber was driving forest clearing and so the community decided to restrict timber harvesting for community needs only to reduce resource pressures.

Observations by the study team suggest that overharvesting concerns are well founded among the communities. In addition, the Gumu and Haleta communities identified illegal logging as a significant risk to surrounding forest resources. This suggests that illegal logging is more prevalent in the northern/northwestern regions of Nggela Sule and represents a key threat to both the forest ecosystems and communities in these areas.

Other key existing or potential threats included:

- Deforestation, where clearing occurs to replace forests with cultivated gardens or other land uses (e.g. village expansion) (Figure 5.12)
- Disappearance of terrestrial fauna due to unsuitable habitats
- Soil degradation from forest clearance
- Clearing adjacent to stream decreasing water levels.

Figure 5.12 Example of area cleared of mixed terrestrial forest and plantation for a new health clinic in Soka, Buena Vista Island.

5.4 Freshwater Swamp

5.4.1 Description of Socio-Ecological Values

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

Freshwater swamps, or 'wild taro' areas, are primarily valued by the community as a location that provides suitable conditions for growing swamp taro *Cyrtosperma chamissonis* ('kakake') and various other food items (e.g. 'Kangkung' water spinach and mushrooms) (Figure 5.13). Swamp taro is not usually consumed on a daily basis, rather it is cultivated as a means of food security for times of food shortages or to supplement other food sources (particularly in Soka, Gumu and Toa). Sago palm (*Metroxylon salomonense)* plantations are also commonly located around freshwater swamps, providing an essential source of building materials (roofs for dwellings), as well as food (refer to Section

5.10 for further discussion on sago palm plantations). The above community uses are concentrated to the swamps in close proximity to the villages.

Figure 5.13 Swamp taro in freshwater swamp west of Toa

5.4.2 Sensitivities and Threats

Key existing threats to freshwater swamps and the resources provided by them are increasing population pressures and saltwater intrusion (particularly in Toa). Note that communities often grouped 'freshwater swamp' and 'rivers, streams and freshwater springs' together when discussing threats. Community concerns around overharvesting were mainly focused on sago palm, which will be further discussed in Section 5.10.

Saltwater intrusion occurs in swamps near the coast as a result of very high tides, and 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 when swamp taro may take 10 years until it is ready for harvesting (BMT WBM, 2017a). Saltwater intrusion is also likely to impact on the biodiversity of lowland swamps however further information is needed to understand the species that inhabit these ecosystems.

In terms of other threats, the following is noted:

- Decreasing water levels as a result of adjacent vegetation clearing (affecting freshwater wetlands established beside existing rivers/streams).
- Drought and hot temperatures causing the swamps to dry out periodically

- Landslides
- Sedimentation/water quality impacts from illegal logging activities
- Degradation of water quality from the chemicals used to treat mosquito nets (treated nets were provided to rural communities by The Ministry of Health and Medical Services). When the mosquito nets are placed in the rivers (e.g. to harvest prawns), the chemical kills prawns, eels and other aquatic species (flagged in Vuranimala only).

5.5 Mangroves

5.5.1 Description of Socio-Ecological Values

While mangroves constitute a relatively small proportion of the overall forest areas on Nggela, they are the dominant ecosystem type along the island's major rivers (Nggela Sule and Nggela Pile) and sheltered bays (Buena Vista and Sandfly). Mangroves dominate the coastal margin of Nggela (including Mboli Passage) and sometimes extend out to reef flats.

With the exception of localised areas of natural or anthropogenic disturbance, mangroves were generally found to be in good condition (Figure 5.14). 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, sanitation) and areas of presumably natural drainage alteration and coastal erosion (e.g. Figure 5.15 D). Most coastal mangroves were observed to occur in isolated patches, while more continuous bands of mangroves were observed along major rivers. This is likely due to the western coastline of Nggela being too exposed to sustain mangroves, with isolated patches instead establishing sporadically in more sheltered bays/inlets. This has significant implications for both the overharvesting of mangrove resources (discussed further in the following section) and climate change resilience.

The mangrove communities of Nggela Islands tend to be dominated by species of *Rhizophora, Bruguiera* and *Nypa fruticans*. Examples of these mangrove types are shown in Figure 5.15.

A)

B)

Figure 5.14 Mangrove communities in good condition along the Mbetitina River en route to Gumu A) downstream and B) midstream.

A)

B)

C)

D)

Figure 5.15 Example mangrove species across Nggela Islands: A) *Nypa fructans*, B) *Rhizophora* .sp., C) *Rhizophora* .sp., D) remnants of *Bruguiera* sp.

Mangrove ecosystems are highly valued by the people of Nggela. However, this is typically due to their food provisioning services rather than for their raw materials. Mangrove timber appeared to be the least preferred timber source across the five communities, with uses being confined to rafters and beams in some community buildings. Timber harvesting practices varied between communities. For example, Vuranimala does not harvest any mangrove timber due to concerns around mangrove health and recognition of a need to protect them. In contrast, Toa and Haleta appeared to rely more heavily on mangrove timber, with most workshop groups identifying this resource as critical for community functioning. Timber from mangroves was not typically exported and tended to be harvested solely for community use. Mangroves were rarely used for firewood across the five communities.

Mangrove ecosystems were primarily identified as critical ecosystems due to the range of food that they supply to the communities. The main food types sourced from mangrove ecosystems in Nggela include:

- Mangrove shells (bivalves)
- Mud crab (*Scylla serrata*) and various fish
- Mangrove fruit.

The communities also acknowledged that mangroves provide regulating and habitat ecosystem services in the form of providing breeding/spawning areas for fish and serving a major role in shoreline protection and stabilisation.

5.5.2 Sensitivities and Threats

Currently, there is no active management to ensure the sustainability of resources harvested from mangrove ecosystems on Nggela. Overharvesting therefore represents the primary threat to both mangrove plants (i.e. timber) and foods derived from mangrove ecosystems, particularly in the face of population growth, climate change and other compounding threats. However, it should be noted that two of the five Nggela communities have made attempts to re-plant mangroves along their coastlines (Figure 5.17). Mangrove replanting efforts at Haleta were unsuccessful due to the exposed nature of the coastline. Overall, key threats identified for the mangrove ecosystems include:

- Overharvesting and concentrated clearing of mangroves (e.g. Figure 5.16) Such practices already appear unsustainable at localised high-use areas, particularly given the relatively small, isolated nature of mangrove patches along the coastlines of Nggela Sule and Nggela Pile. Overharvesting can also threaten the foods sourced in mangroves (e.g. mud crab, bivalves).
- Population growth increases the demand for mangroves ecosystem services
- Oil spills were identified by the Gumu community as impacting mangroves along the river
- Sanitation – many villages such as Vuranimala use mangrove areas as toilet areas.

Although not explicitly identified by the communities, additional threats to mangrove ecosystems on Nggela could include:

- Mangrove shells (bivalves) are susceptible to desiccation and spoiling during prolonged periods of low tide when air temperatures are hot
- 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 threaten mangroves through processes such as coastal erosion and altered hydrology that can cause prolonged inundation

Figure 5.16 Example of larger scale mangrove clearing in Soka for the future development of a new medical facility.

Figure 5.17 Successful mangrove re-planting efforts at Vuranimala

5.6 Reef

5.6.1 Description of Socio-Ecological Values

Coastal communities of the Nggela Islands rely heavily on the marine environment as a source of food. Communities which are located further inland along major rivers (e.g. Gumu) typically have reduced reliance on the marine environment and instead depend on terrestrial food sources.

In addition to food provision, marine environments around Nggela 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 Nggela Islands and comprising mainly fringing and patch reef forms.

Dedicated reef assessments were not undertaken for this assessment. However, reef surveys were due to be undertaken by WCS the week after BMT concluded their field work. Preliminary results from these surveys (courtesy of WCS) indicate that the reefs around Nggela are typically in poor health, with the exception of some reefs near Vuranimala. For more detailed results on the condition of Nggela reefs refer to the forthcoming WCS Biological Survey report.

Presently, the only major land clearing activities which may occur on the islands are illegal logging practices (generally confined to northern and northwestern Nggela Sule). However, there are a variety of major river systems (e.g. Mbetitina River, Kongga River, Kirighi River) which discharge into the marine environment and provide a source of additional sediment loads to the local reefs (i.e. beyond natural sediment inputs).

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 (for all surveyed communities except for Gumu). Animals sourced from, or otherwise dependent on reef habitats, are primarily used as food, but also provide the primary means of income for many communities through the sale of products at major markets in Tulagi, Honiara and Auki. Notably, the community indicated that they have observed severe depletion in inshore reef-based food sources, necessitating a shift to fishing in offshore sub tidal reefs.

Key fauna targeted for consumption and/or sale include:

- Reef associated fish targeted via diving, line fishing, net fishing and dynamite fishing (only practiced in some communities – many have recently stopped this practice)
- Invertebrates such as trochus (*Tectus niloticus*), clams (Figure 5.18) and sea cucumbers (Note: there is currently a national ban on *bêche-de-mer* harvest - communities use this as source of income when the ban is lifted).

Soka, Toa and Vuranimala also harvest seaweed from the marine environment to sell at markets for a source of income.

Coral, both dead and live coral, is harvested from the reefs to provide construction materials (e.g. coral rock for construction of sea walls and other uses – Figure 5.20), and lime sold to chew with betel nut. Demand for corals and stones from Honiara encourages significant harvesting amongst some communities who sell and export the material (e.g. Soka – this community does not use coral for local building materials and only harvests it for export). It is worth noting that Vuranimala did not identify coral as a key ecosystem service relied on by the village during the consultations, despite appearing to use the resource heavily (Figure 5.20). Informal conversations with local residents indicated that the community no longer harvests much coral from the reefs because they are worried for the health of the reefs (despite wanting to build more sea walls etc.)

The communities also acknowledged that reefs provide regulating and habitat ecosystem services in the form of species protection and expressed concern over the observed decreases in reef health and productivity.

Seagrass meadows were present at three communities (Soka, Toa and Vuranimala) in shallow and protected waters with sandy substrata off the coast of the villages. These areas are sometimes referred to as 'marine lagoons', however, distinctions between marine lagoons and reefs were not provided by any of the Nggela communities regarding marine resource use. While seagrass was not identified by the communities as an important ecosystem/service, it is worth mentioning here that they provide important fauna habitat and ecosystem services such as primary productivity, nutrient and carbon cycling and substrate stabilisation (BMT WBM, 2017a). The seagrass meadows observed during the field work for this project were in good condition, with a high seagrass coverage within meadows and plants in good health (Figure 5.19)

Figure 5.18 Collection of harvested clam shells at Soka

A)

B)

Figure 5.19 Seagrass meadows adjacent to A) Toa village and B) Vuranimala village

Figure 5.20 A) coral rubble used to create a path around the church in Vuranimala, B) and C) seawalls constructed out of coral rock at Vuranimala, D) extracted coral (Soka)

5.6.2 Sensitivities and Threats

It has been suggested that overharvesting of reef resources is already evident. Community members in every workshop stated that they now need to travel further away from the village to find bigger fish. Given the high importance of reef resources for food and income, unsustainable harvesting is a major concern in the face of human population growth and growing market demand. Similar patterns have been observed for clam shells, with community members noting that they are now very hard to find.

Many of the communities on Nggela Islands engage in dynamite fishing to increase their catches. This destructive fishing method causes widespread damage to coral reefs and is likely the primary factor behind their current poor condition. During the consultations, the project team were informed that the five communities had recently stopped dynamite fishing out of concern for reef health. However, the practice is still undertaken by other communities on Nggela, as well as by fisherman from neighbouring provinces who want to increase their catches for market. This is likely exacerbated by Nggela's proximity to a wide range of major markets (Honiara, Tulagi and Auki).

Community members from Toa and Vuranimala expressed concerns regarding coral bleaching, explaining that they had seen more and more unexplained coral deaths over recent years. This could be linked to ocean acidification and demonstrate its ability to multiply existing threats.

Other key threats include:

- Pollution from Honiara (reefs no longer clean)
- Competing fishermen from neighbouring provinces due to proximity to market (these fishermen also tend to use destructive fishing techniques to increase their catches)
- Destruction of corals for lime extraction
- Oil spills from ships
- Illegal logging impacting water quality – sediment being discharged into the marine environment
- Climate change risks such as increased sea temperature, coral bleaching ocean acidification and damage from more frequent or more intense storms/cyclones.
- Given the poor waste management and sanitation practices on the island, there is recognition that pollution from these sources may be having effects on the surrounding reefs and reef resources. However, the environmental responses and extent of effects is not known.

5.7 Rivers/Streams/Groundwater

5.7.1 Description of Socio-Ecological Values

For the purposes of this assessment, non-marine waters have been consolidated into a single ecosystem category and include the various streams, rivers and groundwater springs present within Nggela Islands. Notably, this category also includes estuarine rivers, which become freshwater-dominant further upstream. There are a variety of major river systems on Nggela Sule and Nggela Pile (e.g. Mbetitina River, Kongga River, Kirighi River), while the Buena Vista and Sandfly Islands mainly contain smaller unnamed tributaries and streams. The primary rivers and streams utilised by the various Nggela communities were identified as the following:

- Soka: two small unnamed streams on Buena Vista Island (located at approximately 8.89931°S, 160.02067°E and 8.90087°S and 160.02141°E)
- Gumu: located approximately 3km upstream on the banks of the Mbetitina river, just past its junction with Nggumu river. The Mbetitina river has a wide river mouth and notable delta area on the south-western coast of Nggela Sule (approximately 9.0774°S, 160.21802°E)

- Vuranimala: an unnamed tributary which flows into the Ulunimbeti river (located at approximately 9.16371°S, 160.32468°E). Mapping also indicates another small tributary to the southeast of the village (Tavesapa river – approximately 9.17488°S and 160.32774°E) however this was not visited by the project team and was therefore unable to be ground-truthed.
- Toa: an unnamed stream to the west/southwest of the main village area. It is unclear whether this stream flows directly to the coast from this location or whether it joins the Rumu river (mapped as occurring slightly further southwest). The unnamed stream is located at approximately 9.15156°S, 160.38579°E). There us another unnamed stream which flows into the newer village expansion area at approximately 9.14588°S, 160.39393°E.
- Haleta: two unnamed streams at approximately 9.09714°S, 160.11151°E and 9.09703°S, 160.11706°E

Freshwater streams present on the island are primarily small, spring fed steams that flow to the estuarine ‘rivers’ (Figure 5.21). The ecological condition and/or ecosystem health of the rivers and streams is variable, ranging from near pristine (typically for larger river systems and those located furthest from frequent human activity, such as Mbetitina river) to somewhat modified. The rivers and streams at most communities remained mostly unmodified, however, clearing of natural riparian vegetation along stream banks for gardens and buildings is common (Figure 5.22). The rivers and streams at Toa can be classed as somewhat modified due to (1) modified banks/channelisation associated with the village’s tilapia aquaculture venture (Figure 5.23), and (2) the community’s construction of a small dam further upstream (accompanied by a tank which is the primary source of drinking water). The tilapia aquaculture nursery was established as part of a broader project by the UN Development Fund which developed a large farm (irrigated by the dam) behind the Toa village.

It should also be noted that coastal lagoons were observed at Soka, Haleta and Vuranimala where smaller streams flowed to the coast but were separated from the sea by a small foredune ridge (e.g. Figure 5.24). The areas also presumably receive water from tidal overwash. There was a noticeable lack of vegetation around these systems, as well as increased algae development and erosion.

A)

B)

C)

D)

Figure 5.21 A) Freshwater stream behind Soka village, B) freshwater spring-fed stream behind Toa’s ‘old village’, C) tributary from Mbetitina/Nggumu river at Gumu, D) small stream mouth

A) B)

Figure 5.22 Clearing of stream banks for gardens and buildings at Soka, A) looking upstream and B) looking downstream.

A) B)

Figure 5.23 Channelisation of the river/stream (A) to sustain a large garden and series of tilapia aquaculture ponds (B).

Figure 5.24 Example of coastal lagoon at Soka

The communities of Nggela Islands are dependent on rivers and streams for a number of essential services, including:

- Supply of freshwater, most importantly as drinking water when rainwater tank supplies are inadequate, but also for cooking, washing and bathing when groundwater well supplies are insufficient. Groundwater springs are also used as drinking water sources and feed freshwater to local streams.
- Provision of food sources that are important for supplementing marine derived protein, providing a means of food security, and providing variety in the diet. Key fauna groups targeted in rivers for food include eel fish, prawns and various other fish.
- Vuranimala identified that these ecosystems also provide regulating and habitat ecosystem services in the form of breeding/spawning areas for fish.
- Supply of water to crops along the riverbanks and in freshwater swamps (e.g. sago palm and wild taro) – providing food security.

Gumu also relies heavily on Mbetitina river for transport to Tulagi market, where they are the largest seller of garden produce (fruits and vegetables etc.). Boats are the only means of transporting both goods and people to/from Gumu. However, this ecosystem service was not identified by the community participants during the workshop.

Nggela communities are also dependent on groundwater primarily for the supply of freshwater for cooking, washing and bathing. Rainwater tank water or water from rivers/streams are typically reserved as the preferred drinking water source, however, groundwater and springs provide a backup water source during exceptionally dry periods. Groundwater wells were observed at most of the five communities with the exception of Gumu and Haleta (note that Haleta did not receive as detailed site visit) (Figure 5.25).

A) B) C)

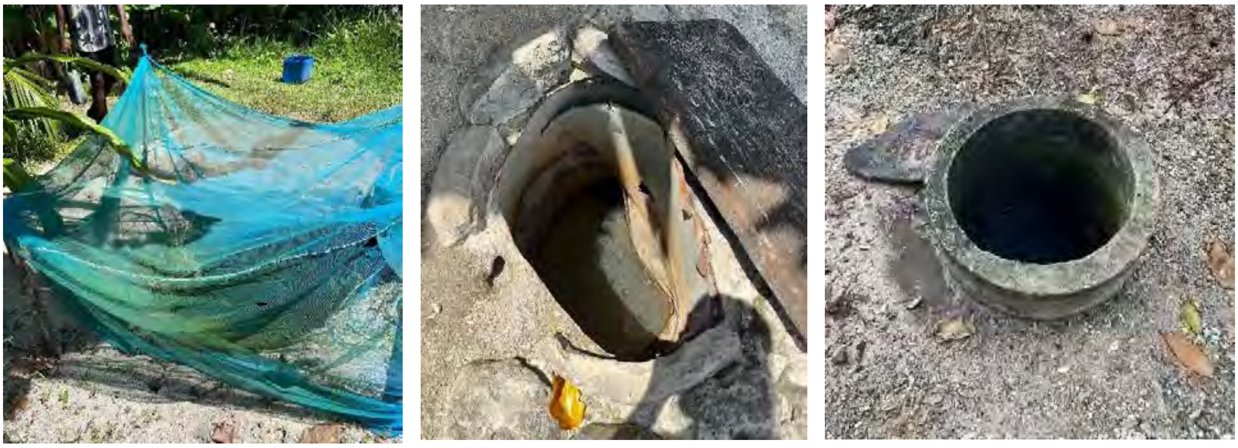


Figure 5.25 Examples of groundwater wells at A) Soka, B), C) Vuranimala

5.7.2 Sensitivities and Threats

In terms of ecosystem health and the suitability of Nggela's rivers, streams and groundwater as a source of direct provisioning services (particularly water supply) to the local community, the most significant concerns are contamination and clearing of adjacent riparian vegetation. The threats identified for these ecosystems are very similar to those outlined for 'freshwater swamps' since the communities often grouped these ecosystem types together when discussing concerns.

The following specific contamination inputs and risks were noted:

- Sedimentation and other pollutants from illegal logging activities (already being observed by Gumu and Haleta)
- Degradation of water quality from the chemicals used to treat mosquito nets (treated nets were provided to rural communities by The Ministry of Health and Medical Services). When the mosquito nets are placed in the rivers (e.g. to harvest prawns), the chemical kills prawns, eels and other aquatic species (observed in Vuranimala).
- Pollution from sanitation uses / toilets
- Saltwater intrusion into coastal groundwater wells (particular concern for Vuranimala, where most groundwater wells are within approximately 10 m of the sea).

While not specifically noted by the communities, it is suspected that pollution from domestic animals (especially pigs), rubbish disposal, vessel and outboard motor spills and leaks (fuel/oils) could be contributing to reductions in water quality.

Communities are also worried about the effects of clearing riparian vegetation adjacent to waterways for new gardens/house sites, as some have already noticed significant reductions in stream levels. Although not currently a threat, if clearing increases, it could destabilise soils and banks making them more vulnerable to soil erosion during high rainfall and/or flood events.

The following additional threats were noted:

- Extreme dry periods causing streams and rivers to dry out periodically. This has become a significant problem for the community of Toa, which often experiences water shortages during the dry season. The village has to introduce water restrictions during these periods to manage water use. It is expected that such effects may become more frequent or intensify with climate change.

- Extreme wet periods causing flooding and making the rivers/stream waters inaccessible/unsafe for drinking. It is expected that such effects may become more frequent or intensify with climate change.

- Landslides - 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.

- Overharvesting of aquatic fauna (e.g. eels, tilapia, prawns).

It is worth noting that there are elevated risks for aquatic ecosystems in close proximity to local aquaculture ventures farming Tilapia, which is an invasive species.

Most of the above threats 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.

5.8 Sandy Beaches, Islands and Coastal Areas

5.8.1 Description of Socio-Ecological Values

Nggela coastlines are dominated by white coral beaches, with muddy mangrove environments typically confined to areas protected from the open ocean by smaller islets and along major rivers. All communities except Gumu (located inland) had a strip of sandy beach adjacent to the built settlement areas (i.e. separating the settlements from the sea) (examples are shown in Figure 5.26). Due to their proximity to villages, sandy beaches are often used as sanitation/toilet areas. However, the more visually obvious disturbance is coastal erosion.

While comparatively small in land area, sandy beaches, islands and coastal areas 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 (with the exception of village high-use areas). Sandy beaches directly adjacent to villages typically contain more sparse vegetation which, in turn, increases their exposure to coastal erosion. It is unclear what specifically has contributed to the sparseness of vegetation along village foreshores, but it is likely to relate to one or more of the following processes: timber harvesting, clearing land for new houses, significant coastal erosion or storm tide events, previous cyclones or intense storms. Variations in intertidal and terrestrial vegetation establishment and health on Nggela beaches are shown in (Figure 5.27).

A)

B)

C)

D)

Figure 5.26 Examples of sandy beaches at A) Soka, B) Toa, C) Vuranimala and D) Haleta

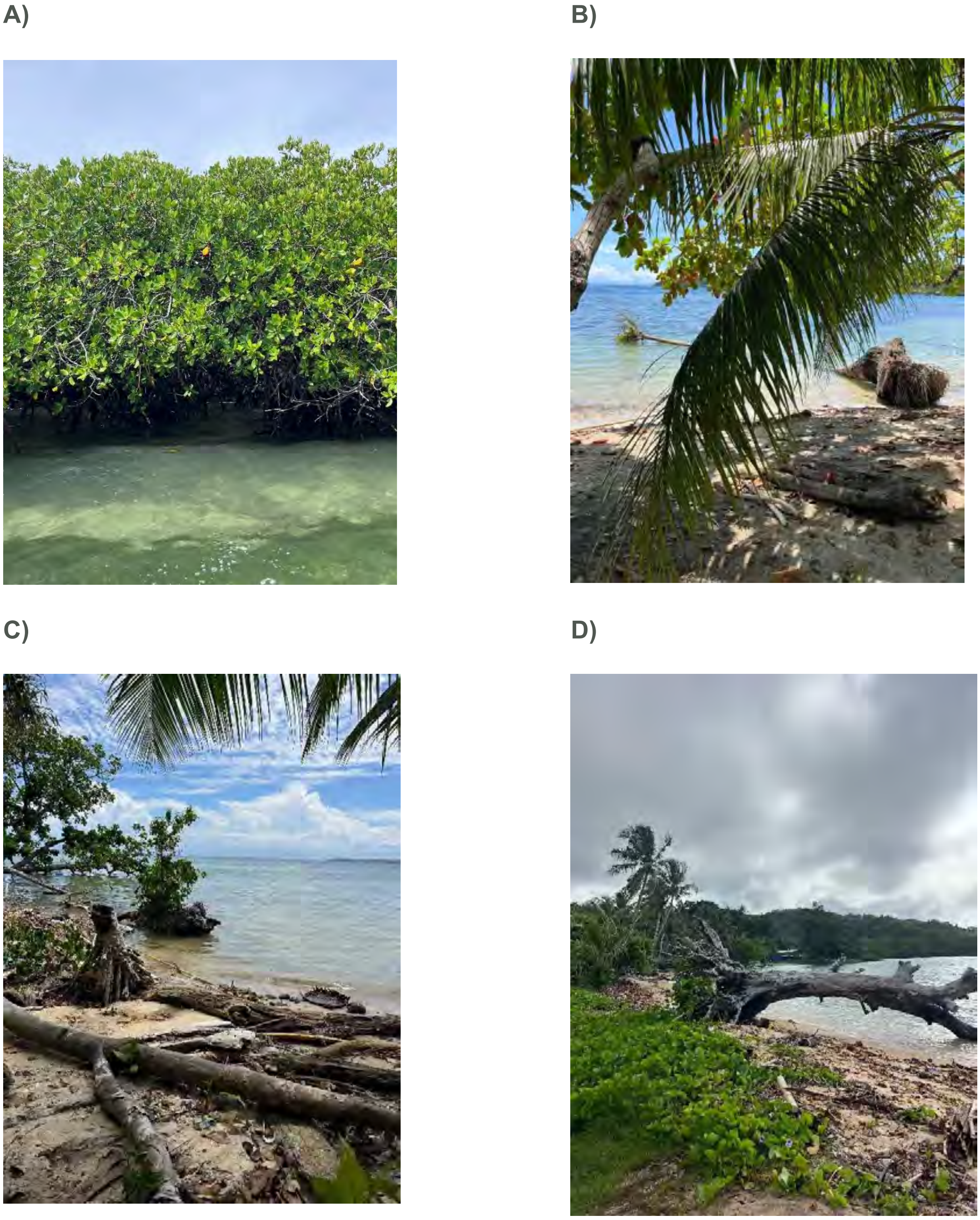


Figure 5.27 Variety in vegetation types and condition on high-use sandy beaches in Nggela Islands

Sandy beaches are most highly valued by the communities as a source of food and income via seasonal crab harvests ('crab areas'). They are also valued by some communities as sanitation areas.

Other services valued by the community include

- A source of sand and gravel (i.e. coral rubble), which are used in building construction requiring concrete and other uses around the village such as creating footpaths (Figure 5.28, see also Figure 5.20 A).
- A source of groundwater springs (Toa)

Although not explicitly identified by the communities, sandy beaches also provide safe boat or canoe landing areas and allow community members to transport goods to market.

Figure 5.28 Piles of extracted sand and coral rubble for construction at Vuranimala

5.8.2 Sensitivities and Threats

Key threats identified for sandy beaches, islands and coastal areas are primarily associated with coastal erosion and permanent inundation through sea level rise. Coastal erosion was typically discussed in conjunction with sea level rise; however, it is recognised that such erosion can be either acute or chronic. Acute coastal erosion typically occurs during storm surge/storm tide and extreme/king tide events and can be exacerbated by sea level rise. In contrast, more chronic coastal erosion may arise directly from sea level rise but could be difficult to separate from the natural high dynamicity of sandy coastal areas. Specific concerns from communities included:

- 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).
- Sanitation impacting water quality and surrounding ecosystems
- Climate change altering the seasonal cycles of crabs
- Overharvesting of crabs (although villages note that populations typically recover by the following season at present levels)

Although not identified by the communities, other threats to sandy beaches, islands and coastal areas could include clearing of vegetation and the potential flow on effects to food sources, as well as odification of sandy shores through foreshore protection works impacting natural shoreline processes (Figure 5.30 – see also Figure 5.20 C).

A)

B)

Figure 5.29 A) Example of beach erosion along exposed coast at Soka, and B) sea level inundation of previous foreshore protection works.

A)

B)

Figure 5.30 Examples of foreshore protection works.

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 (BMT WBM, 2017a). Even in the absence of climate change, the implications of this high dynamicity are that the construction of built structure 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 (BMT WBM, 2017a).

5.9 Cultivated Land - Gardens

5.9.1 Description of Socio-Ecological Values

While in a highly modified state through human cultivation, subsistence food gardens represent the terrestrial ecosystem type most highly valued by Nggela communities. Gardens are essential for food provision, with the communities being almost solely reliant on their local subsistence produce for their fruit and vegetable needs. For the Gumu community, garden produce also constitutes their primary source of income, being the main supplier of fruit and vegetables at Tulagi market.

Food gardens within the five Nggela communities include domestic fruit and vegetable crops (e.g. root vegetable patches, orchards etc.) located either by houses or in dedicated agricultural – ‘garden’ – plots. These dedicated agricultural plots encompass much of the land immediately surrounding each village (Figures 5.1 – 5.5).

Staple vegetable crops include sweet potato, cassava and taro, and are often grown in dedicated monoculture plots. Gardens located around houses (i.e. within the village) are more commonly comprised of a mixture of various vegetables and/or fruits (Figure 5.31). Plant foods found around each village, and not necessarily in dedicated garden plots, include: a) bananas, b) betel nut, c) cut nut, d) pana, e) yam, f) melon, g) corn, h) peanuts.

The communities also acknowledged that gardens provide cultural ecosystem services in the form of ‘solving family issues’.

Figure 5.31 Examples of garden varieties across the Nggela communities; A) mixed produce garden in Soka, B) cassava crops in Soka, C) mixed produce irrigated garden at Toa, D) various fruit trees, cut nut and cassava in Toa, E) mixed produce garden in Toa, F) fruit and vegetable plants around houses in Vuranimala.

5.9.2 Sensitivities and Threats

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

- Insect pests are a major management concern if they become well established, while the projected increase in temperature from climate change is likely to heighten the risk of food crops becoming more susceptible to pests.
- Destruction by feral and other animals (wild pigs, chickens, megapode birds), noting that wild pigs are perceived to be the worst offenders.
- Increasing demand on gardens through population growth and limited space/opportunity for garden expansion (particularly in Soka and Haleta).
- Reduced fallow periods as a result of intense garden usage (from growing population) causing soil fertility issues.
- Anti-social behaviour in the form of stealing garden produce, which may become exacerbated by population growth, times of low food supply and limited land availability for gardens to expand for accommodating a growing population.
- Changes in climate – the community in Soka are experiencing longer periods of dry/sunny weather rather than shorter, more frequent wet/dry cycles which affects crops.
- Landslides (e.g. Figure 5.32)

Although not explicitly identified by the communities, it is likely that heavy rainfall events and storms, resulting in flooding and high winds, also represent a threat to gardens (damage, waterlogging etc.)

Figure 5.32 Past landslide site in Soka which caused damage to surrounding gardens

5.10 Cultivated Land - Plantation

5.10.1 Description of Socio-Ecological Values

When considering cultivated lands, plantations are typically seen by local communities as a distinct 'ecosystem' to the gardens. This is largely due to plantations containing distinct groups of plant species and being subject to some different threats. Plantations typically occur in large, dedicated plots in and around villages, particularly in places like Gumu which are less constrained by natural land capital and rely heavily on plantations for income generation. Plantations are dedicated to the cultivated tree crops that the community are reliant upon, primarily coconut *Cocos nucifera*, betel nut *Areca catechu*, and sago palm (Figure 5.33). Other plantation crops occur in small, isolated areas including, for example, cocoa *Theobroma cacao* and cut nut *Barringtonia edulis*.

Plantation plants are primarily grown for commercial purposes, to sell both locally and at Honiara (e.g. betel nut), however, they are versatile in that they also provide food for local consumption (e.g. coconut) and building materials (e.g. sago palm). Sago palm leaves provide the main source of material for roofing and walls of dwellings.

There are also indirect food provisioning values associated with these plantations, such as coconut crabs (*Birgus latro*). Coconut crabs are commonly harvested in Central Province, however, they were only recognised by one of the Nggela communities as a key food source (Toa). Coconut crabs are the largest land crabs and as of 2018 they are listed as vulnerable on the International Union for Conservation of Nature (IUCN) Red List.

In terms of plantation condition, it was noted (during the Nggela Islands site visit) that many of the existing coconut plantations are quite old, having been established by the previous generation. Anecdotal evidence suggests that the aging trees in these plantations are no longer at optimum productivity and produce a lower yield of fruit than younger trees (BMT WBM, 2017b). There was no evidence to suggest that new coconut trees were being planted to compensate for the existing aging coconut plantations.

A)

B)

C)

D)

Figure 5.33 Main plantation crops (excluding sago palm): A) coconut, B) betel nut, C) harvested cocoa and D) cut nut

5.10.2 Sensitivities and Threats

Key threats identified by communities for plantations were typically shared across all plantation types, with the exception of some unique threats for coconut and sago palm plantations. Identified threats included:

- Insect pests are a major management concern if they become well established (e.g. birds eating fruit, rhinoceros beetle affecting coconut plantations). The projected increase in temperature from climate change is likely to heighten the risk of vegetation becoming more susceptible to pests.
- Anti-social behaviour in the form of stealing garden produce, which may become exacerbated by population growth, times of low food supply and limited land availability for gardens to expand for accommodating a growing population.
- Overharvesting plantation resources due to increasing populations – experiencing decreasing plantation yields and no new replanting has been taking place. This was recognised as a particular problem for sago palm in Vuranimala, since the sago palm plantation is communal.
- Landslides.

Additional threats not explicitly identified by the Nggela communities include:

- The location of coconut plantations along, or in close proximity to, the shoreline being prone to coastal erosion (especially from cyclone and storm surge).
- Aging plantations need replacement with younger trees for improved resilience and productivity.
- A high dependency 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.

5.11 Conservation or Tabu Area

5.11.1 Description of Socio-Ecological Values

While these do not constitute distinct ecosystem types and are instead comprised of a variety of ecosystem types which have already been discussed (e.g. reefs, forests etc.), communities on Nggela Islands consistently recognised these areas as having distinct socio-ecological values.

Conservation or tabu areas represent areas of certain ecosystems (typically forests and reefs) which are informally protected via voluntary managed areas or chief-mandated taboos (‘tabu’) (Figures 5.1 – 5.5). The distinct ecosystem services consistently identified for these areas included provisioning services, habitat services and cultural services. Socio-ecological values identified by the communities included:

- Tourism providing a source of income. This is typically for marine areas through diving and selling local products to visiting vessels (particularly for Soka, Vuranimala and Haleta). Haleta also noted their ‘wharf’ as one of the most important areas for sustaining their community since it allows tourist and trading vessels to anchor near the village.
- Sacred areas of cultural significance providing spiritual experience and a sense of belonging. These were typically located in forests.
- Resource protection (e.g. protecting virgin forests for the next generation).

5.11.2 Sensitivities and Threats

The sensitivities and threats affecting these areas have been captured in each individual ecosystem type which constitute those conserved/tabu areas. Please refer relevant sections above.

5.12 Marine (Other)

5.12.1 Description of Socio-Ecological Values

The remaining marine environments around Nggela Islands primarily comprise deeper open waters and associated habitats including, for example, deeper seabeds and pelagic waters (i.e. those marine habitats which lay beyond inshore reefs). Notably there has been a shift towards fishing in offshore reefs amongst Nggela communities, due to widely observed declines in nearshore fisheries resources. Deep sea fishing ground are primarily used for both local sustenance and commercial trade through fishing (line, net) and diving.

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; nutrient and carbon cycling by both phytoplankton and zooplankton (BMT WBM, 2017a).

5.12.2 Sensitivities and Threats

The main threats to open waters and offshore marine environments are very similar to those identified for inshore reefs. These include:

- Overharvesting of fish and other marine fauna, which may worsen due to rising fishing pressure as the local population increases and resources continue to decline in nearshore reefs.
- The use of destructive fishing methods
- Pollution from Honiara

- Competing fishermen from neighbouring provinces due to proximity to market (these fishermen also tend to use destructive fishing techniques to increase their catches)
- Oil spills from ships
- Climate change threats including an increase in sea temperature and the associated coral bleaching and ocean acidification.

5.13 Other (Village)

5.13.1 Description of Values

While it is recognised that these systems do not represent an ecosystem type, most communities identified aspects of their built settlements which were integral to daily life. For example, schools, churches and clinics which provide valuable services to the community such as education, spiritual support and basic healthcare. Although these do not constitute ‘socio-ecological’ values, the project team decided that these areas should still be included in the report, largely due to the valid concerns/threats about them raised by the communities. Other village components which were identified by the communities included:

- Rainwater tanks as an important source of water (particularly in Toa)
- Toa’s ‘old settlement’ which not only provides food and water via groundwater springs and gardens, but also has significant cultural value
- Wharf which allows tourist and trade vessels to dock near Haleta.

5.13.2 Sensitivities and Threats

Key threats to the villages (built settlements) identified by community members include:

- Permanent inundation due to sea level rise and associated beach erosion (raised as a major concern for all communities except for Gumu). All communities are located on very low elevations and already experience frequent seawater intrusion during high tides. Most communities have observed the water slowly encroaching into the villages.
- Having nowhere to shelter and be protected from cyclones or tsunamis. This was a particular concern for Vuranimala and Toa which are located on more exposed coastlines of Nggela.
- Food security more broadly (identified as a major concern at all five communities)
- Lack of proper sanitation (identified as a major concern at all five communities)
- Not having enough rainwater tanks to provide water security
- Lack of rural electrification
- The Vuranimala community expressed their concern about not having enough medical areas/clinics.

These key threats should be used as a guide for any NGOs looking for opportunities to fund development projects in the five communities, as well as in Nggela Islands more broadly.

6 Savo Island Context

6.1 Savo Island Setting

6.1.1 Geographic

Savo Island is located in the centre of Central Province, approximately 35 km north-northwest of Honiara. The island is the 6-km-diameter emergent summit of an andesitic-dacitic stratovolcano, which rises from the Iron Bottom Sound (Petterson et al., 2003). Savo has erupted at least three times within recorded history, with the last eruption being in 1847 (GVP, 2021). However, it has recently experienced an increase in volcanic activity (GVP, 2021; Petterson et al., 2003; Solomon Islands Historical Encyclopaedia, 2020a). The summit of Savo Island is approximately 400 m, with the island increasing in elevation from the coast into the centre (Petterson et al., 2003). The island is dominated by dense rainforest, with some narrow sandy beaches present along the coastline, mainly on the north of the island. The waters around the island were the site of most of the major naval battles during the Battle of Guadalcanal in World War II, resulting in many shipwrecks located to the southeast of the island. Unlike Nggela Islands, there are no coral reefs surrounding the island and its coastlines are exposed to the high wave energies of the open ocean. This project focuses on the village of Panueli on Savo Island's north coast.

6.1.2 Cultural

Melanesian megapode birds have had a longstanding history with Savo Island and remain integral to the island's identity. It is thought that the geothermal environment of the island attracts the birds, who utilise the warm volcanic sand to incubate their eggs. Megapode eggs are the primary source of protein for Savo communities, and their consumption and trade are critical for food security. However, megapode birds are also very important culturally to the people of Savo Island who recount kastom stories of the megapode's arrival on the island and continue to honour the birds through dedicated shrine areas. Unfortunately, the island is observing a substantial decline in megapode birds (and eggs) due to overharvesting pressures and a loss of respect for the birds amongst younger generations. Similar to Nggela, Savo Island communities are witnessing a shift away from traditional regulatory systems and a decline in respect for cultural traditions and rules. For example, historically, children were not allowed in the megapode fields and harvesting would be restricted to certain seasons to allow the populations to recover (SIBC, 2017). These rules are no longer followed, with the field now open to the public and community members harvesting eggs every week (SIBC, 2017). During the consultations in Panueli, the project team were informed that the loss of respect for the birds amongst younger generations was a major concern for community members.

Also similar to Nggela, communities on Savo Island maintain customary land tenure via matrilineal inheritance. However, an exception to this typical land ownership system is the main megapode laying field near Panueli community. Savo Island residents, particularly those from the Panueli community, have a highly organized system of ownership and rights to the field which includes tabu and kastom (local customary practice) restrictions (although these are not always followed) (Georgeou and Hawksley, 2017). All communities on Savo Island also remain connected via a single dirt road which spans the circumference of the island.

6.1.3 Socio-Economic Profile

Most communities on Savo Island rely on the production and sale of agricultural produce as their main source of income. Produce is primarily sold at Honiara Central Market. Communities typically sell the following products at the central market, or other markets in Honiara: slippery cabbage; cacao; cassava; chickens; corn; eggplant; kumara (sweet potato); mango; watermelon; betel nut; cut nut; ngali nut (*Canarium indicumi*); pawpaw; peanuts; pineapple; pumpkin; malay apple (*Syzygium malaccense*); tomato; and several varieties of beans and capsicum (Georgeou and Hawksley, 2017). Savo Islanders grow some crops specifically to sell at market (cash crops e.g. melon and peanut), while other harvested products (e.g. malay apple and nuts) are sold seasonally (Georgeou and Hawksley, 2017). Savo Islanders also rely on the sale of megapode eggs as a key source of income, which are also sold at markets in Honiara (Georgeou and Hawksley, 2017). A megapode egg is around twice the size of a chicken egg and sells for around SBD10–12 per egg (Georgeou and Hawksley, 2017).

7 Savo Island Socio-Ecological Values, Sensitivities and Threats

The Panueli community on Savo Island are entirely dependent on their surrounding ecosystems to sustain their livelihoods and earn an income. The social, cultural and economic values of the community are therefore directly intertwined with the surrounding ecosystem values. This section provides a brief description of the key ecosystems directly utilised by the Panueli community and the associated ecosystem services which constitute their value for the community.

This section also includes a summary of the human and climate threats (‘worries and concerns’) to each ecosystem (and its services) identified by the local community. Sensitivities of ecosystems and their services to human and climate change threats are briefly discussed, however, sensitivities to climate change-related threats will be discussed in more detail in the Climate Change Vulnerability Assessment (Section 11).

In order to accurately document and convey the concepts and values communicated to us by the communities, we have attempted to retain a similar differentiation of different ‘ecosystem types’. For example, the community clearly distinguishes between ‘megapode fields’ and ‘sandy beaches’ in terms of the ecosystem services and management challenges for each, despite the laying fields occurring along the sandy foredunes.

We first provide an overview (Section 7.1) of the key ecosystems and ecosystem services which form the socio-ecological values for Panueli, followed by a more detailed examination of each ecosystem / service in the subsequent sections (Sections 7.3 to 7.13)

7.1 Overview – Ecosystems and Ecosystem Services

7.1.1 Community-Derived Identification

The Panueli community consistently recognised 6 main ecosystems on which they were directly dependent, including:

1. Megapode Fields
2. Sandy Beaches, Islands and Coastal Areas
3. Cultivated Land – Gardens
4. Cultivated Land – Plantations
5. Marine
6. Other (Village).

Other ecosystems and or services derived from elsewhere (e.g. drinking water from rainfall to rainwater tanks, submarine volcano vents providing soil heat etc.) were also occasionally recognised and have been documented in the ‘Other (Village)’ category.

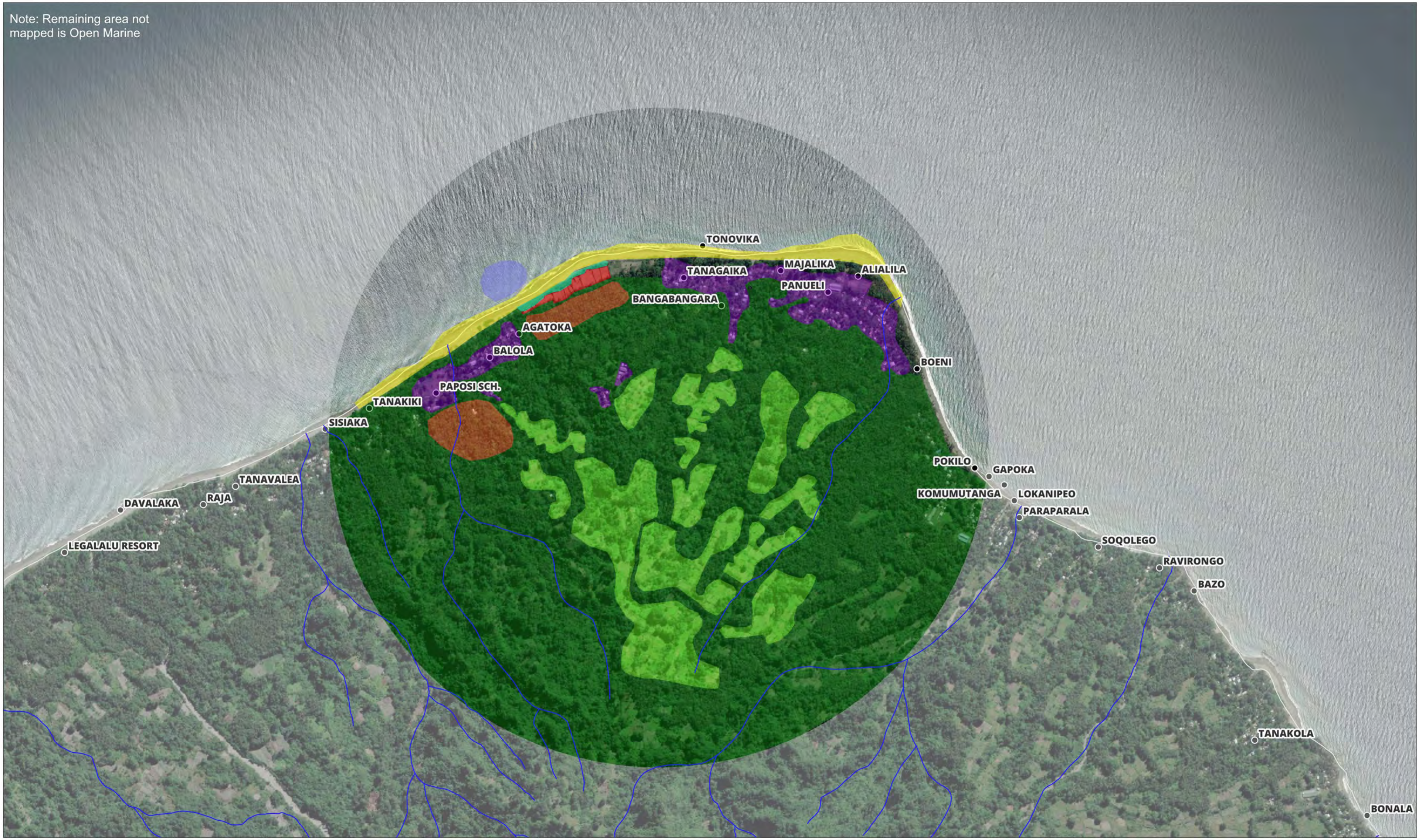
A map showing the spatial distribution and extent of these ecosystems is provided in Figure 7.1. Note that this mapping is to be considered indicative only, and has been derived from existing GIS data, discernment of ecosystems through remote sensing, community-derived information, and rapid field mapping (i.e. in close proximity to villages). Extensive and/or detailed ground works to verify and validate ecosystem maps were not undertaken as part of this project.

Table 7.1 lists the respective ecosystem services for each ecosystem, as identified by the Panueli community. The relative frequency that each ecosystem service was identified in the consultation (i.e. identified by one group only or by both groups) is provided as an indicator of the importance of that service (and associated ecosystem). Based on this indicator, the essential ecosystem and/or ecosystem services on which the community was most reliant include:

- Megapode fields for food security (all year around – a main source of protein), a key source of income and of profound cultural significance.
- Sandy beaches providing the main sanitation areas, as well as recreation via swimming.
- Gardens as the main source of food and income via production of a wide variety of fruit and vegetables.
- Coconut plantation providing a source of food and income (via income).
- The village area itself as the primary area of habitation and community interaction.

It can be seen in Table 7.2 that some broad ecosystem services (e.g. food or income) are sourced from a variety of ecosystems. In contrast, some ecosystem services are more specialised and may only be associated with one or two ecosystems (e.g. drinking water sources, cultural values). This is important in the context of climate change resilience, since there may be limited alternative sources for some essential ecosystem services if the original source is undermined.

Areas of direct community utilisation of land and sea resourcesare shown spatially in Figure 7.2. Generally, the community accesses and uses the full range of ecosystems with and immediately surrounding their village, occasionally venturing further afield (particularly for offshore fishing grounds).



LEGEND

- Rivers and streams (desktop)
- Coastline

Community Ecosystem Classifications

- Forest
- Built settlement
- Sandy beaches
- Gardens
- Plantation
- Subsea Volcano
- Megapode fields
- Vegetated dunes

Title:

Distribution of key ecosystems in Panueli focus area, Savo Island

Figure: 7-1

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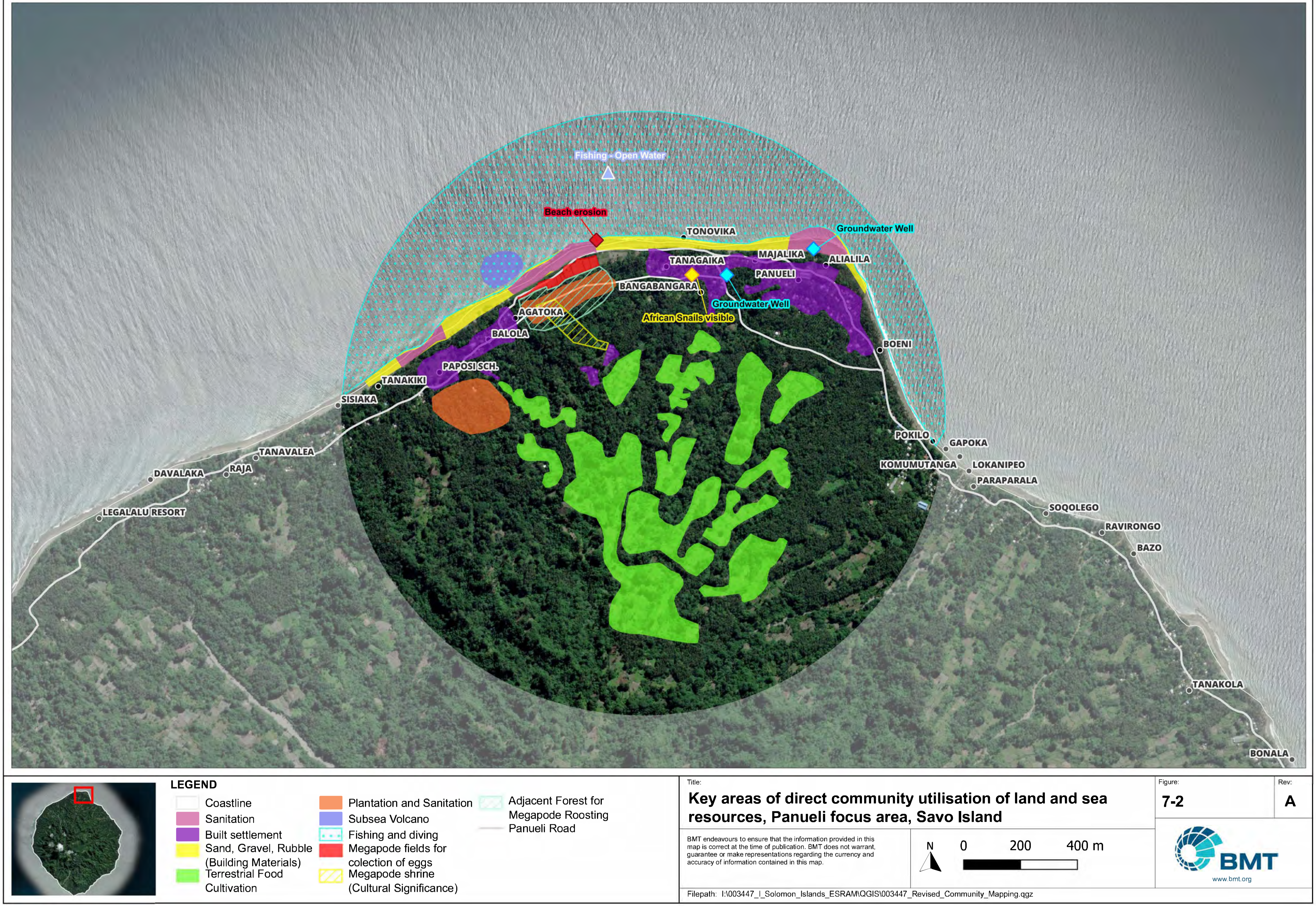
Table 7.1 Inventory of ecosystems and ecosystem services identified by Panueli community (✓ denotes the frequency of each ecosystem service identified). Higher frequencies are in yellow and lower frequencies in blue.

Ecosystems	Key Ecosystem Services identified by Panueli community	Frequency of Identification by the Community (two groups)
		Panueli
Megapode field	Cultural significance (kastom), sacred, respected. Traditional food source. Locals even use eggs to barter for goods when money is not available.	✓✓
	Megapode eggs – source of food throughout the year and income. Main source of protein for communities. Money to improve living standards.	✓✓
	Adjacent forest important for bird rest and roost	✓
	Solving community issues – *social value*	✓
Sandy beaches, islands and coastal areas	Sanitation area	✓✓
	Collecting rubble, gravel and sand for building materials/bricks and for selling	✓
	Recreation	✓✓
	Copra drying area	✓
Gardens	Food and income source (fruit and vegetable crops for domestic and commercial use, e.g. cassava, sweet potato, cabbage, mango, melon, corn, peanuts etc.)	✓✓
Plantation	Betel nut – small scale commercial	✓
	Cocoa – small scale commercial	✓
	Coconut – small scale commercial (copra) and food security	✓✓
	Sanitation	✓
Marine	Deep sea fishing grounds for food security and income, fishing and diving	✓

Ecosystems	Key Ecosystem Services identified by Panueli community	Frequency of Identification by the Community (two groups)
		Panueli
	Swimming for leisure	✓
	Habitat for marine species (corals and fish)	✓
Other	Village (clinic, school, church, playing field and road)	✓✓
	Submarine volcano (vent) – provides heat source for megapode field so that they lay eggs	✓
	Rainwater tanks	✓
	Cultural and traditional shrines of Megapode field	✓

Table 7.2 Summary of ecosystem sources for key ecosystem services

Key Ecosystems	Food (land)	Food (sea, river)	Water (drinking)	Water (other)	Building materials	Copra drying area	Income (market)	Species Protection	Sanitation	Recreation	Cultural significance
Megapode Fields and adjacent forest	✓						✓	✓			✓
Sandy beaches, islands and coastal areas					✓	✓	✓		✓	✓	
Gardens	✓						✓				
Plantations	✓						✓		✓		
Marine (other)		✓						✓		✓	
Other (rainfall)			✓	✓							
Other (submarine volcano vent)	✓						✓	✓			



Title:

Key areas of direct community utilisation of land and sea resources, Panueli focus area, Savo Island

Figure: 7-2

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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7.1.2 Additional Ecosystem Services Identification

Most of the ecosystem services recognised by Panueli would be classified as provisioning services (i.e. the provision of food, water and raw materials). However, groups also identified ecosystem services classified as habitat services (e.g. biodiversity, bird roost areas) and cultural services (e.g. cultural significance of the megapode fields). In addition to these services, there were a number of additional services not accounted for. The complete list of regulating, habitat and cultural services (listed in general terms based on a study by de Groot et al. (2012)) is presented in Table 5.3. 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 (BMT WBM, 2017b). Ecosystems that provide multiple ecosystem services, especially critical services (i.e. provision of water and food), are considered crucial for community resilience on Savo.

As noted in Section 5.1.2, 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, sea level rise
- Geology and geomorphology – including both fluvial and land-based geomorphology. Volcanic processes from Savo Volcano contribute significantly to fluvial inputs on the island, as well as to land stability more broadly through mechanisms such as earthquakes and landslides. Community members from Panueli also noted the volcano's impact on water quality (streams not always safe to drink) and regularity of water flows.
- Sediment loads
- 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 and marine waters)
- Biological processes (e.g. primary productivity, carbon cycling by bacteria, zooplankton grazing, bioturbation and other fauna interactions).

As described above in Section 5.1.2, the list of services in Table 5.3 was applied across the different ecosystems (where relevant) as part of the economic valuations (Section 10) in order to fill gaps where services were not identified by the local community.

7.2 Overview – Sensitivities and Threats

7.2.1 Community-Derived Identification

The consultation at Panueli included an open discussion on the threats which were perceived to be affecting the key ecosystems (and associated services) described above. Community members were encouraged to share their worries and concerns regarding specific ecosystems, as well as any changes in the ecosystems they have observed over the years. Table 7.3 presents a summary of the ecosystem threats identified by Panueli residents and therefore demonstrates the biggest threats as perceived by the local community. Initial threat prioritisation has been undertaken based on community attitudes, with more severe perceived threats highlighted in red and less severe threats highlighted in orange.

Based on the summary information in Table 7.3 the greatest perceived threats to the Panueli community were:

- Most threats impacting the megapode field. These threats included beach degradation/erosion, inundation by sea level rise, human disturbance/gardening, loss of respect, overharvesting of megapode eggs, wild animals and volcanic eruption.
- Coastal erosion of beaches from storm surges (cyclones), extreme/king tides and longer-term from sea level rise
- Sea level rise inundation of beaches.
- Lower yields among coconut plantations (perceived by community to be potentially due to changing climatic conditions, but more likely associated with the age of the plantations/trees).
- Overarching threat of volcanic eruption on Savo Island.
- Overarching concerns around sanitation and waste disposal (particularly medical waste) contributing to spread of disease etc.

Table 7.4 provides a summary of the key threats to Savo Islands' ecosystems and services broken down into non-climate and climate related threats. 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 the human resilience, ecosystems are subject to significant anthropogenic threats such as pollution and overharvesting of megapode resources (BMT WBM, 2017a). Furthermore, these threats are exacerbated by the current and projected adverse impacts of climate change (to be explored further in Section 11).

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 Savo Island to future climate change impacts (BMT WBM, 2017b).

Table 7.3 Perceived sensitivity of the community to identified threats.

Ecosystems	Key Threats ('worries') identified by Panueli community	Initial Threat Severity
		Panueli
Megapode field	Beach degradation and erosion from high wave energy combined with sea level rise	High
	Sea level rise inundation	High
	Human disturbance and gardening	High
	Loss of respect for fields and megapode traditions, people disobeying rules. No law enforcement.	High
	Drought	Medium
	Overharvesting of megapode eggs – have observed less birds	High
	Disturbance of adjacent forest land where birds roost	High
	Eruption of submarine volcano	High
	Volcanic eruption	High
	Wild animals and dogs	High
	Lack of formal management guidelines	Medium
Sandy beaches, islands and coastal areas	Coastal erosion	High
	Inundation from sea level rise	High
	Frequent adverse weather conditions	Medium
	Volcanic eruption	High
Gardens	Soil erosion from repetitive cycles of sun/dry and heavy rain	Medium
	Insects/pests – particularly the African Snail. Has spread to most of the island (from west towards east)	Medium
	Volcanic eruption	High
Plantation	Climate change affecting conditions for production of coconuts – seeing lower yields now	High
	Insects/pests (African Snail and Rhinoceros/coconut beetle)	Medium

Ecosystems	Key Threats ('worries') identified by Panueli community	Initial Threat Severity
		Panueli
	Spread of disease from proximity to sanitation area	High
	Volcanic eruption	High
Marine	Overharvesting (bigger fish declining) – population increase and market demand	Medium
	Pollution (rubbish)	Medium
	Sanitation area impacting water quality	High
Other	Sea level rise inundation of the clinic (located very close to the coast)	High
	Erosion around key structures (e.g. church)	Medium
	Volcanic eruption	High
	School is very close to volcanic outlet	Medium
	School located in a flash flooding area	Medium
	Pollution/waste – no means of safely disposing of medical waste from the clinic	High

Table 7.4 Summary of key threats to each ecosystem service (services and threats identified by community)

Ecosystems	Key Ecosystem Services identified by Panueli Community	Climate Related Threats								Non-Climate Related Threats									
		Sea level rise, saline intrusion	Drought / dry periods	Flooding / wet periods	Coastal / beach erosion	Cyclones and storms	Invasives / pests / disease	Changing seasonal cycles	Rapid wet/dry cycles causing soil erosion	Human disturbance	Pollution (rubbish)	Sanitation (disease risk)	Volcanic eruption	Population growth	Overharvesting - economic	Inadequate resource management	Loss of respect	No enforcement to protect kastom rules	Wild animals and stray dogs
Megapode Fields	Cultural significance (kastom)	✓	✓		✓					✓			✓	✓	✓	✓	✓	✓	✓
	Food and income source	✓	✓		✓					✓			✓	✓	✓	✓	✓	✓	✓
	Adjacent forest important for bird roost									✓			✓			✓	✓	✓	✓
	Solving community issues	✓	✓		✓					✓			✓	✓	✓	✓	✓	✓	✓
Sandy beaches, islands and coastal areas	Sanitation area	✓			✓	✓						✓	✓						
	Recreation	✓			✓	✓							✓						
	Building materials	✓			✓	✓							✓						
	Copra drying area	✓			✓	✓							✓						
Gardens	Food and income source						✓		✓			✓	✓						
Plantations	Coconuts (copra) – small scale commercial, food security						✓	✓				✓	✓						
	Cocoa – small scale commercial						✓					✓	✓						
	Betel nut – small scale commercial						✓					✓	✓						
	Sanitation											✓	✓						
Marine (Other)	Deep sea fishing grounds – food and income										✓	✓		✓	✓	✓			
	Recreation										✓	✓							
	Habitat for marine species (species protection)										✓	✓		✓	✓	✓			
Other (Village)	Built settlement (clinic, school, church etc.)	✓		✓					✓		✓		✓						
	Submarine volcano (vent) providing megapode heat source												✓						
	Rainwater tanks – water provision		✓										✓						

7.3 Megapode Field

7.3.1 Description of Socio-Ecological Values

The main megapode laying fields on Savo Island are located on the northern coast of Savo Island just behind the beach foredunes approximately 50m from the water's edge (Figure 7.2). The laying fields are comprised of approximately 9 plots, which are separated by fences made from coconut leaves (Figure 7.3). The fences serve a dual purpose of distinguishing between the various plots and protecting the birds from stray dogs (although this isn't 100% effective). The laying fields are backed by an adjacent forested area, which the community also regards as important for the megapode life cycle (i.e. bird roosting/resting areas).

The birds typically lay their eggs at night or dawn and community members will harvest them in the morning. At the time of writing, harvesting the eggs occurred once a week on Saturdays. Following the egg harvesting, community members rake the sand to cover any human footprints and also occasionally dig holes for the megapode birds to use to encourage them to lay. Of the approximately 9 megapode field plots, there is only one remaining which consistently used by the birds.

The megapode fields provide important ecosystem services not only for the Panueli community, but Savo Island more broadly, including:

- Food security – communities rely heavily on megapode eggs as a food source throughout the year. Eggs are the Panueli community's primary source of protein.
- Income generation – selling megapode eggs at Honiara Central Market is one of the main sources of income for the Panueli community which, in turn, allows them to improve living standards within the village. The eggs sell for around SBD10–12 per egg (approximately $1 USD) at market.
- Cultural services since the megapode eggs have always been a traditional food source on Savo. The eggs represent kastom beliefs and are often used to solve family issues in Savo communities. Locals even use eggs to barter for goods when money is not available.

The forested area adjacent to the megapode fields was typically in good condition. Degradation is primarily restricted to edge effects in the vicinity of villages, cultivated lands and the main track, however, the expansion of these areas is beginning to encroach into the megapode forest. If land clearing for gardens and houses continues around the forest, it may become thin and fragmented, reducing its habitat values.

Figure 7.3 Main megapode laying area near Panueli village. A) a relatively unused megapode field, B) and C) more frequently used megapode fields with holes dug into the sand to encourage laying, and D) a megapode shrine area in the adjacent forest.

7.3.2 Sensitivities and Threats

It has been suggested that overharvesting of megapode eggs is already evident. Community members in the workshop stated that they now see much fewer megapode birds and find very few eggs. Currently, there is no active management to ensure the sustainability of megapode egg harvesting near Panueli. Overharvesting therefore represents the primary threat to megapode populations, particularly in the face of population growth, climate change and other compounding threats. The intensive harvesting practices employed by communities on Savo Island mean that very few megapode eggs reach maturity to replenish the adult bird population. Overharvesting of megapode resources has not always been a significant problem on Savo Island and is partly attributed to the recent shift away from traditional regulatory systems and declines in respect for megapode practices. The community have recently introduced a $100 SBD fine for killing megapode birds, however there are very few means to enforce such rules. During the consultations in Panueli, the project team were informed that the loss of respect for the birds amongst younger generations was a major concern for community members.

Human disturbance and land clearing for gardening also constitute significant threats to the megapode fields, by reducing the amount of healthy forest habitat for available for birds to roost behind the laying fields. Notably, the Panueli community also has serious concerns around sea level rise and coastal erosion, since the laying fields are located on beach dunes approximately only 50 m from the sea. Overall, key threats identified for the megapode fields include:

- Overharvesting of megapode eggs driven by population growth and also market pressures. Lack of formal management guidelines
- Loss of respect for the fields, rules and megapode traditions and lack of law enforcement to uphold these rules/values/traditions
- Human disturbance and gardening, including disturbance of adjacent forest land where birds roost
- Beach degradation and erosion from high wave energy combined with sea level rise
- Permanent inundation from sea level rise
- Volcanic eruption
- Eruption of submarine volcano
- Drought
- Wild animals and dogs

7.4 Sandy Beaches, Islands and Coastal Areas

7.4.1 Description of Socio-Ecological Values

Narrow sandy beaches surround the entirety of Savo Island and constitute the boundary between the dense rainforest and the ocean. The widest beaches on the island are located on the northern coastline, adjacent to the Panueli village. Due to their proximity to villages, sandy beaches are often used as sanitation/toilet areas. However, the more visually obvious disturbance is coastal erosion. Savo Island does not have any coral reefs and is particularly exposed to the high wave energies of the open ocean. As a result, the beaches on the island typically plateau out from the foredunes before hitting a steep descent down towards the water where the waves have cut away at the sand and/or gravel (Figure 7.4). This makes boat landings more dangerous and presents an extra transportation challenge for the people of Savo. While comparatively small in land area, the beaches and coastal areas of Savo Island tend to support a variety of intertidal and terrestrial vegetation types (coastal dune vegetation and lowland forest), which generally appear to be in very good condition (with the exception of village high-use areas) (Figure 7.4). There are no mangroves present on Savo Island due to the exposed nature of the coastlines.

A) B)

Figure 7.4 A) steep gradient down towards the water created by coastal erosion from high wave energies, B) lowland forest and coastal dune vegetation outside Panueli village.

Sandy beaches are most highly valued by the community as areas for recreation, as well as sanitation areas. Other services valued by the community include:

- A source of sand and gravel (i.e. coral rubble), which are used in building construction requiring concrete/bricks. These materials are also sold as an additional source of income.
- Open spaces for copra drying (Figure 7.5)

Figure 7.5 Beach foredune space used for copra drying activities

7.4.2 Sensitivities and Threats

Key threats identified for sandy beaches, islands and coastal areas are primarily associated with coastal erosion and permanent inundation through sea level rise. Specific concerns included:

- Existing coastal erosion from high wave energies
- Additional coastal erosion from adverse weather conditions, e.g. 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).
- Volcanic eruption
- Eruption of submarine volcano.

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 (BMT WBM, 2017b).

7.5 Cultivated Land - Gardens

7.5.1 Description of Socio-Ecological Values

While in a highly modified state through human cultivation, subsistence food gardens represent a highly valued terrestrial ecosystem type by Panueli. Gardens are essential for food provision, with the community being solely reliant on their local subsistence produce for their fruit and vegetable needs. For the Panueli community, garden produce constitutes their primary source of income (alongside megapode eggs) and they are a key supplier of fruit and vegetables at Honiara Central Market. This allows the community access to other more varied food sources such as fish (which are typically bought at market rather than fished).

Food gardens at Panueli include domestic fruit and vegetable crops (e.g. root vegetable patches, orchards etc.) located closer to houses and dedicated agricultural – 'garden' – plots located further inland behind the village. These dedicated agricultural plots encompass much of the land between the village and steep slopes of the volcano (Figure 7.1). Resources from gardens (e.g. soil, propagules) may also be used to develop smaller 'sup sup' gardens, which are small elevated garden beds. They are usually located near houses and used for growing smaller sized vegetables for local consumption.

Staple vegetable crops include sweet potato and cassava, which are often grown in dedicated monoculture plots. Gardens located around houses (i.e. within the village) are more commonly comprised of a mixture of various vegetables and/or fruits. Panueli typically sells the following products at Honiara Central Market, or other markets in Honiara: malay apple, mango, watermelon, peanuts, nuts (betel nut, cut nut, ngali nut). The community also used to sell a wider range of vegetables such as capsicum, tomatoes and beans, however approximately 6 years ago an infestation of Giant African Snail (*Lissachatina fulica*) severely impacted crops. Now the community grow above-ground vegetables in 'sup sup' gardens for local consumption and can only sell leftovers which have not been impacted by the pest. The snails are an invasive species which was first reported in the Solomon Islands in 2006.

7.5.2 Sensitivities and Threats

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

- The Giant African Snail is a major management concern for the community of Panueli and Savo Island more broadly (Figure 7.6). It started in the west of the island and has spread most of the way to the east. The snail decimates vegetable crops in community garden plots. It should also be noted that projected increase in temperature from climate change is likely to heighten the risk of food crops becoming more susceptible to pests.
- Volcanic eruption
- Soil erosion from repetitive, rapid cycles of sun/dry and heavy rain

Although not explicitly identified by the community, it is likely that the following additional factors also represent a threat to gardens:

- heavy rainfall events and storms, resulting in flooding and high winds, also represent a threat to gardens (damage, waterlogging etc.)
- Destruction by feral and other animals (wild pigs, chickens, megapode birds), noting that wild pigs are the worst offenders.
- Reduced fallow periods as a result of intense garden usage (from growing population) causing soil fertility issues.

A)

B)

Figure 7.6 A) leaf damage inflicted by the African Snail and B) African Snail on vegetation along the road at Panueli

7.6 Cultivated Land - Plantation

7.6.1 Description of Socio-Ecological Values

Similar to Nggela Islands, plantations typically occur in large, dedicated plots in and around villages. In Panueli, they are primarily located behind the megapode forest area along either side of the main road. Another large plantation patch is located to the west of the village before the garden areas and steep slopes (Figure 7.1). Plantations are dedicated to the cultivated tree crops that the community are reliant upon, primarily coconut, betel nut, and cocoa (Figure 7.7). Other plantation crops occur in small, isolated areas including, for example, cut nut. Plantation plants are primarily grown for commercial purposes, to sell both locally and at Honiara (e.g. betel nut, copra from coconut), however, they are versatile in that they also provide food for local consumption (e.g. coconut). The community at Panueli also use the plantation area for sanitation purposes.

In terms of plantation condition, it was noted (during the Panueli site visit) that many of the existing coconut plantations are quite old, having been established by the previous generation. Anecdotal evidence suggests that the aging trees in these plantations are no longer at optimum productivity and produce a lower yield of fruit than younger trees (BMT WBM, 2017b). There was no evidence to suggest that new coconut trees were being planted to compensate for the existing aging coconut plantations.

A) B)

Figure 7.7 A) smaller plots of betel nut planted closer to houses and B) coconut trees with weedy undergrowth.

7.6.2 Sensitivities and Threats

Key threats identified by communities for plantations were typically shared across all plantation types, with the exception of some unique threats for coconut plantations. Identified threats included:

- Insect pests are a major management concern if they become well established (e.g. African Snail, rhinoceros beetle affecting coconut plantations). The projected increase in temperature from climate change may heighten the risk of vegetation becoming more susceptible to pests.
- Climate change affecting conditions for production of coconuts. The community expressed that they are seeing lower yields of coconut trees now and this could be due to changes in climate/seasonal cycles. While this could be impacting coconut tree yield, it is also likely that the age of the trees in these plantations is impacting the yield (i.e. they are no longer at optimum productivity).
- Spread of disease from proximity to sanitation area.
- Volcanic eruption.

Additional threats not explicitly identified by the Panueli community, but that are likely to impact the community in the near future, include:

- Overharvesting plantation resources due to increasing populations – experiencing decreasing plantation yields and no new replanting has been taking place.
- Aging plantations need replacement with younger trees for improved resilience and productivity.

7.7 Marine

7.7.1 Description of Socio-Ecological Values

Due to the lack of inshore coral reefs around Savo Island, the surrounding marine environment (open waters) typically comprises deeper open waters and associated habitats including, for example, deeper seabeds and pelagic waters. The offshore marine environment around Savo Island was recognised during the consultation at Panueli as providing the following ecosystem services:

- Deep sea fishing grounds for food security and income generation (via fishing and diving)
- Swimming for leisure (recreation)

The community also recognised these areas as providing habitat services for marine species (e.g. habitats for deepwater corals and fish).

Although not specifically identified by the community during the consultation, the offshore marine environment provides a broad range of additional ecosystem services that are essential, such as: climate, atmospheric and water cycle regulation; primary productivity by phytoplankton; nutrient and carbon cycling by both phytoplankton and zooplankton (BMT WBM, 2017b).

7.7.2 Sensitivities and threats

It has been suggested that overharvesting of marine resources is already evident. Community members stated that it is harder to catch bigger fish now than before (see less big fish). The main threats to open waters and offshore marine environments were therefore recognised as:

- Overharvesting of fish due to rising fishing pressure as the local population increases and market demand also increases
- Pollution (e.g. rubbish from Honiara)
- Sanitation area (i.e. beach) impacting water quality.

7.8 Other (Village)

7.8.1 Description of Values

While it is recognised that these systems do not represent an ecosystem type, most communities identified aspects of their built settlements which were integral to daily life. For example, schools, churches, playing fields and clinics which provide valuable services to the community such as education, spiritual support and basic healthcare. Although these do not constitute 'socio-ecological' values, the project team decided that these areas should still be included in the report, largely due to the valid concerns/threats about them raised by the communities. Village components which were identified by Panueli included:

- Rainwater tanks as an important source of water (further discussed below)
- Road which connects all communities on Savo Island – allows connectivity between villages and also functions to facilitate tourist access
- Submarine volcano (vent) which provides the heat source for the megapode laying fields.

Rivers/Streams/Groundwater

Water resources in the form of rivers, streams or groundwater wells were not explicitly identified by the Panueli community during the workshop as being integral for community functioning. Informal discussions with community members following the workshop revealed that Panueli almost exclusively relies on rainwater tank water for the provision of drinking water. While there are some seasonal streams on the island (e.g. Tanovalea and Veury at either end of the village), these are typically only used for non-drinking (i.e. cooking, washing etc.) purposes since the volcano chemicals impact the water quality. Volcanic activity also dries up any streams, preventing them from flowing year-round. Water from streams is therefore only typically available during heavy rains. Groundwater is the main source of non-drinking water in Panueli, with multiple established groundwater wells present around the village (Figure 7.8). There have been previous funded projects for rainwater tanks in Panueli village and they have approximately 20 in operation.

A) B)

Figure 7.8 A) groundwater well near the centre of Panueli community, and B) a groundwater well located near the beach and main clinic in Panueli.

Forests

Terrestrial forests were not explicitly identified by the Panueli community during the workshop as being integral for community functioning. However, timber structures were observed by the project team throughout the built settlement. It is therefore likely that, while not explicitly identified by community members, forests provide the following ecosystem services to Panueli:

- Timber for housing / building
- Fuel wood (for cooking)

7.8.2 Sensitivities and Threats

Key threats to the village (built settlement) identified by community members include:

- **Volcanic eruption**
- Sea level rise inundation of the clinic (which is located very close to the coast)
- Erosion around key structures such as the church
- School is located very close to a volcanic outlet. This outlet is also a valley which experiences flash flooding.
- Pollution/waste – there are currently no means of safely disposing of medical waste from the clinic. The community expressed their desire for an incinerator to enable proper disposal of medical waste.

These key threats should be used as a guide for any NGOs looking for opportunities to fund development projects in Panueli. In particular, the community are **most concerned about the threat of volcanic eruption** and were open to a variety of mitigating actions, including relocation. **Volcanic eruption is a significant threat to communities on Savo Island and disaster mitigation actions should be prioritised.**

8 Russell Islands Context

8.1 Russell Islands Setting

8.1.1 Geographic

The Russell Islands are located at the western extent of Central Province approximately 48 km northwest of Guadalcanal. The island group is comprised of two main islands: Pavuvu and Mbanika, as well as numerous smaller islets. Most of Pavuvu is occupied by the ridges and valleys of Mt Pavuvu which create rugged cliffs along the southern/south-western coast (Davis, 1947). The island is covered in dense tropical rainforest, while Mbanika is dominated by coconut plantations. The low terraces that provide plantation sites are underlain by deep coral deposits (Davis, 1947). Coconut plantations have also extended out to some of the islets, however, most islets to the north (e.g. Karumulun) remain heavily forested. The islands are surrounded by coral reefs and are considered to have some of the most biodiverse marine ecosystems in the Solomon Islands. This project focuses on the following two communities: Marulaon and Karumulun, which are located on the islets north of Pavuvu.

8.1.2 Cultural Context

The Russell Islands have an extensive history of coconut plantations and were known to once produce the highest yields per acre in the Solomon Islands (Davis, 1947). Most of Mbanika and large swaths of Pavuvu Island are currently, or have historically been, covered with coconut palms for copra production (Figure 8.1). Commercial coconut plantations were first established on Mbanika Island from 1900 at Banika and Yandina (Davis, 1947). Banika Plantation was subsequently bought over by the Lever Brothers, who expanded the plantations to Pavuvu, as well as the islets of Kokia, Faeilau and Ufa (Davis, 1947). The Yandina Plantation was also bought and extended by The Malaita Company and then Fairymead Sugar Company (Davis, 1947). Plantation land was either leased from local communities (who owned the land via customary tenure) or directly from the government (who would purchase the land from local communities or acquire it by alienation) (Davis, 1947).

During World War II, the plantations were neglected as Russell Islands became a strategically significant military base. However, efforts were made to rehabilitate the plantations in the post-war period, and copra production resumed. As part of these efforts, Tikopian labour migrations to the Russell Islands began in 1949 to work on coconut estates (Larson, 1968). The government wanted to relieve population pressures on the small Tikopia Island, located on the southeastern tip of Solomon Islands, and Lever's plantation management wanted to expand the workforce (Larson, 1968). Therefore, although most of these migrations were temporary, there is likely to have been a lasting Tikopian impact on Russell Islands' culture.

8.1.3 Socio-Economic Profile

The selling of copra remains Russell Islands' main source of income, however, the islands also have some of the richest inshore fishing grounds in the Solomon Islands. Similar to Nggela, overexploitation has led to perceived reductions in marine resources at inshore reefs and a shift towards fishing in offshore sub tidal reefs (MFMR/WorldFish, 2022). Population growth is a key driver of the overexploitation by increasing the number of people relying on marine resources for food security and income. Furthermore, as the coconut plantations across the islands shut down, the plantation workers also began to depend on the sea resources to sustain their own livelihoods. This exacerbated existing pressures on marine resources.

In recent years there has been an increased focus on marine conservation in the Russell Islands, with more and more communities implementing concerted efforts to preserve resources for future generations. There is growing recognition of the critical need for Russell Island communities to unite in safeguarding their marine resources, with community leaders such as Chief Lennard Ngaham of

Marulaon leading the charge (Alex, 2024). The Russell Island Fisheries Association (RIFA), a community-based fisheries network, was established in 2019 as another initiative to ease the pressures of overexploitation and maintain sustainable use of marine resources. However, further capacity building is needed for the committee members of the network to achieve the desired outcomes (MFMR/WorldFish, 2022).

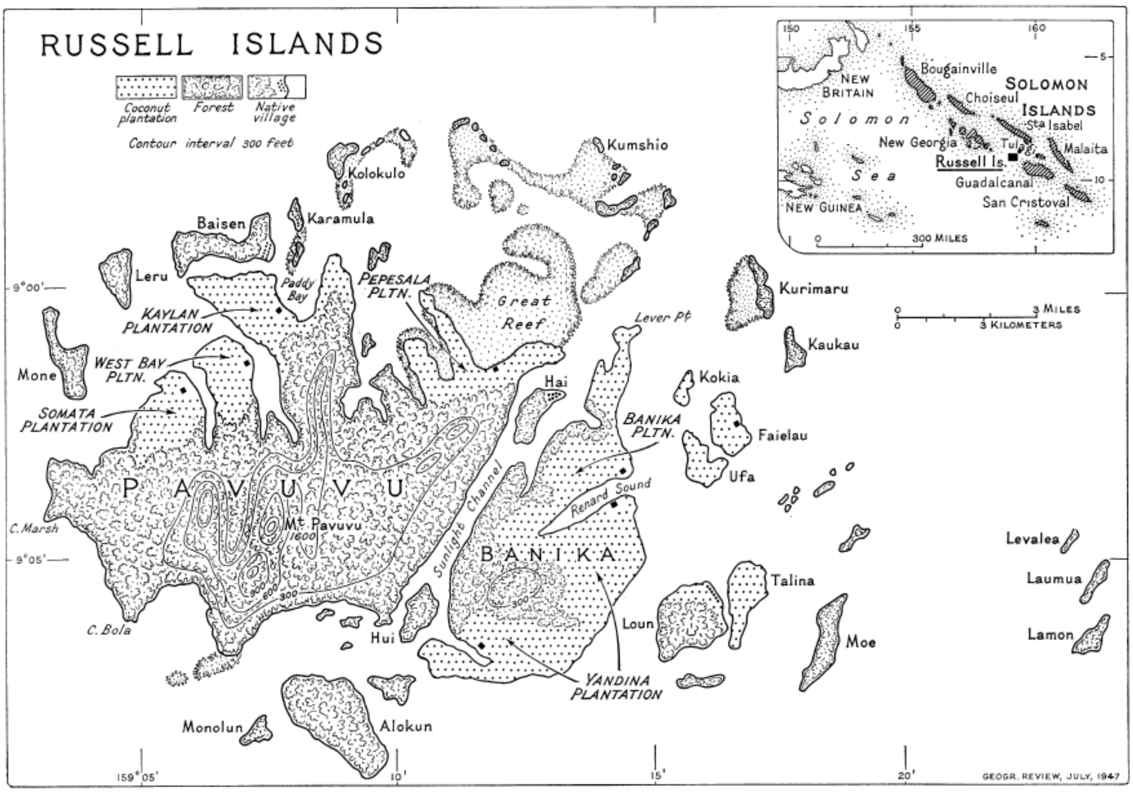


FIG. 1—The coconut plantations of the Russell Islands. The inset shows the position of the group in the Solomon Islands chain.

Figure 8.1 Historic extent of coconut plantations on Mbanika and Pavuvu islands in Russell Islands.

9 Russell Islands Socio-Ecological Values, Sensitivities and Threats

Russell Island communities are almost entirely dependent on their surrounding ecosystems to sustain their livelihoods and earn an income. The social, cultural and economic values of the community are therefore directly intertwined with the surrounding ecosystem values. This section provides a brief description of the key ecosystems directly utilised by the Marulaon and Karumulun communities and the associated ecosystem services which constitute their value for the communities.

The section also includes a summary of the human and climate threats ('worries and concerns') to each ecosystem (and its services) identified by the local community. Sensitivities of ecosystems and their services to human and climate change threats are briefly discussed, however, sensitivities to climate change-related threats will be discussed in more detail in the Climate Change Vulnerability Assessment (Section 11).

In order to accurately document and convey the concepts and values communicated to us by the communities, we have attempted to retain a similar differentiation of different 'ecosystem types'. For example, Marulaon and Karumulun clearly distinguish between 'marine conservation areas (e.g. MPAs)' and offshore fishing grounds in terms of the ecosystem services and management challenges for each, despite both being in the marine environment.

We first provide an overview (Section 9.1) of the key ecosystems and ecosystem services which form the socio-ecological values for Marulaon and Karumulun, followed by a more detailed examination of each ecosystem / service in the subsequent sections (Sections 9.3 to 9.13).

9.1 Overview – Ecosystems and Ecosystem Services

9.1.1 Community-Derived Identification

The Russell communities consistently recognised 10 main ecosystems on which they were directly dependent, including:

1. Terrestrial forest
2. Swamp/river/groundwater
3. Mangroves
4. Reef
5. Sandy beaches, islands and coastal areas
6. Cultivated land – gardens
7. Cultivated land – plantations
8. Conservation or Tabu areas
9. Marine (Other)
10. Other (Village).

Other ecosystems and or services derived from elsewhere (e.g. drinking water from rainfall to rainwater tanks, tourist ship anchorage etc.) were also occasionally recognised and have been documented in the 'Other (Village)' category. Communities also distinguished between 'local' and 'mainland' ecosystems, where 'local' referred to a particular ecosystem which was present on the same island/in the vicinity of the village. 'Mainland' was used to indicate the same ecosystem type, but located further from the village on the mainland, which often provided slightly different ecosystem services. The 'local' and 'mainland' equivalents of each ecosystem type will be discussed together in the relevant section.

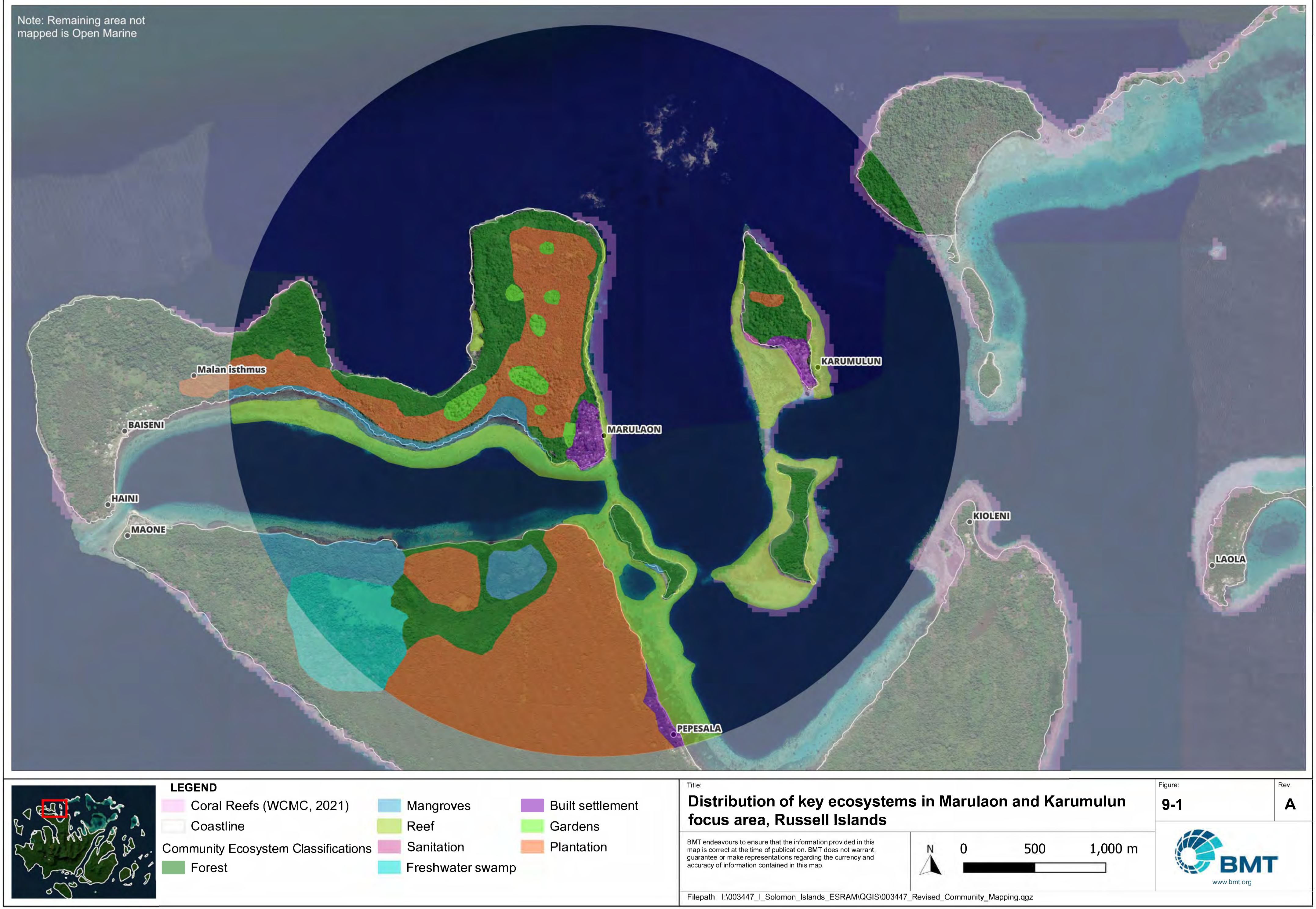
A map showing the spatial distribution and extent of these ecosystems is provided in Figure 9.1. Note that this mapping is to be considered indicative only, and has been derived from existing GIS data, discernment of ecosystems through remote sensing, community-derived information, and rapid field mapping (in close proximity to villages). Extensive and/or detailed ground works to verify and validate ecosystem maps were not undertaken as part of this project. Groundwater springs, in particular, are not well represented in the mapping as they are difficult to detect remotely.

Table 9.1 lists the respective ecosystem services for each ecosystem, as identified by the Russell Island communities. The relative frequency that each ecosystem service was identified at each community consultation is also provided as an indicator of the importance of that service (and associated ecosystem), as perceived by the local communities. Based on this indicator, the essential ecosystem and/or ecosystem services on which the communities were most reliant include:

- Forests as areas which provide herbs for traditional medicines. These areas are also highly valued by Marulaon for their role as habitat for key animals such as coconut crab, opossum, snakes and birds.
- Marine Managed Area (MMA) around Marulaon Island region which provides conservation for marine species to allow them to recover. The community consistently noted the importance of this area for future food security.
- MPA around Kusuvao Island which provides legal conservation of marine ecosystems. It also functions as a popular tourist diving site which is a key source of income for Karumulun (via the Bilikiki anchorage).
- Coconut plantations as the main source of income for both communities (selling copra). They also provide a source of food.
- The village area itself as the primary area of habitation and community interaction.

It can be seen in Table 9.2 that some broad ecosystem services (e.g. income or food) are sourced from a variety of ecosystems. In contrast, some ecosystem services are more specialised and may only be associated with one or two ecosystems (e.g. drinking water sources, coastline protection). This is important in the context of climate change resilience, since there may be limited alternative sources for some essential ecosystem services if the original source is undermined.

Areas of direct community utilisation of land and sea resources, as well as key threats, are shown spatially in Figure 9.2. Generally, the community accesses and uses the full range of ecosystems with and immediately surrounding their village, occasionally venturing further afield (particularly for offshore fishing grounds).



Title:

Distribution of key ecosystems in Marulaon and Karumulun focus area, Russell Islands

Figure: 9-1

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BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Table 9.1 Inventory of ecosystems and ecosystem services identified by Russell communities (✓ denotes the frequency of each ecosystem service identified at each village). Higher frequencies are highlighted in pink, medium frequencies in yellow and lower frequencies in blue.

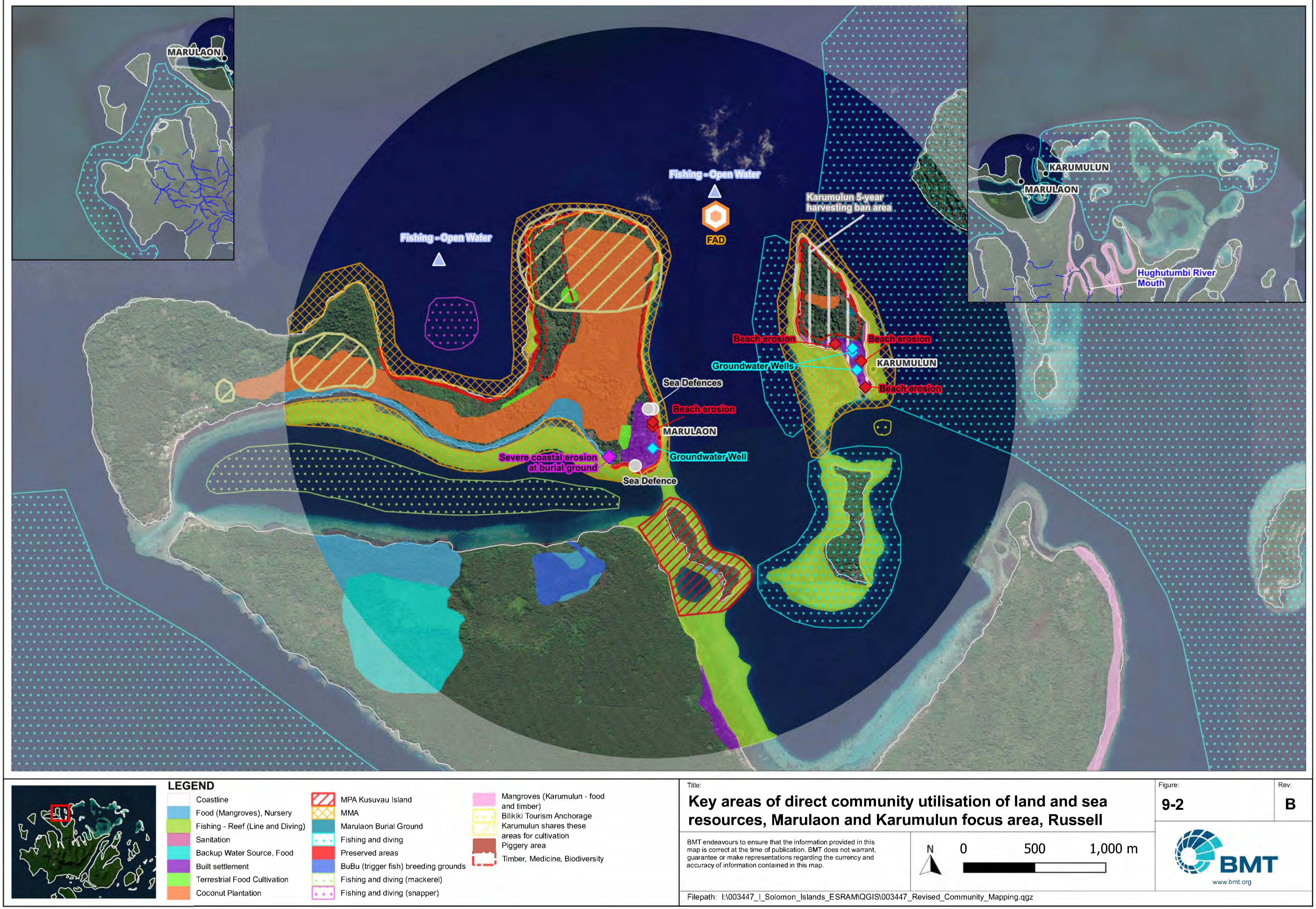
Ecosystems	Key Ecosystem Services identified by Russell communities	Frequency of Identification by Each Community (three groups in Marulaon, two groups in Karumulun)	
		Marulaon	Karumulun
Forest	Timber source - building materials (rocky part of Marulaon island has sections of secondary forest reserved for local building materials)	✓✓	✓
	Timber milling area – for selling	✓	
	Timber source – fuelwood/firewood		✓
	Bush material for houses		✓
	Medicine	✓✓✓	✓
	Wildlife habitat	✓✓✓	
	Clearing for gardening and coconut plantation	✓	✓
Swamp / river / groundwater (local)	Collecting mud crabs for food security and source of income	✓	
	Collecting mud shells for food security and source of income	✓	
	Swamp taro and sago palm for food security	✓	
	Groundwater springs - water source (washing, bathing, other)	✓	✓
Swamp / river (mainland)	Backup water source (drinking and cooking)	✓	✓
	Sago palm and swamp taro for food security		✓
	Building materials – cutting sticks	✓	
Mangroves (local)	Mangrove shells (bivalve molluscs – food source)	✓✓	

Ecosystems	Key Ecosystem Services identified by Russell communities	Frequency of Identification by Each Community (three groups in Marulaon, two groups in Karumulun)	
		Marulaon	Karumulun
	Fish breeding area	✓✓	
	Breeding area for other marine invertebrates/vertebrates	✓✓	
	Other food (mud crabs, fruit, snails)	✓✓	
	Coastline protection	✓	
Mangroves (mainland)	Backup food source – area to harvest shells/crabs	✓	✓
	Cut sticks to build traditional houses	✓	✓
Reefs	Fishing, food source and small-scale commercial trade	✓	
Sandy beaches / coastal areas	Sanitation area		✓✓
	Gravel and sand for building materials	✓	
Gardens	Food and income source (fruit and vegetable crops for domestic and commercial use, e.g. cassava, sweet potato, yam, pana etc.)	✓✓	✓
Plantation (local)	Coconuts (copra) – small scale commercial (main source of income), food security	✓✓✓	✓
	Coconuts – source of coconut crabs for eating and selling		✓
Plantation (other islands)	Collection of coconut crabs, sago palm (pandanus and bush materials), betel nut, ngali nut, cut nut		✓
Conservation or Tabu Area	MMA around Marulaon – conservation of species and ecosystems, allow species to recover, food security	✓✓✓	✓
	Tourist dive sites - income	✓✓	✓
	Marine Conservation Area - conservation of species and ecosystems, allow species to recover	✓✓	

Ecosystems	Key Ecosystem Services identified by Russell communities	Frequency of Identification by Each Community (three groups in Marulaon, two groups in Karumulun)	
		Marulaon	Karumulun
	MPA around Kusuvao Island – set up in 2012 to conserve ecosystems, popular tourist diving site – key source of income for Karumulun (e.g. Bilikiki anchorage)	✓✓✓	✓✓
	Tabu area around Karumulun Island (extends 50m offshore) – no fishing to conserve ecosystems		✓
	MPA around Kusuvao Island – sea cucumber preservation	✓	
	Along the cliffs and limestone caves there are preserved areas for sea snails, coconut crabs, shells and other animals since there has been overharvesting in the past – to allow populations to recover.	✓	
	Cliffs and limestone caves also serve as a crab breeding area	✓	
	Karumulun Island – not allowed to harvest coconut crab, possum, shells from land and sea for 5 years – for conservation purposes to let species recover		✓✓
Marine (other)	Deep sea fishing grounds for food security and income, fishing and diving (snapper and mackerel)	✓✓✓	✓
	Breeding grounds for fish	✓	
	Fish Aggregating Device (FAD) installed by Fisheries Office in 2012, increases fish for food and income	✓✓	✓
	Sea cucumber area – collecting sea cucumbers for selling (when not banned)	✓	✓
	Passage for outboard motorboats (cleared by dynamite) to allow transportation		✓
Other (Village)	Village (church, community hall, future kindy, playing ground, burial ground, road, rest house, piggery area)	✓✓✓	✓✓

Table 9.2 Summary of ecosystem sources for key ecosystem services

Key Ecosystems	Food (land)	Food (sea, river)	Water (drinking)	Water (other)	Building materials	Fuelwood	Income (market)	Biodiversity / wildlife habitat	Medicine	Land for gardening	Fish breeding	Sanitation	Transport	Income (tourism)	Cultural significance	Coastline protection
Forest					✓	✓	✓	✓	✓	✓						
Swamp, rivers, groundwater	✓		✓	✓			✓									
Mangroves	✓				✓			✓			✓					✓
Reefs		✓					✓									
Sandy beaches, islands and coastal areas					✓							✓				
Gardens	✓						✓									
Plantations	✓						✓									
Conservation or Tabu Area								✓						✓		
Marine (other)		✓					✓				✓		✓			
Other (rainfall)			✓													
Other (village)															✓	



Title:

Key areas of direct community utilisation of land and sea resources, Marulaon and Karumulun focus area, Russell

Figure: 9-2

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9.1.2 Additional Ecosystem Services Identification

Most of the ecosystem services recognised by the Marulaon and Karumulun communities would be classified as provisioning services (i.e. the provision of food, water and raw materials). However, another dominant theme was the recognition of ecosystem services classified as habitat services (e.g. biodiversity, conservation for future generations, important wildlife habitat etc.). In addition to these services, there were a number of additional services not accounted for. The complete list of regulating, habitat and cultural services (listed in general terms based on a study by de Groot et al. (2012)) is presented in Table 5.3. 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 (BMT WBM, 2017b). Ecosystems that provide multiple ecosystem services, especially critical services (i.e. provision of water and food), are considered crucial for community resilience in Russell Islands (if managed sustainably).

As noted in Section 5.1.2, 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, sea level rise
- Geology and geomorphology – including both fluvial and land-based geomorphology. While volcanic processes contributed significantly the geomorphology of Russell Islands in the past, current impacts are primarily restricted to various submarine volcanoes (particularly Kavachi). Kavachi is considered highly active and frequently erupts, which can impact shipping in the area (and presumably water quality etc.). However, fluvial and land geomorphology impacts are typically minimal.
- Sediment loads
- 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 and marine waters)
- Biological processes (e.g. primary productivity, carbon cycling by bacteria, zooplankton grazing, bioturbation and other fauna interactions).

As described above in Section 5.1.2, the list of services in Table 5.3 was applied across the different ecosystems (where relevant) as part of the economic valuations (Section 10) in order to fill gaps where services were not identified by the local community.

9.2 Overview – Sensitivities and Threats

9.2.1 Community-Derived Identification

Consultations at the two Russell Island communities included an open discussion on threats which were perceived to be affecting the key ecosystems (and associated services) described above. Community members were encouraged to share their worries and concerns regarding specific ecosystems, as well as any changes in the ecosystems they have observed over the years. Table 9.3 presents a summary of the ecosystem threats identified by the Russell communities and therefore demonstrates the biggest threats as perceived by Marulaon and Karumulun. Initial threat prioritisation has been undertaken based on community attitudes, with more severe perceived threats highlighted in red and less severe threats highlighted in orange.

Notably, the following ecosystems have been combined, since communities often grouped these ecosystems together when discussing threats:

- 'Swamp' and 'rivers, streams and freshwater springs'
- 'Reefs' and 'Marine (other)' combined into 'sea resources'.

As discussed above, communities distinguished between 'local' and 'mainland' ecosystems, where 'local' referred to a particular ecosystem which was present on the same island/in the vicinity of the village. 'Mainland' was used to indicate the same ecosystem type, but located further from the village on the mainland, which often provided slightly different ecosystem services. The threats for 'local' and 'mainland' components of specific ecosystems are presented together, since the communities did not distinguish between them when discussing threats/concerns.

Based on the summary information in Table 9.3, the greatest perceived threats to the communities within Russell Islands were:

- Overharvesting of forest resources due to increases in population. Both communities noted that they have been finding it harder to source larger trees and, in the case of Karumulun, needed to obtain forest resources from the mainland instead.
- Overharvesting of fish in reefs due to increases in population and market demand. Communities also noted that the closure of major plantations lead to increased pressures on the marine environment as plantation workers set up livelihoods. The presence of protected marine areas near the communities has meant that areas with no protection (further away) are overharvested.
- Sea level rise inundation of villages (particularly in the case of Karumulun). Some areas are already being washed into the sea (e.g. Marulaon burial ground).
- Not enough rainwater tanks for drinking water security.

Table 9.4 provides a summary of the key threats to Russell Islands' ecosystems and services broken down into non-climate and climate related threats. 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 the human resilience, ecosystems are subject to significant anthropogenic threats such as pollution and overharvesting of marine resources (BMT WBM, 2017b). Furthermore, these threats are exacerbated by the current and projected adverse impacts of climate change (to be explored further in Section 11).

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 Russell Islands to future climate change impacts (BMT WBM, 2017b).

Table 9.3 Inventory of ecosystem threats identified by Russell communities (✓ denotes identification of threat by community). Red cells indicate more severe threats as perceived by the local communities, orange cells indicate less severe threats.

Ecosystems	Key Threats ('worries') identified by Russell Island communities	Sensitivity	
		Marulaon	Karumulun
Forest	Overharvesting of forest resources (harder to find big trees) – population increase and market demand	✓	✓
	Overharvesting of medicine resources – need to travel further to find the resources	✓	
	Minimal replanting of virgin forest areas (wildlife has moved on)	✓	
	Clearing of forest areas for gardens. Sustainable gardening practices of shifting cultivation (to let soil recover) result in more clearing – exacerbated by population pressures	✓	✓
Swamp / river / groundwater	Areas dry out in the dry season and need to be careful about managing water resources in dry season	✓	
	More frequent El Niño climate conditions may dry up these areas	✓	
	Clearing of forest areas causing changes in rainfall patterns – potential microclimate impacts	✓	
Mangroves	Overharvesting of mangrove shells – however this is recovering following harvesting restrictions/protections	✓	
	People cutting down mangroves for firewood and building materials (not allowed)	✓	
	Damaged by storms and cyclones (but have noticed less cyclones than before)	✓	
Sea Resources	Once the plantations shut down, the works joined in harvesting sea resources to sustain livelihoods – increased the pressure on sea resources – influx of new harvesters	✓	✓
	Overharvesting - fish stock is going down. More deep sea fishing required to catch good fish. Also need to travel further.	✓	✓
	Coral bleaching	✓	
	Overharvesting of clam shells (but populations have improved again in protected areas)	✓	
	Sea level rise inundation	✓	✓

Ecosystems	Key Threats ('worries') identified by Russell Island communities	Sensitivity	
		Marulaon	Karumulun
Sandy beaches / coastal areas	Beach erosion	✓	✓
	Gravel and sand for building materials is being washed away	✓	
Gardens	Overused soil from intensive gardening (have started using shifting cultivation to let soil recover)	✓	
	Lack of training to understand soil fertility and plan gardens appropriately	✓	
	Insects/pests (worms) affect certain crops	✓	✓
	Population increases	✓	✓
Plantation	No new planting/re-planting taking place, only a small number of people plant new trees	✓	
	Yield is reducing due to poor management (e.g. used to clear around trees to remove weeds and bushes but this has lapsed) but demand is increasing (population growth)	✓	
	Utility of coconuts to earn income is restricted to dried copra. Need to diversify so they can produce more from coconuts and earn more income	✓	
	Local coconut variety only (slower growing and longer between harvests) as opposed to hybrid varieties	✓	
	Insects/pests (rhinoceros beetle)		✓
Conservation or Tabu area	Education of communities is a challenge to understand the need for the restrictions	✓	
	Lack of legal enforcement for protected/conserved areas	✓	
	Coral bleaching	✓	
Other	Sea level rise inundation of villages	✓	✓
	Lack of kindergarten for all the young children	✓	✓
	Island depends on rainwater but don't have enough rainwater tanks	✓	✓

Ecosystems	Key Threats (‘worries’) identified by Russell Island communities	Sensitivity	
		Marulaon	Karumulun
	Poor sanitation increasing the risk of disease		✓
	Diminishing copra buyers	✓	

Table 9.4 Summary of key threats to each ecosystem service (services and threats identified by communities)

Ecosystems	Key Ecosystem Services identified by Russell Island communities	Climate Related Threats								Non-Climate Related Threats								
		Sea level rise, saline intrusion	Drought / dry periods	Changing microclimates	Coastal / beach erosion	Cyclones and storms	Invasives / pests / disease	Ocean acidification	Changing seasonal cycles (e.g. El Niño)	Sanitation (solid waste mgmt.)	Land clearing and modification	Population growth	Overharvesting - economic	Inadequate resource management	Lack of replanting efforts	Lack of education/ capacity building	Lower soil fertility	Lack of legal enforcement
Forest	Timber source - building materials										✓	✓		✓				
	Timber source - fuelwood / firewood										✓	✓		✓				
	Timber milling area – for selling										✓	✓	✓	✓				
	Bush material for houses										✓	✓		✓				
	Medicine										✓	✓		✓				
	Wildlife										✓							
	Potential gardening land											✓		✓				
Mangroves	Food (fish, shells/molluscs, crabs, fruit)					✓					✓	✓	✓	✓				
	Fish breeding area					✓					✓			✓				
	Breeding area for other marine invertebrates/vertebrates					✓					✓			✓				
	Coastline protection					✓					✓			✓				
	Building materials (sticks)					✓					✓	✓		✓				
Sea Resources	Food/trade source (fish, shells etc)							✓				✓	✓	✓				
	Breeding ground for fish										✓			✓				
	Transport – outboard motorboat passage					✓												
Swamp, rivers, groundwater	Water source	✓	✓	✓					✓				✓					
	Food source (mud crabs, mud shells, swamp taro, sago palm)		✓	✓					✓				✓					
Sandy beaches, islands and coastal areas	Sanitation area	✓			✓					✓			✓					
	Building materials	✓			✓								✓					
Gardens	Food and income source						✓					✓	✓	✓		✓	✓	
Plantations	Coconuts (copra) – small scale commercial (main income), food security						✓					✓	✓	✓	✓			
	Food/trade source (coconut crabs)											✓						
	Betel nut, ngali nut, cut nut for food/income (mainland)											✓		✓				
	Sago palm - building materials (mainland)											✓		✓				

Ecosystems	Key Ecosystem Services identified by Russell Island communities	Climate Related Threats								Non-Climate Related Threats									
		Sea level rise, saline intrusion	Drought / dry periods	Changing microclimates	Coastal / beach erosion	Cyclones and storms	Invasives / pests / disease	Ocean acidification	Changing seasonal cycles (e.g. El Niño)	Sanitation (solid waste mgmt.)	Land clearing and modification	Population growth	Overharvesting - economic	Inadequate resource management	Lack of replanting efforts	Lack of education/ capacity building	Lower soil fertility	Lack of legal enforcement
Conservation or Tabu Area	Species conservation – future food security											✓				✓		✓
	Tourism income (dive sites)							✓								✓		✓
	Protection of resources (e.g. virgin forest, allowing cliff fauna to recover)											✓				✓		✓
	Crab breeding area											✓						
Other (Village)	Built settlement (school, church, clinic etc.)	✓								✓						✓		
	Rainwater tanks – water provision		✓															

9.3 Terrestrial Forest

9.3.1 Description of Socio-Ecological Values

Russell Islands are heavily vegetated, with tropical forest covering the bulk of the interior of Pavuvu Island and most islets (Figure 9.1). The interior of Mbanika Island is dominated by coconut plantations mixed with degraded tropical forests. The remaining land is primarily comprised of mangroves, freshwater and saline swamps. The forests provide important ecosystem services for the local community including the provision of food, medicine, timber and fuel. The ecosystem services were identified by the local communities as necessary for daily life, and include:

- Timber and bush material for building
- Timber milling areas for small-scale export (income source)
- Fuel wood (for cooking)
- Medicine.

Community members from Marulaon also recognised the habitat services of the forests (rather than just their provisioning services) by highlighting ‘wildlife habitat’ as a key ecosystem service. Another ecosystem service which was consistently recognised by the communities was the land capital provided by forests (i.e. they represented lands that could be cleared for gardens or coconut plantation). Crucially, in addition to those services identified by workshop participants, 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.

The terrestrial forests surrounding Marulaon and Karumulun were typically in good condition (Figure 9.3). Most of the forests around Marulaon are secondary forests which were re-planted following extensive clearing by previous generations. However, the Marulaon community expressed a desire to protect areas of secondary forest (as well as any remaining virgin forest) to promote proper management and encourage the return of wildlife. Unlike on the larger island of Marulaon, the forested area on Karumulun is very constrained. It is located on one half of the small island while the built settlement occupies the other (Figure 9.4). Its small, isolated nature means that there is very little opportunity for the forest (and its species) to adapt to climate change through mechanisms such as shifting ranges or species migration. This indicates a reduced resilience (and higher sensitivity) of Karumulun forests to climate change.

At both communities, degradation is primarily restricted to edge effects in the vicinity of villages, cultivated land and tracks. Some wider spread clearing occurs from time to time, usually for the purposes of creating land for cultivation. Neither community identified the forest as providing food provisioning services in the form of hunting. This could be due to a lack of wildlife in forest areas from previous widespread clearing.

A) B)

Figure 9.3 A) looking across gardens at Marulaon towards secondary forest, B) the beginning of the forest areas at Karumulun.

Figure 9.4 Karumulun Island (foreground), looking across to Marulaon Island in the west (background) (source: Douglas Junior Pikacha, ESSI).

9.3.2 Sensitivities and Threats

The primary threat is forest clearing and the risk of overharvesting timber and other bush materials (e.g. medicines), particularly as growing populations place an increased demand on forest and land resources. Note that no formal management measures are in place (e.g. replanting regimes, legally protected areas), however both communities have locally protected areas of forest to reduce the pressures of overharvesting and allow wildlife to return. Further information on these protected areas is included in Section 9.11.

There was a strong awareness across both communities that some target forest species (especially bigger, more mature trees, or plants used for medicines) are getting harder to find and that the current practices are unsustainable. The community at Marulaon explained that their ancestors undertook extensive clearing of the virgin forests and did not establish sustainable management practices, however, this is something that the current (and future generations) want to do better. Both Marulaon and Karumulun have started making changes to harvesting practices to alleviate some of the pressures of overharvesting on forests. Further information on these protected areas is included in Section 9.11.

Other key existing or potential threats included:

- Deforestation, where clearing occurs to replace forests with cultivated gardens. The community at Marulaon acknowledged that recent advances in garden management (i.e. employing shifting cultivation to let the soil recover) resulted in more extensive forest clearing to make space.
- Deforestation, where clearing occurs to replace forests with other land uses (e.g. village expansion). The community at Karumulun are concerned about the impact of sea level rise on their forest – as the community is forced to move to higher ground, more forest will need to be cleared (it is located on the higher part of the island).
- Disappearance of terrestrial fauna due to unsuitable habitats (wildlife has moved on).

9.4 Swamp/River/Groundwater

9.4.1 Description of Socio-Ecological Values

For the purposes of this assessment, non-marine waters have been consolidated into a single ecosystem category and include the various freshwater swamp lands, rivers and groundwater springs present within Russell Islands. Notably, this category also includes estuarine rivers, which become freshwater-dominant further upstream.

There are no major river systems on Marulaon or Karamulun, with surface freshwater typically confined to (presumably) small, spring fed steams. However, no freshwater streams were observed by the project team on either island during the site visits. The two communities rely almost exclusively on rainwater tanks for the provision of drinking water, but rivers on the mainland (i.e. along the northern coast of Pavuvu Island) provide a backup water source. Marulaon have relied exclusively on rainwater tanks since 2000, when they were provided a number of rainwater tanks by NGOs. In contrast, Karumulun still has some reliance on mainland rivers (particularly Hughutumbi River) to supplement drinking water demands. Hughutumbi River mouth is located on the northeastern coast of Pavuvu Island, approximately 8 km from Karumulun (Figure 9.2). The ecological condition and/or ecosystem health of local streams could not be determined, since none were identified during the site visit. However, the ecosystem health of Hughutumbi River (and other mainland rivers) is assumed to be good since it does not experience frequent human activity (no surrounding villages visible in the aerial imagery, and Karumulun uses this as a backup source only).

Groundwater is used by both communities for the supply of freshwater for washing and bathing (Figure 9.5). The groundwater table at Karumulun is assumed to be very high, with community members stating that “when it is high tide, water comes up through the crab holes”.

Figure 9.5 Groundwater wells at A), B) Marulaon and C), D) Karumulun.

Freshwater lowland swamps are generally located around small surface expressions of groundwater or river floodplains. Freshwater swamps are important for services such as flood control, food security, and the provision of important habitat for aquatic flora and fauna. Freshwater swamps are not well represented in the mapping prepared for this assessment due to a combination of their small size (sometimes only a few meters in diameter) relative to the scale of the mapping, and also from being obscured by overhanging canopies making them difficult to detect on aerial imagery.

No freshwater swamps were identified by the communities at Marulaon or Karumulun on their respective islands, however, freshwater swamps on the mainland (northern coast of Pavuvu Island) were identified as providing critical ecosystem services (Figure 9.1). Freshwater swamps are primarily valued by the community as a location that provides suitable conditions for growing swamp taro. Swamp taro is not usually consumed on a daily basis, rather it is cultivated as a means of food security for times of food shortages or to supplement other food sources. Sago palm (*Metroxylon salomonense*) plantations are also commonly located around freshwater swamps, providing an essential source of building materials (roofs for dwellings), as well as food.

The communities of Russell Islands are therefore dependent on freshwater swamps, rivers and groundwater for a number of essential services, including:

- Mainland rivers: supply of freshwater, most importantly as backup drinking water when rainwater tank supplies are inadequate, but also for cooking, washing and bathing.
- Groundwater: supply of freshwater for washing and bathing.
- Provision of food sources that are important for supplementing marine derived protein, providing a means of food security, and providing variety in the diet. For example, swamp taro, sago palm, mud crabs, mud shells.
- Collection of mud crabs and mud shells for sale at market (income generation) (present in estuarine rivers)
- Building materials (cutting sticks).

9.4.2 Sensitivities and Threats

Key existing threats to swamps, rivers and groundwater identified by the communities were mainly centred around climatic changes. Increased dry periods were the largest concern, with the communities recognising that more frequent El Niño events may dry up these areas. The communities did not discuss specific concerns around overharvesting, however, it is important to recognise that this may become more of a threat into the future as populations continue to increase.

Although not explicitly identified by the communities, saltwater intrusion could pose a threat to freshwater swamps on Pavuvu Island which are located near the coast. 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 when swamp taro may take 10 years until it is ready for harvesting (BMT WBM, 2017a). Saltwater intrusion is also likely to impact on the biodiversity of lowland swamps however further information is needed to understand the species that inhabit these ecosystems. Saltwater intrusion may also pose a threat to groundwater wells, particularly in very low-lying communities such as Karumulun.

In terms of other threats, the following is noted:

- Drought and hot temperatures causing the swamps to dry out periodically (villages already need to be careful about managing water resources in the dry season). This could be exacerbated by more frequent El Niño climate conditions in future under climate change.
- Clearing of forest areas causing changes to rainfall patterns – potential microclimate changes as a result of widespread vegetation clearing.

9.5 Mangroves

9.5.1 Description of Socio-Ecological Values

While mangroves constitute a relatively small proportion of the overall forest areas on Russell Islands, they are the dominant ecosystem type along Pavuvu Island's northern coastline, and Marulaon's southern coastline.

The mangroves on Marulaon extend from a larger saline swamp forest on the western edge of the village, along the southern coastline, almost to the western side of the island. The mangrove communities of Marulaon Island tend to be dominated by species of *Rhizophora.* Unfortunately, due to time constraints, the project team were unable to visit the dense mangroves on Marulaon and instead were only able to visit the edges (Figure 9.6). It is assumed that the mangroves on Marulaon are in good condition, primarily because the community is not allowed to harvest timber from them. This is out of recognition of the valuable habitat services that the mangroves provide for aquatic fauna (fish breeding areas, snail habitat etc.).

A) B)

Figure 9.6 Examples of *Rhizophora*.sp. mangroves on Marulaon Island in the vicinity of the village.

Unlike Marulaon, there are no mangrove ecosystems on the island of Karumulun. Instead, the community identified mangrove areas on the mainland which provided them with key ecosystem services. These mangrove areas are located around the mouth of Hughatumi River and along adjacent coastlines in the north-east of Pavuvu island (Figure 9.2). From the aerial imagery, these mangrove areas appear denser and more continuous than those observed on Marulaon. The ecological condition and/or ecosystem health of these mangroves could not be determined, since a site visit to the area was not conducted. However, the ecosystem health is assumed to be very good since the mangroves are located further from village high-use areas and are only visited when resources are needed. This is supported by the aerial imagery which shows large, continuous bands of mangroves around Hughatumi River with consistent dark-green canopies.

Mangrove ecosystems are highly valued by the people of Russell Islands for their food provisioning and habitat services. The main food types sourced from mangrove ecosystems in Russell Islands include:

- Mangrove shells (bivalves)
- Mud crab and various fish
- Mangrove snails
- Mangrove fruit.

The communities also acknowledged that mangroves provide regulating and habitat ecosystem services in the form of providing breeding/spawning areas for fish and other marine invertebrates/vertebrates, as well as serving a major role in shoreline protection and stabilisation.

9.5.2 Sensitivities and Threats

Currently, there is no active management to ensure the sustainability of food resources harvested from mangrove ecosystems in Russell Islands (noting that Marulaon has local restrictions protecting mangrove timber from harvest). Overharvesting of foods derived from mangrove ecosystems therefore represents the primary threat, particularly in the face of population growth, climate change and other compounding threats. However, both Marulaon and Karumulun place temporary restrictions on harvesting mangrove resources when the pressures of overharvesting become evident (discussed further in Section 9.10). For example, the Marulaon community noticed severe declines in mangrove shells and restricted their harvest to allow the populations to recover. It should also be noted that the Marulaon community have engaged in some mangrove re-planting initiatives in attempts to expand mangrove habitat. Overall, key threats identified for the mangrove ecosystems include:

- Overharvesting of the foods sourced in mangroves (e.g. mud crab, bivalves).
- Population growth increasing the demand for mangroves ecosystem services
- People cutting down mangroves for firewood and building materials despite this being against the rules
- Damage by storms and cyclones.

While not explicitly identified by the community, additional threats to mangrove ecosystems in Russell Islands could include:

- Overharvesting of mangrove timber in areas/around communities where no harvesting restrictions exist
- Overharvesting of foods sourced from mangroves in areas/around communities where no harvesting restrictions are enacted
- Mangrove shells (bivalves) are susceptible to desiccation and spoiling during prolonged periods of low tide when air temperatures are hot
- 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 threaten mangroves through processes such as coastal erosion and altered hydrology that can cause prolonged inundation.

9.6 Reef

9.6.1 Description of Socio-Ecological values

Coastal communities of the Russell Islands rely heavily on the marine environment as a source of food. In addition to food provision, marine environments around Russell Islands 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 most of Pavuvu and Mbanika Islands, as well as many of the islets.

Dedicated reef assessments were not undertaken for this assessment. However, reef surveys are due to be undertaken by WCS in February 2025. For results on the condition of Russell Island reefs, refer to the forthcoming WCS Biological Survey report.

Presently, there are no major land clearing activities which occur on Marulaon or Karumulun, (although wider land clearing may take place on government-owned plantations). However, there are a variety of major river systems which discharge into the marine environment around Pavuvu Island (e.g. Hughutumbi River, Kokolaon River) and Mbanika Island (Bukelun River), which provide a source of additional sediment loads to the local reefs (i.e. beyond natural sediment inputs).

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 the primary means of income for many communities through the sale of products at markets (e.g. at Yandina or Honiara). Notably, the community indicated that they have observed severe depletion in inshore reef-based food sources, necessitating a shift to fishing in offshore sub tidal reefs.

Key fauna targeted for consumption and/or sale include:

- Reef associated fish targeted via diving, line fishing and net fishing
- Invertebrates such as clams and sea cucumbers (Note: there is currently a national ban on *bêche-de-mer* harvest - communities use this as source of income when the ban is lifted).

Crucially, Marulaon and Karumulun have established locally marine managed areas (MMAs) around their respective islands in an effort to ease the pressures of overharvesting on inshore reefs (tabu areas). In addition to the MMAs, there is an established MPA around Kusuvao Island which functions as a strict no-take zone. The establishment of these conservation areas has reduced the communities' reliance on inshore marine resources, with the focus instead shifting to offshore marine environments. The conservation areas are discussed in more detail in Section 9.10.

Communities did not identify the harvesting of coral for construction materials or income as key ecosystem services provided by reefs. Some piles of coral rubble and sand were identified by the project team within Marulaon's burial ground, which indicates that these practices do take place. However, it is unclear whether such practices are only undertaken for special circumstances (e.g. to create tombstones) or whether they have ceased entirely. Multiple sea walls constructed from coral rubble were observed by the project team during site visits at Marulaon which indicates that coral harvesting has occurred in the past (Figure 9.7).

Figure 9.7 Coral rubble wharf at Marulaon

9.6.2 Sensitivities and Threats

It has been suggested that overharvesting of reef resources is already evident. Community members in each workshop stated that they had observed declines in reef resources around nearby inshore reefs, prior to the establishment of the MMAs and MPA. However, all community members understood the role of the MMAs and MPA in creating sustainable harvesting practices by allowing marine populations to recover. Similar patterns have been observed for clam shells, with community members noting that they are now very hard to find (although populations have improved again within protected areas).

Given the high importance of reef resources for food and income, unsustainable harvesting remains a major concern in the face of human population growth and growing market demand, particularly in other areas not protected by MMAs or MPAs (e.g. deep sea fishing areas, offshore reefs) (see Section 9.11). Furthermore, as coconut plantations across the islands shut down, the plantation workers also begin depending on the sea resources to sustain their own livelihoods. This exacerbates existing pressures on marine resources.

Community members from Marulaon expressed concerns regarding coral bleaching, explaining that they had seen more and more unexplained coral deaths over recent years. This could be linked to ocean acidification and demonstrate its ability to compound existing threats. The community have recently started planting some corals in an attempt to re-establish these features.

Additional threats not explicitly identified by the Russell Island communities include:

- Pollution
- Climate change risks such as increased sea temperature and damage from more frequent or more intense storms/cyclones.
- Given the poor waste management and sanitation practices on the island, there is recognition that pollution from these sources may be having effects on the surrounding reefs and reef resources. However, the environmental responses and extent of effects is not known.

9.7 Sandy Beaches, Islands and Coastal Areas

9.7.1 Description of Socio-Ecological Values

Russell Islands' coastlines are dominated by a mix of narrow sandy beaches, gravel beaches, rocky shores and steep rocky cliffs. Mixed sand/gravel beaches are present along the southern coastlines of Marulaon and Karumulun Islands, which transition to more rocky cliffs towards the northern coast of Marulaon (Figure 9.8). Karamulun is a sand island, however, most of the original sandy beaches have been lost to sea level rise and associated chronic coastal erosion. Instead, due to the encroaching sea forming a narrow spit on its southern end, most of the built settlement area can now be considered the beach (Figure 9.9).

A) B)

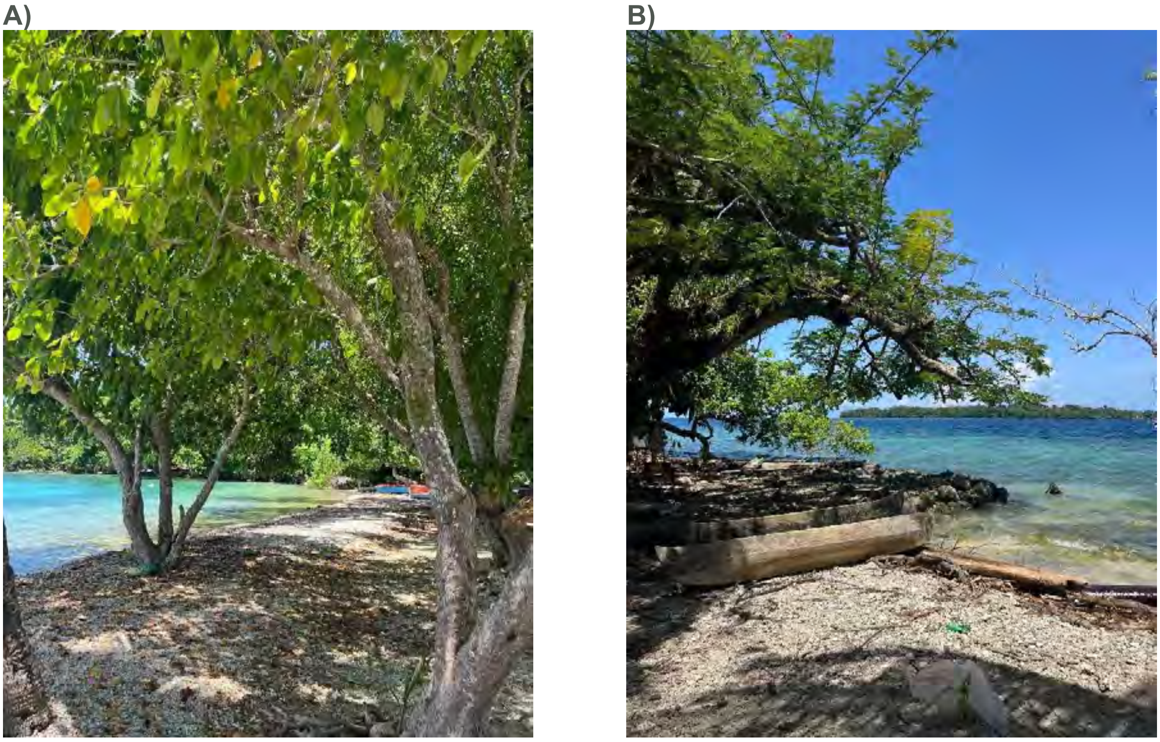

Figure 9.8 Examples of sandy/gravel beaches at Marulaon

Figure 9.9 Narrow strip of built settlement on sand remaining on the southern end of Karumulun (source: Douglas Junior Pikacha, ESSI).

While comparatively small in land area, sandy beaches, islands and coastal areas tend to support a substantial variety of intertidal and terrestrial vegetation types (e.g. mangroves and lowland forest), which generally appear to be in good condition (with the exception of village high-use areas). Sandy beaches directly adjacent to villages typically contain more sparse vegetation which, in turn, increases their exposure to coastal erosion. It is unclear what specifically has contributed to the sparseness of vegetation along village foreshores, but it is likely to relate to one or more of the following processes: timber harvesting, clearing land for new houses, significant coastal erosion or storm tide events, previous cyclones or intense storms. Variations in intertidal and terrestrial vegetation establishment and health on Marulaon beaches are shown in (Figure 9.10). As mentioned above, some intertidal and terrestrial vegetation types on the southern end of Karumulun have already been lost to permanent inundation as a result of sea level rise. However, some sparse lowland forest remains interspersed with the built settlement (Figure 9.11). In the northern end of the island, more dense lowland forest is observed.

Sandy beaches are most highly valued by Karumulun as sanitation areas (due to their proximity to villages) and by Marulaon as a source of sand and gravel. Sand and gravel (i.e. coral rubble) are often used in building construction requiring concrete (e.g. tombstones for burial grounds). Although not explicitly identified by the communities, sandy beaches also provide safe boat or canoe landing areas and allow community members to transport goods to market.

Figure 9.10 Variety in vegetation types and condition on high-use sandy beaches around Marulaon A) mangroves, B) dense lowland forest, C), D) more sparse beach front vegetation

A) B)

Figure 9.11 Remaining sparse vegetation throughout the Karumulun village.

9.7.2 Sensitivities and Threats

The largest threats for sandy beaches, islands and coastal areas in Russell Islands are coastal erosion and permanent inundation through sea level rise. Coastal erosion was typically discussed in conjunction with sea level rise; however, it is recognised that such erosion can be either acute or chronic. Acute coastal erosion typically occurs during storm surge/storm tide and extreme/king tide events which are then exacerbated by sea level rise. In contrast, more chronic coastal erosion may arise directly from sea level rise but could be difficult to separate from the natural high dynamicity of sandy coastal areas.

Karumulun is already experiencing the effects of sea level rise, with large portions of the island already washed away and destroyed over the years. During the site visit, community members showed the project team part of the island which had been cut off and permanently inundated as a result of sea level rise (Figure 9.12). The same area was captured in a 2017 news article by Solomon Islands Broadcasting Corporation and can be used for a visual comparison of erosion/sea level rise impacts between 2017 and 2024 (Figure 9.13) (Sei, 2017). Coastal erosion is also a significant concern for members of the Marulaon community, particularly with regards to their burial grounds, which are located close to the sea and have already started sinking (Figure 9.14).

Specific concerns from the two communities included:

- Existing coastal erosion through cyclones, storm and rough seas (Figure 9.15)
- Potential future exacerbation of coastal erosion through climate change effects (e.g. sea level rise, increase in the frequency or intensity of cyclones).
- Coastal erosion washing away gravel and sand for building materials.

Although not identified by the communities, other threats to sandy beaches, islands and coastal areas could include clearing of vegetation and the potential flow on effects to food sources, as well as modification of sandy shores through foreshore protection works impacting natural shoreline processes.

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 (BMT WBM, 2017b). Even in the absence of climate change, the implications of this high dynamicity are that the construction of built structure 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 (BMT WBM, 2017b).

Figure 9.12 Part of Karumulun Island which has been cut off and destroyed by sea level rise (indicated by the small stick which has been encircled in red)

Figure 9.13 Part of Karumulun island that has been cut off due to sea level rise (from Solomon Islands Broadcasting Corporation in 2017 (Sei, 2017)).

Figure 9.14 Proximity of graves within the burial ground to the eroding coastal cliff edge.

Figure 9.15 Example of severe beach erosion on the southern tip of Karumulun Island.

9.8 Cultivated Land - Gardens

9.8.1 Description of Socio-Ecological Values

While in a highly modified state through human cultivation, subsistence food gardens represent a highly valued terrestrial ecosystem by Russell Island communities. Gardens are essential for food provision, with the communities being almost solely reliant on their local subsistence produce for their fruit and vegetable needs. Garden produce also provides a key source of income, through small scale commercial trade at markets.

Food gardens within the Marulaon and Karumulun communities include domestic fruit and vegetable crops (e.g. root vegetable patches, orchards etc.) located either by houses or in dedicated agricultural – ‘garden’ – plots. These dedicated agricultural plots typically encompass much of the land immediately surrounding each village, however, Karumulun’s dedicated plots are located on the island of Marulaon due to the minimal available land capital on the small island (Figure 9.2).

Staple vegetable crops, such as cassava and taro, are often grown in dedicated monoculture plots (Figure 9.16). Gardens located around houses (i.e. within the village) are more commonly comprised of a mixture of various vegetables and/or fruits (Figure 9.16). Plant foods found around each village, and not necessarily in dedicated garden plots, include: a) bananas, b) betel nut, c) sweet potato, d) pana, e) yam, f) ngali nut, g) mango.

A)

B)

C)

D)

Figure 9.16 Examples of garden varieties across the Russell communities; A), B) ngali nut trees in Marulaon, C) taro plot in Marulaon, D) cassava plants in Marulaon, E) mixed produce garden in Marulaon, F) banana trees in Karumulun.

9.8.2 Sensitivities and Threats

The local communities identified the following as the key existing threats and concerns for gardens:

- Insect pests are a major management concern if they become well established, while the projected increase in temperature from climate change is likely to heighten the risk of food crops becoming more susceptible to pests. Currently worms are the only concern which only affect certain crops.
- Increasing demand on gardens through population growth and limited space/opportunity for garden expansion. This is exacerbated on Marulaon Island since it contains gardens for both Marulaon and Karumulun.
- Soil fertility issues from intense garden usage (from growing population). However, it should be noted that the community of Marulaon have started practicing shifting cultivation to allow the soil to better recover.
- Lack of training/education to understand soil fertility and the best ways to plan gardens to maximise this.

Although not explicitly identified by the communities, it is likely that heavy rainfall events and storms, resulting in flooding and high winds, also represent a threat to gardens (damage, waterlogging etc.).

9.9 Cultivated Land - Plantation

9.9.1 Description of Socio-Ecological Values

When considering cultivated lands, plantations are typically seen by local communities as a distinct 'ecosystem' to the gardens. This is largely due to plantations containing distinct groups of plant species and being subject to some different threats. Plantations typically occur in large, dedicated plots in and around villages. However, in the Russell Islands, these plantations are even more expansive, with most of Mbanika and large swaths of Pavuvu island covered with coconut palms (Figure 9.1). Extensive coconut plantations are also observed in many islets around the Russell Islands, including Marulaon. These are linked to Russell Islands' extensive history of cultivated coconut plantations which were known to produce some of the highest copra yields in the Solomon Islands. As a result of this, most of the islands are currently, or have historically been, covered with coconut palms.

The plantations on Marulaon Island are comprised almost exclusively of coconut palms, so the community often visit the mainland for other crops which occur in small, isolated plantations including, for example, betel nut, ngali nut, cut nut, and sago palm (in mainland freshwater swamps).

Plantation plants are primarily grown for commercial purposes, to sell both locally and at Honiara (e.g. betel nut), however, they are versatile in that they also provide food for local consumption (e.g. coconut) and building materials. Selling copra from coconut plantations remains the primary source of income for many communities in Russell Islands (including Marulaon). There are also indirect food provisioning values associated with these plantations, such as coconut crabs. Coconut crabs are the largest land crabs and as of 2018 they are listed as vulnerable on the IUCN Red List.

In terms of plantation condition, it was noted by both the project team and the Marulaon community that many of the existing coconut plantations are quite old, having been established by the previous generations. Anecdotal evidence suggests that the aging trees in these plantations are no longer at optimum productivity and produce a lower yield of fruit than younger trees (BMT WBM, 2017a). Community members from Marulaon also cited poor management (i.e. no weeding taking place anymore) as a potential reason for decreasing yields. The project team were informed that some re-planting has taken place in Marulaon, however, the small scale of these initiatives did not compensate for the existing aging coconut plantations.

Figure 9.17 The start of extensive coconut plantations to the northwest of Marulaon village (top right of image) (source: Douglas Junior Pikacha, ESSI).

9.9.2 Sensitivities and Threats

Key threats identified by Marulaon and Karumulun for plantations typically applied exclusively to coconut plantations, since these are the dominant type and provide the majority of income. Identified threats included:

- Insect pests are a major management concern if they become well established (e.g. rhinoceros beetle). The projected increase in temperature from climate change is likely to heighten the risk of vegetation becoming more susceptible to pests.
- Overharvesting plantation resources due to increasing populations – experiencing decreasing plantation yields and very minimal replanting has been taking place.
- Decreasing coconut yields from plantations as a result of poor management practices (e.g. no longer clear around trees and remove weeds and bushes)
- Lack of diversity in coconut-derived products. Currently, the utility of coconuts to earn income is restricted to dried copra. Community members want to be able to produce more products from coconuts to earn more income.
- Access to local coconut variety only. The communities currently only have access to the local variety of coconut which is slower growing and necessitates longer periods between harvests. Hybrid varieties of coconut are faster growing.

Additional threats not explicitly identified by the Russell Island communities include:

- The location of coconut plantations along, or in close proximity to, the shoreline being prone to coastal erosion (especially from cyclone and storm surge)
- Aging plantations need replacement with younger trees for improved resilience and productivity.

9.10 Conservation or Tabu Areas

9.10.1 Description of Socio-Ecological Values

While these do not constitute distinct ecosystem types and are instead comprised of a variety of ecosystem types which have already been discussed (e.g. reefs, forests etc.), communities on Russell Islands consistently recognised these areas as having distinct socio-ecological values.

Conservation or tabu areas represent areas of certain ecosystems (typically forests and reefs) which are informally protected via voluntary managed areas or chief-mandated taboos ('tabu') (Figure 9.2). There are three key conservation areas which were consistently recognised by the Marulaon and Karumulun communities:

1. Marulaon MMA - this area includes all inshore areas on the entire eastern, southern and northern sides of Marulaon Island and extends westward almost as far as Leru passage. The area is a tabu fishing ground which can only be opened by the chief for important, typically religious, occasions (e.g. Easter and Christmas). Socio-ecological values identified by the Marulain community included:
    a. Conservation of marine species and ecosystems to allow populations to recover (habitat services)
    b. Increasing food security for future generations by promoting sustainable harvesting practices
    c. Income generation through tourism (e.g. dive sites).
2. Kusuvao MPA – this area extends around the entire Kusuvao Island and adjacent marine areas. The communities made the decision to set aside Kusuvao Island and the surrounding marine area as an MPA to preserve marine species (particularly sea cucumber). In return, the Fisheries Office installed a FAD in deeper waters off the eastern coast of Marulaon to assist in food provision. Unlike MMAs which can be opened and closed by the chief, MPAs cannot be opened. Socio-ecological values identified for this area include:
    a. Ecosystem conservation (habitat services)
    b. Sea cucumber preservation
    c. Income generation through tourism (dive sites). Tourism is the primary source of income for the Karumulun community, particularly through the Bilikiki dive boat anchorage which is located near the island.
3. Marulaon Preservation Areas – Marulaon implements a variety of harvesting restrictions in terrestrial and coastal ecosystems when overharvesting pressures become evident. These typically take the form of temporary protected areas. For examples, along the cliffs, there are preserved areas for sea snails, coconut crabs, shells and other intertidal fauna to allow the populations to recover from past overharvesting. The community also has specific sections of forest which are preserved for certain purposes (e.g. medicine). Socio-ecological values identified for these areas include:
    a. Ecosystem conservation (habitat services)
    b. Crab breeding area
    c. Increasing food security for future generations by promoting sustainable harvesting practices.

4. Karumulun Tabu Areas – the community at Karumulun have established both a terrestrial and marine tabu area. No fishing is permitted in the marine tabu area which extends to 50 m offshore of Karumulun Island to conserve ecosystems. Karumulun has also established a 5-year ban on harvesting coconut crab, possum and shells from the land or sea to allow the species to recover from overharvesting pressures. Socio-ecological values identified for these areas include:
    a. Ecosystem conservation (habitat services)
    b. Increasing food security for future generations by promoting sustainable harvesting practices.
    c. Income generation through tourism (dive sites).

9.10.2 Sensitivities and Threats

The sensitivities and threats affecting these areas are largely captured in each individual ecosystem type which constitute those conserved/tabu areas. Please refer relevant sections above for further details. In addition to these threats, the communities at Marulaon and Karumulun identified additional threats/challenges which specifically apply to conservation/tabu areas, including:

- Education of communities to understand the need for restrictions
- Lack of legal enforcement for protected/conserved areas (some people still disobey restrictions)
- Coral bleaching.

9.11 Marine (Other)

9.11.1 Description of Socio-Ecological Values

The remaining marine environments around Russell Islands primarily comprise deeper open waters and associated habitats including, for example, deeper seabeds and pelagic waters (i.e. those marine habitats which lay beyond inshore reefs). Unlike inshore marine areas around Marulaon and Karumulun, these areas do not have any harvesting restrictions imposed on them. The establishment of MMAs, MPAs and preservation areas around Marulaon and Karumulun has exacerbated the existing shift towards fishing in offshore reefs. As a result, offshore fishing grounds in the northern Russell Islands are all overfished. As mentioned above, a FAD was installed east of Marulaon in exchange for the communities setting aside marine areas for the Kusuvau MPA. This has also likely increased fishing pressures in the area.

Offshore marine areas are most highly valued by the communities as a source of food and income via deep sea fishing and diving (e.g. for snapper and mackerel). Other services valued by the community include:

- Breeding grounds for fish (habitat services)
- Collecting sea cucumbers for selling (when ban is lifted)
- Passage for outboard motorboats to allow transportation of people and products.

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; nutrient and carbon cycling by both phytoplankton and zooplankton (BMT WBM, 2017b).

9.11.2 Sensitivities and Threats

The main threat to open waters and offshore marine environments is the overharvesting of fish and other marine fauna. This is already exacerbated by the extensive protections over inshore reefs around Marulaon and Karumulun and is likely to worsen due to rising fishing pressure as the local population increases. Other threats are very similar to those identified for inshore reefs.

9.12 Other (Village)

9.12.1 Description of Values

While it is recognised that the village does not represent an ecosystem type, all workshop groups within both communities identified aspects of their built settlements which were integral to daily life. Aspects which were identified included: churches, community halls, future kindergarten development, playing grounds, burial grounds, road, rest house and piggery area. These provide valuable services to the community such as education, spiritual support, connection to ancestors, enrichment of youth and places for tourists to stay. Rainwater tanks were also identified by both communities as a critical source of drinking water. Although these do not constitute ‘socio-ecological’ values, the project team decided that these areas should still be included in the report, largely due to the valid concerns/threats about them raised by the communities.

9.12.2 Sensitivities and Threats

Key threats to the villages (built settlements) identified by community members include:

- **Permanent inundation due to sea level rise and associated beach erosion**. Both communities are located on very low elevations and already experience frequent seawater intrusion and coastal erosion during high tides. For examples of the severity of this threat to villages, refer **Section 9.7.2**.
- Lack of proper sanitation and increased risk of disease (identified as a major concern in Karumulun)
- Not having enough rainwater tanks to provide water security
- Diminishing copra buyers.
- Lack of kindergarten for all the young children.

These key threats should be used as a guide for any NGOs looking for opportunities to fund development projects in the two communities, as well as in Russell Islands more broadly.

10 Valuation of Ecosystem Services

10.1 Grouping of Ecosystem Services

The purpose of quantifying values as part of the ESRAM process is to provide insights on the relative extent and magnitude of ecosystems and ecosystem service values across and between different environments (BMT WBM, 2017b). Ecosystem services contribute to economic well-being by (1) contributing to the generation of income and livelihoods (e.g. fishing, food crops, timber etc.); and (2) preventing damages that impose costs on society (e.g. coastal hazard protection by mangroves providing shoreline stabilisation) (BMT WBM, 2017b).

Identifying the existence of ecosystem services is relatively simple, however, assigning economic values to such services (e.g. clean air, clean water, biodiversity) is complicated since ecosystem goods are often not traded in markets and do not have an obvious economic value (BMT WBM, 2017a). As a result, unregulated markets or goods and services such as ecosystems services, often become compromised or collapse (BMT WBM, 2017a). However, by placing a value on ecosystem services, priorities can be given to protecting and restoring the relevant ecosystems. Additionally, a lack of economic values on ecosystems and their services may encourage overuse since there is no incentive to protect or conserve the service (King and Mazzotta, 2000).

As illustrated by the previous chapter, residents of Central Province are highly dependent on ecosystem services, with a long list of identifiable services developed in consultation with local communities. Valuing each discrete service (e.g. the value of sago palm leaves for roofing materials) is not feasible for the scope of this study due to the project size, lack of site-specific information available and the lack of applicable valuation studies for the more unique ecosystem services. Additionally, there are often dependencies between ecosystem services and 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 (on a Provincial scale). 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. Additional provisioning, regulating, supporting and cultural ecosystem services which are relevant to the Central Province context, but were not explicitly identified by communities during consultations, were also included (de Groot *et al*., 2012). Similar to the Wagina Island ESRAM (BMT WBM, 2017b), the following categorisation of ecosystems was utilised for the purpose of the valuation process:

- Tropical Forest
- Mangrove
- Marine
- Freshwater rivers.

Notably, in line with BMT WBM (2017b), cultivated terrestrial land (e.g. plantations and gardens) have not been included in the ecosystem valuations. While agroecosystems 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 (BMT WBM, 2017b). 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 it is replacing (BMT WBM, 2017b). Groundwater services have also not been included in the valuation, due to its poor representation in valuation studies. Finally, economic valuation was unable to be undertaken for the megapode fields on Savo Island, despite the high reliance on these areas by the community. This was due to a lack of previous studies and paucity of information on harvest numbers.

10.2 Tropical Forests

Tropical forests provide a range of provisioning, regulating, habitat and cultural services to Central Province residents and are estimated to cover approximately 39,780 ha. Key ecosystem services identified by Central Province communities included:

- Timber for building materials, fuelwood, canoe building and export to Honiara (income source)
- Bush materials for houses
- Biodiversity / wildlife habitat
- Food provision (hunting)
- Medicine
- Land which can be cleared for gardens or plantation.

Specific forest-based services and their monetary values were adapted from de Groot *et al.* (2012) and are shown in Table 10.1 below. These values will help to capture some of the important ecosystem services identified by Central Province residents such as the use of plants (e.g. Pandanus) for medicinal purposes as well as the regulating services which support their water systems and erosion control along streamside gardens.

Table 10.1 Summary of tropical forest values (adapted from de Groot *et al.*, 2012)

	Service	USD 2024 adjusted* /ha/p.a.	USD Central Province/p.a.	SBD 2024 /ha/p.a.	SBD Central Province/p.a.
Provisioning Services	Food	$302	$12,013,560	$2,546	$101,279,880
	Raw materials	$127	$5,052,060	$1,070	$42,564,600
	Medicinal	$2,271	$90,340,380	$19,148	$761,707,440
Regulating Services	Climate regulation	$3,086	$122,761,080	$26,020	$1,035,075,600
	Disturbance moderation	$100	$3,978,000	$843	$33,534,540
	Regulation of water flows	$516	$20,526,480	$4,350	$173,043,000
	Erosion prevention	$23	$914,940	$194	$7,717,320
	Pollination	$45	$1,790,100	$379	$15,076,620
Habitat	Genetic services (biodiversity)	$24	$954,720	$202	$8,035,560
Cultural	Recreation (inc. tourism)	$1,309	$52,072,020	$11,037	$439,051,860
Total	**-**	**$7,803**	**$310,403,340**	**$65,789**	**$2,617,086,420**

*Values adjusted from de Groot *et al.* (2012) using a USD Consumer Price Index factor of 1.51 from 2007 – 2024 and USD SBD exchange rate from December 2024.

10.3 Mangroves

Mangroves are another important ecosystem in Central Province, which provide a range of provisioning, regulating, habitat and cultural services to communities on Nggela Islands and Russell Islands (as previously discussed, Savo Island does not contain any mangrove ecosystems). Mangroves make up a large part of the coastal fringe and cover approximately 2,000 ha. Key ecosystem services identified by Central Province communities included:

- Timber for building materials and fuelwood
- Food provision (mangrove shells, fish, mud crabs, fruit etc.)
- Breeding ground for vertebrates and invertebrates
- Coastline protection.

In line with BMT WBM (2017b), values for firewood, building materials and fishing in mangroves were drawn from Warren-Rhodes *et al.,* (2011). The study compares mangrove ecosystem services and values across three geographic locations in the Solomon Islands, the most relevant to Central Province being the village of Talakai in Malaita Province, located on the western coast of the island (facing Central Province) on the same latitude. Valuations for the three ecosystem services are summarised in Table 10.2

Table 10.2 Mangrove ecosystem services values (from Talakali) (Warren-Rhodes *et al.,* 2011)

Ecosystem Service	USD 2024 adjusted* per household/p.a.	SBD 2024 per household/p.a.
Firewood	$1,296 - $2,160	$10,865 - $18,109
Building materials	$34	$288
Fishing in mangroves	$2,478	$20,782
Total	**$3,808 - $4,672**	**$31,935 - $39,179**

*Values adjusted from Warren-Rhodes *et al*. (2011) using a USD conversion of 1 USD = 7.14 SBD (2008) and USD Consumer Price Index factor of 1.46 from 2008 – 2024.

For all other ecosystem services provided by mangroves, values were sourced from de Groot *et al.* (2012). Arena *et al*. (2015) also provides a per hectare value for mangroves for carbon sequestration which can be applied here. Values for the remaining ecosystem services are provided in Table 10.3.

Table 10.3 Summary of mangrove forest values (adapted from de Groot *et al.*, 2012)

	Service	USD 2024 adjusted* /ha/p.a.	USD Central Province/p.a.	SBD 2024 /ha/p.a.	SBD Central Province/p.a.
Provisioning Services	Food	$1,678	$3,356,000	$14,067	$28,134,000
Regulating Services	Climate regulation	$98	$196,000	$822	$1,644,000
	Disturbance moderation	$8,080	$16,160,000	$67,740	$135,480,000
	Waste treatment	$244,809[1]	$489,618,000	$2,052,405	$4,104,810,000

	Service	USD 2024 adjusted* /ha/p.a.	USD Central Province/p.a.	SBD 2024 /ha/p.a.	SBD Central Province/p.a.
	Erosion prevention	$5,933	$11,866,000	$49,740	$99,480,000
	Nutrient services	$68	$136,000	$570	$1,140,000
	Carbon sequestration (Arena *et al.*, 2015)	$539	$1,078,000	$4,519	$9,038,000
Habitat	Genetic services (biodiversity)	$16,078	$32,156,000	$134,793	$269,586,000
	Nursery service (e.g. fish breeding)	$9,800	$18,600,000	$82,160	$164,320,000
Total	**-**	**$287,083**	**$573,166,000**	**$2,406,816**	**$4,813,632,000**

*Values adjusted from de Groot *et al*. (2012) using a USD Consumer Price Index factor of 1.51 from 2007 – 2024 and USD SBD exchange rate from December 2024.

[1]This figure appears high and was drawn from a limited number of studies – 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 recognised or further tested in undertaking economic analysis.

10.4 Marine

Central Province residents rely heavily on the marine environment as a source of food, particularly in Nggela and Russell Islands. Furthermore, marine environments play an important role in providing regulating and supporting services such as natural hazard protection and sanitation services (BMT WBM, 2017a). 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 Nggela, Savo and Russell Islands residents interact with the marine environment through fishing and includes not just coral reefs, but other marine habitats such as shallow sand/rubble, seagrass meadows and nearshore open ocean. Key ecosystem services identified by Central Province communities included:

- Food provision (fishing, shells etc.)
- Income generation (fishing, shells, lime export, coral rubble, seaweed etc.)
- Building materials (coral rubble, sand etc.)
- Species protection / habitat
- Recreation
- Transport (equivalent values for this service were not available in the literature).

All island groups within Central Province fish for subsistence and for commercial purposes, with most residents heavily reliant on fish as a food source (particularly in Nggela and Russell Islands). As a result, fish as an ecosystem service (i.e. provision of food) from the marine environment have a significant value. In line with BMT WBM (2017b), key input values were drawn from a study by Albert *et al.* (2015) which collected data from four communities (including two communities in Nggela Islands – Leitongo and Hagalu) (Table 10.4). In addition, the study considered the marine environment as the coastal zone extending from the shoreline to the outer coral reefs (up to a few kilometres out to sea), meaning the ecosystem did not exclude habitats such as shallow sand/rubble, seagrass meadows and nearshore open ocean. Supplementing these values, Arena *et al.* (2015) provided the values for subsistence, and commercial inshore fishing (Table 10.5).

Table 10.4 Marine ecosystem service values (adapted from Albert *et al.*, 2015)

Ecosystem Service	USD 2024 adjusted* per person/p.a.	USD Central Province (based on 30,326 ppl)/p.a.	SBD 2024 per person/p.a.	SBD Central Province (based on 30,326 ppl)/p.a.
Fish	$2,218	$67,263,068	$18,595	$563,911,970
Seaweed	$1,327	$40,242,602	$11,125	$337,376,750
Clam	$902	$27,354,052	$7,562	$229,325,212
Trochus	$387	$11,736,162	$3,244	$98,377,544
Shell	$493	$14,950,718	$4,133	$125,337,358
Fisheries Total	$6,880	$208,642,880	$57,680	$1,749,203,680
Coral Total (sand, rubble, stone etc.)	$2,943	$89,249,418	$24,673	$748,233,398
Total	**$9,823**	**$297,892,298**	**$82,353**	**$2,497,437,078**

*Values adjusted from Albert *et al*. (2015) using a USD Consumer Price Index factor of 1.33 from 2007 – 2024 and USD SBD exchange rate from December 2024.

Note: the figures above are per person engaging in the activity based on respondents, 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.

Table 10.5 Summary of Central Province Ecosystem Service Values (adapted from Arena *et al.* 2015)

Ecosystem Service	USD 2024 adjusted* per person/p.a.	USD Central Province (based on 30,326 ppl)/p.a.	SBD 2024 per person/p.a.	SBD Central Province (based on 30,326 ppl)/p.a.
Subsistence fisheries	$201	$6,095,526	$1,685	$51,099,310
Inshore commercial	$23	$697,498	$191	$5,792,266

*Values adjusted from Arena *et al.* (2015) using a USD conversion of 1 SBD = 0.1332 USD (2013) and USD Consumer Price Index factor of 1.35 from 2013 – 2024.

All other regulating, habitat and cultural service values of marine environments were taken from de Groot *et al.* (2012) (Table 10.6). The de Groot *et al.* (2012) study divides the marine environment into coral reefs, and coastal systems (which include seagrass, shallow seas of continental shelves, rocky shores and beaches). Values for both ecosystem categories are provided below. Coral reefs are estimated to cover approximately 9,620 ha in Central Province (Arena *et al.*, 2015). The area of 'coastal systems' coverage was crudely estimated by multiplying the Central Province coastline (1,473.3 km) (Arena *et al.*, 2015) by one kilometre out to sea, which is 1,473.3 km^2 (147,330 ha), then subtracting the area of coral reefs to arrive at 137,710 ha.

Table 10.6 Summary of marine values (coral reefs) (adapted from de Groot *et al.*, 2012)

	Service	USD 2024 adjusted* /ha/p.a.	USD Central Province /p.a.	SBD 2024 /ha/p.a.	SBD Central Province /p.a.
Provisioning Services	Genetic resources	$49,902	$480,057,240	$418,363	$4,024,655,883
	Ornamental	$713	$6,859,060	$5,978	$57,504,301
Regulating Services	Climate regulation	$1,794	$17,258,280	$15,040	$144,688,242
	Disturbance moderation	$25,656	$246,810,720	$215,092	$2,069,187,033
	Waste treatment	$128	$1,231,360	$1,073	$10,323,353
	Erosion prevention	$231,353[1]	$2,225,615,860	$1,939,594	$18,658,895,685
Habitat	Genetic services (biodiversity)	$24,477	$235,468,740	$205,208	$1,974,099,275
Cultural	Recreation	$145,416[1]	$1,398,901,920	$1,219,124	$11,727,974,027
	Cognitive development	$1,729	$16,632,980	$14,495	$139,445,914
Total	**-**	**$481,168**	**$4,628,836,160**	**$4,033,968**	**$38,806,773,715**

*Values adjusted from de Groot *et al*. (2012) using a USD Consumer Price Index factor of 1.51 from 2007 – 2024 and USD SBD exchange rate from December 2024.

[1]This figure appears high and was drawn from a limited number of studies – 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 recognised or further tested in undertaking economic analysis.

Table 10.7 Summary of marine values (coastal systems) (adapted from de Groot *et al.*, 2012)

	Service	USD 2024 adjusted* /ha/p.a.	USD Central Province /p.a.	SBD 2024 /ha/p.a.	SBD Central Province /p.a.
Regulating Services	Climate regulation	$723	$99,564,330	$6,061	$834,717,473
	Erosion prevention	$38,306	$5,275,119,260	$321,146	$44,225,017,340
Habitat	Genetic services (biodiversity)	$272	$37,457,120	$2,280	$314,029,257
	Nursey services	$293	$40,349,030	$2,456	$338,274,163
Cultural	Recreation	$387	$53,293,770	$3,244	$446,798,980
	Cognitive development	$33	$4,544,430	$277	$38,099,138
Total	**-**	**$40,014**	**$5,510,327,940**	**$335,465**	**$46,196,936,351**

*Values adjusted from de Groot *et al*. (2012) using a USD Consumer Price Index factor of 1.51 from 2007 – 2024 and USD SBD exchange rate from December 2024.

10.5 Freshwater Rivers

Freshwater rivers provide a range of provisioning, regulating, habitat and cultural services to Central Province residents and are estimated to cover approximately 1,550 ha. Key ecosystem services identified by Central Province communities included:

- Water source (drinking and domestic)
- Irrigation of streamside gardens (food security)
- Food provision (fishing for prawns, eels etc.)
- Fish breeding ground

Freshwater river services and their monetary values were adapted from de Groot *et al.* (2012) and are shown in Table 10.8 below. These values will help to capture some of the important ecosystem services identified by Central Province residents such as rivers being able to provide irrigation for streamside gardens as well as the many regulating services.

Table 10.8 Summary of freshwater river values (adapted from de Groot *et al.*, 2012)

	Service	USD 2024 adjusted* /ha/p.a.	USD Central Province/p.a.	SBD 2024 /ha/p.a.	SBD Central Province/p.a.
Provisioning Services	Food	$160	$248,000	$1,341	$2,079,158
	Water	$2,730	$4,231,500	$22,887	$35,475,627
Regulating Services	Waste treatment	$282	$437,100	$2,364	$3,664,515
Habitat	Genetic services (biodiversity)	None provided	-	-	-
Cultural	Recreation (inc. tourism)	$3,271	$5,070,050	$27,423	$42,505,778
Total	**-**	**$6,443**	**$9,986,650**	**$54,016**	**$83,725,078**

*Values adjusted from de Groot *et al.* (2012) using a USD Consumer Price Index factor of 1.51 from 2007 – 2024 and USD SBD exchange rate from December 2024.

10.6 Summary of Economic Valuations

The economic value estimates above clearly demonstrate the significant value communities derive from ecosystem services. At an ecosystem level for Central Province, the estimated economic values for ecosystem services considered above are:

- **freshwater rivers** USD $9,986,650 (2024) or SBD $83,725,078
- **coral reefs** USD $4,628,836,160 (2024) or SBD $38,806,773,715
- **coastal systems** USD $5,510,327,940 (2024) or SBD $46,196,936,351
- **mangroves** USD $573,166,000 (2024) or SBD $4,813,632,000
- **forests** USD $310,403,340 or SBD $2,617,086,420.

The value of marine environments (coral reefs and coastal systems) is substantially higher than other ecosystems, likely due to the diverse services they provide and the significant contribution of erosion prevention. Crucially, erosion protection by mangroves is not valued at the same scale which is not a true representative of the key role mangroves play in this ecosystem service (BMT WBM, 2017b). As noted in BMT WBM (2017b), the unbalanced valuation is likely 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 these erosion protection services provided by reefs, coastal systems and mangroves are functioning at full capacity will be crucial to the province's resilience to future adverse impacts of climate change, particularly when considering the projected sea level rise, increase in extreme rainfall events and higher intensity tropical cyclones (see Section 10 for climate change projections).

The provision of food by marine ecosystems is a critical service for the people of Central Province 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 $6,880 (2024) and SBD $57,680 per person each year. Based on the estimated population of Central Province from the 2019 census (30,326), total fisheries are valued at USD $208,642,880 (2024) and SBD $1,749,203,680 per annum. The heavy reliance on marine resources for the well-being and livelihood of Central Province residents (particularly Nggela and Russell Islands communities), 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 justification for policy and programs to protect ecosystems and prioritise the allocation of program spending to maximise the environmental benefits per dollar spent (King and Mazzotta 2000). The values presented above and the heavy dependency Central Province residents have on ecosystem services, reiterates the strong economic case for investing in ecosystem services. There is also a need for Nggela, Savo and Russell Island communities to better understand the value of ecosystem services, which may play a role in their improved management.

11 Climate Change Vulnerability Assessment

11.1 Future Climate Projections

The most recent scenarios used to characterise possible future development pathways for human societies are known as Shared Socio-economic Pathways (SSPs) and were introduced in the latest IPCC report (AR6). The SSPs are part of a scenario framework that allows for exploring a range of socioeconomic and climatic conditions. Crucially, the five SSPs correspond to different degrees warming and represent five distinct trajectories or pathways into the future (Figure 11.1). The exploration of these plausible futures and broad-scale trends in socioeconomic development until the end of the 21st century is based on socioeconomic challenges for mitigation and adaptation (Meinshausen *et al.*, 2020).

Scenario SSP1 represents a sustainable world with equitable development, low population growth and efficient resource use. SSP2 represents a middle-of-the road pathway with moderate population growth and economic development. SSP3 represents a fragmented world with high equality, regional conflicts, and slow economic growth. SSP4 represents a world with rapid economic growth, high fossil fuel use, and limited environmental regulation. Finally, SSP5 represents a fossil-fuel-intensive word with high technological development but limited environmental concern (Lee et al., 2021). Each SSP provides a unique narrative concerning future socioeconomic conditions and influencing climate change impacts, mitigation and adaption strategies (Figure 11.2).

The following section summarises the climate projections for the Solomon Islands based on the **SSP5-8.5 scenario** for the near term (2021-2040) and long term (2081-2100). SSP5-8.5 is the highest emission scenario in AR6, whereby technological development continues rapidly, but there is limited environmental concern (Shiogama *et al.*, 2023). This scenario was selected to present a **conservative assessment** of climate change vulnerability based on the most intense climate projections. All projected changes represent the overall change relative to 1995 – 2014 levels of each climate variable.

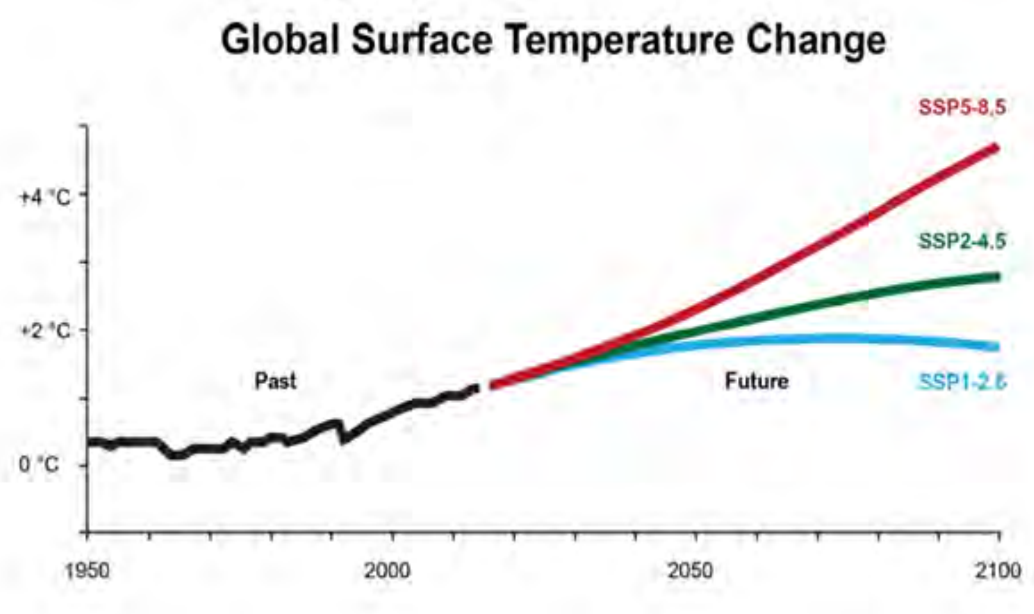

Figure 11.1 Pathways to different climate futures

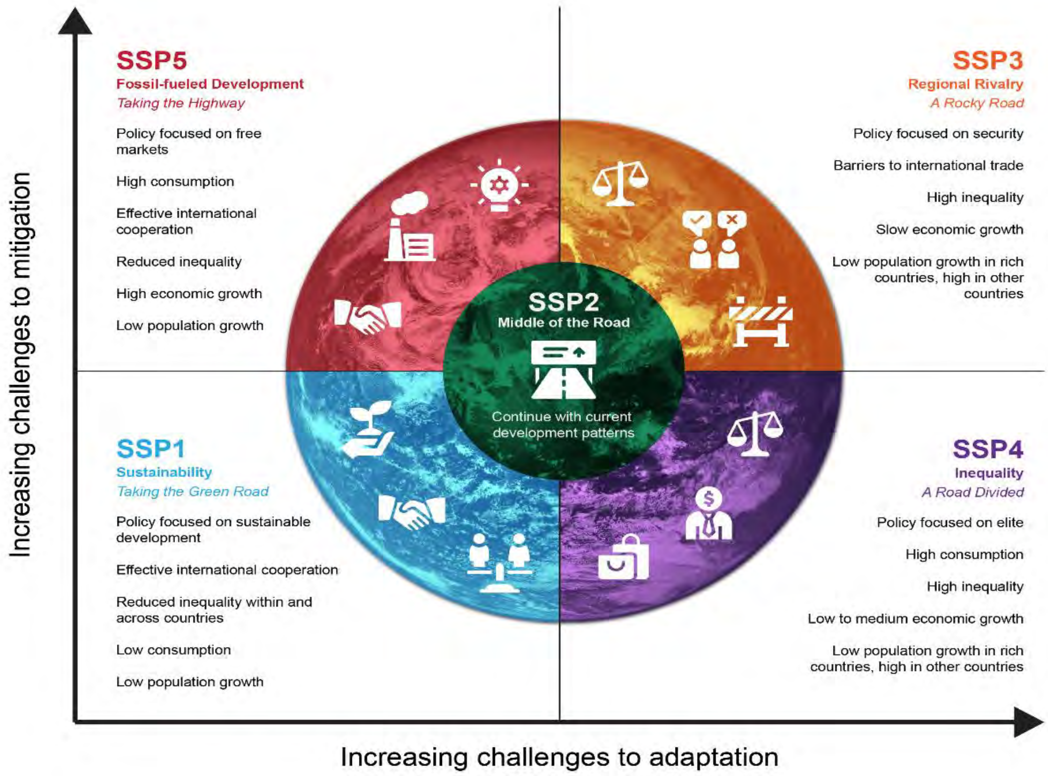

Figure 11.2 Global Shared Socio-Economic Pathways characterised along two broad axes: challenges to mitigation and challenges to adaptation (Climate Data Canada, 2024)

11.1.2 Temperature, Rainfall and Sea Level

Table 11.1 provides a summary of the projections for temperature (land and sea), rainfall and sea level for the Equatorial Pacific Region under the SSP5-8.5 scenario from the CMIP6 climate model (IPCC, 2024).

Table 11.1 Summary of AR6 Median Climate Change Projections for the Equatorial Pacific Region under the SSP5-8.5 scenario (IPCC, 2024)

Climate Variable	Near Term (2021-2040)	Long Term (2081-2100)
Air Temperature		
Mean Temperature (°C change)	0.7	3.4
Maximum Temperature (°C change)	0.7	3.3
Minimum Temperature (°C change)	0.7	3.3
Rainfall		
Total Precipitation Change (%)	4.2	23.5
Maximum 1-day Precipitation Change (%)	5.9	40.6
Maximum 5-day Precipitation Change (%)	5.0	33.4
Consecutive Dry Days (CDD) (change in days)	-1.2	-7.5

Climate Variable	Near Term (2021-2040)	Long Term (2081-2100)
Standardised Precipitation Index (SPI-6) Change (%)	17.4	72.7
Sea Surface Temperature (SST)		
SST (°C change)	0.7	3.2
Sea Level Rise (SLR)		
SLR (m change)	0.1	0.7

For the Solomon Islands, these projections (considering the SSP5-8.5 trajectory) can be summarised as follows:

- Increases in the mean, maximum and minimum temperatures by approximately 0.7°C by 2040 and 3.4°C by 2100. This indicates a consistent warming trend for the Solomon Islands, with temperatures throughout the year predicted to increase.
- There is high confidence that the temperature of extremely hot days will increase, as well as the frequency of extremely hot days (Lee *et al*., 2021).
- Increase in total annual precipitation of approximately 23.5% by 2100. This is likely to manifest through increased intensity of rainfall events as seen through the increases in both maximum 1-day precipitation (41%) and maximum 5-day precipitation (33%) parameters. This indicates an increase in the maximum amount of precipitation received during extreme events.
- Solomon Islands may also see an increase in the frequency of rainfall events based on the tentative reductions in consecutive dry days predicted. This is also supported by a positive increase in SPI, indicating precipitation is expected to be higher than the long-term average.
- It is important to note that there is low confidence in the magnitude of rainfall projections and uncertainty around projected changes in the ENSO. However, the overall proportion of time spent in drought is expected to decrease. CDD projections indicate a decrease in dry days (by 1.2 days in the near term and 7.5 days in the long term).
- Sea surface temperature will continue to increase in the Solomon Islands, with warming of approximately 0.7°C relative to 1995-2014 levels predicted by 2040 and 3.2°C predicted by 2100.
- Sea level rise will continue to increase in the Solomon Islands. Predictions for the Equatorial Pacific indicate increases of approximately 0.1 m by 2040 (relative to 1995-2014 levels) and 0.7 m by 2100. However, previous studies have indicated the Solomon Islands have historically experienced sea level rise at rates above the global average (e.g. The World Bank, 2021). This suggests the actual SLR rates may be higher than predicted.

The AR6 report also includes projected changes in annual maximum daily precipitation (relative to 1850-1900) across multiple warming scenarios and highlights that annual wettest-day precipitation is expected to increase for the Solomon Islands. Also of relevance are projections of tropical cyclone activity, which are likely to cause significant rainfall events (refer following section). In addition, the AR6 report provides projections on the increased frequency of extreme sea level events by 2040, which highlights Solomon Islands as one of the regions where extreme events are likely to occur annually (Lee *et al*., 2021).

11.1.3 Cyclones

Arias *et al*. (2021) includes AR6 high and medium confidence predictions of changes in tropical cyclones into the mid-21st century. Based on AR6 predictions, tropical cyclone intensity is expected to increase in the Pacific region for both the SSP2-4.5 and SSP5-8.5 scenarios. This also correlates with the wetter extremes and more precipitation predicted for the region. However, for the Solomon Islands, there is a medium level of confidence that there will be an overall decrease in cyclone genesis frequency for the south-west basin.

11.1.4 Waves

Predictions from the IPCC AR5 report suggested a possible decrease in wave activity in the Solomon Islands (with low confidence), however, similar predictions are not included in the AR6 report. AR5 predictions indicated (with low confidence) that during December–March, projected changes will include a significant decrease in mean wave height, accompanied by a decrease in wave period, with no significant change in direction. AR5 also predicted a decrease in the strength of prevailing winds, with no change in the height of larger storm waves. Adopted future wave conditions are therefore the same as existing wave conditions.

11.1.5 Ocean Acidification

As stated in Section 3.1.3, the aragonite saturation state in the Solomon Islands has decreased since the 18th Century. Between 1991-2011, the mean surface-ocean pH has declined by 0.018 ± 0.004 units per decade in 70% of ocean biomes, with the eastern Equatorial Pacific and South pacific subtropical constituting two of three global hotspots (Lauvset *et al*., 2015). Due to the close link between carbonate ion concentrations and pH, the saturation state of aragonite follows the same trends, with high-latitude regions being the most vulnerable due to their naturally lower mean values (Bindoff *et al.*, 2019). There is very high confidence that levels will continue to decrease with increases in atmospheric carbon dioxide. The AR6 report predicts that the area of the surface ocean (0–10 m) very likely to be characterised by undersaturated aragonite conditions is as high as 16 - 20% by 2100 (Bindoff *et al.*, 2019). Undersaturated aragonite conditions are likely to be concentrated in the Equatorial and Eastern Pacific.

11.1.6 Coral Bleaching

The risk coral bleaching increases with elevated water temperatures and depends on the duration and magnitude of the temperature rise. There is very high confidence that as the ocean warms the risk of coral bleaching increases. However, the degree of coral bleaching is also determined by the rate of change of sea surface temperature, as well as the complexity of changes at the reef-scale and presence of other stressors.

11.2 Climate Change Threats

The potential effects of these climate change threats on the broad marine, aquatic and terrestrial ecosystems of the Solomon Islands and their ecosystem services are summarised in Table 11.2 based on BMT WBM (2017b). Climate change threats have focused on the use of projections which have high to very high confidence of occurring and represent the highest risks to the Solomon Islands. Whilst drought may be an issue there is limited capacity to predict future scenarios for the Solomon Islands based on current projections and it has not been considered further. In addition, future scenarios for more intense cyclones and altered wave patterns are not well established.

Table 11.2 Summary of potential effects of key climate change threats on the marine, aquatic and terrestrial ecosystems and their ecosystem services (BMT WBM, 2017b)

Key Threat	Ecosystem	Potential Impacts
Sea and air temperatures will continue to rise, with projections of up to 0.7°C by 2040 and 3.3°C by 2100	Terrestrial vegetation communities	• Changes to the composition and structure of communities (e.g. spread of insects, pathogens, herbivores and pests) • Ecological changes may impact native vegetation community responses to stressors (e.g. fire, drought, storms and erosion) and impact on fauna habitat values • Reduced crop yields in agricultural lands from increased prevalence of pests and disease • Increased heat stress on agricultural crops • Negative impacts on human health with increases in the number of hot days
	Marine ecosystems	• Alter aquatic ecological processes • Effect the distribution of aquatic species • Impact on the quality of water resources for human and agricultural use • Affect algal production and the availability of light, oxygen and carbon • Affect nitrogen fixation and denitrification in estuaries • Increased risk of coral bleaching. • Long-term ocean warming will reduce the time between coral bleaching risk events. If these occur more often than once every five years, the long-term viability of coral reef ecosystems becomes threatened (Donner, 2005)
The total annual precipitation is predicted to increase by 4% by 2040 and 23.5% by 2100. Increases are likely to be due to increased intensity of rainfall events.	Terrestrial vegetation communities	• More frequent episodes of soil saturation and associated increases in soil stability • Increased soil erosion and landslide frequency
	Freshwater ecosystems	• Changes in the frequency, duration, and timing of extreme rainfall events and long-term changes in runoff may alter hydrologic characteristics of aquatic ecosystems and affect species composition and productivity
	Marine and estuarine ecosystems	• Changes to the patterns and quality of freshwater flow to coastal and estuarine habitats • Changes to runoff will influence water residence time, nutrient delivery, vertical stratification and salinity. These properties can have significant effects on phytoplankton populations and increase the risk of eutrophication • Changes in freshwater flow and timing can also affect migration and spawning of many estuarine and marine fishery species
Sea level will continue to rise, with projected increases of 0.1 m by 2040 and 0.7 m by 2100	Sandy beaches, islands and coastal areas	• Exacerbating shoreline erosion • Inundation of low-lying coastal habitats and infrastructure • Saline intrusion of surface waters and coastal aquifers • Higher levels of sea flooding • Increased landward reach of sea waves and storm surges • Degradation of reefs following bleaching or from ocean acidification may result in increased wave energy across reef flats and exacerbated shoreline erosion with sea level rise (Sheppard *et al*., 2005). • Erosion of sandy barrier islands altering local wave conditions • Compounding impacts with increased cyclone intensity • Less severe impacts if coastal ecosystems have space and capacity to accrete vertically
Ocean acidification is projected to increase with an associated	Marine ecosystems	• Reductions in the ability of carbonate flora and fauna to calcify • Potential increased dissolution of nutrients and carbonate minerals in sediments

Key Threat	Ecosystem	Potential Impacts
decline in aragonite concentrations		• Increased concentrations of dissolved CO_2 in oceans may lead to higher rates of photosynthesis by submerged aquatic vegetation • Potential increased algae growth in lagoons and estuaries which could decrease light availability to submerged aquatic vegetation • Reduced aragonite saturation states inhibiting coral growth • Impacts on the growth of crustaceans and molluscs - subsequent fisheries industry impacts

Crucially, the way in which Solomon Island ecosystems and their services respond to the impacts of climate change will depend on the extent of ecosystem degradation from other anthropogenic pressures, the magnitude and frequency of climate change threats and the adaptive capacity of services (BMT WBM, 2017a). Each climate change threat does not exist in isolation, and instead their impacts are complicated by the feedback and interactions of other climate change stressors. For example, rainfall patterns together with sea level rise and human land use will likely be the key determinants of water quality in coastal and marine ecosystems of the Solomon Islands. Additionally, the impacts of ocean acidification on reef health will likely be compounded by other stressors such as coral bleaching, storm damage, water quality and fishing pressures.

The following section provides a vulnerability assessment to calculate exposure, sensitivity and adaptive capacity of the key socio-ecological values identified in Sections 5, 7 and 9 to the main climate changes identified for the Solomon Islands: temperature rise, more extreme rain events, sea level rise and ocean acidification.

11.3 Vulnerability of Socio-Ecological Systems to Climate Change Threats

As discussed in Section 2.7, the vulnerability of ecosystem services to climate change is defined as the degree to which a system is susceptible to the adverse effects of climate change. This susceptibility is a function of its physical exposure, sensitivity and its adaptive capacity (ability to adjust or cope) with climate change variations. This section provides a vulnerability assessment to calculate exposure, sensitivity and adaptive capacity of key ecosystem services for Nggela Islands, Savo Island and Russell Islands to key climate change threats. Whilst the list of key climate threats is not comprehensive, it includes those which have high to very high confidence of occurring and represent the highest risks to the Solomon Islands.

Based on the critical climate variables or threats assessed for this project, by 2040 sea level rise could potentially impact a range of ecosystem services essential to the communities of Central Province. While sea level rise will continue to impact on coastal ecosystem services to 2100 and beyond, the projected magnitude of temperature increase for both air and seas are likely to become the dominant climate change threat to the largest proportion of Central Province’s ecosystem services. Coral reefs and their services will be highly vulnerable to projected ocean acidification levels by 2100, which may also be exacerbated by sea temperature rises of up to 3.2°C.

11.3.1 Air and Sea Temperatures

As discussed in the Solomon Islands National ESRAM Assessment, and demonstrated by the recent AR6 projections (Table 11.1), surface air temperatures in the Pacific are very closely related to sea surface temperatures (BMT WBM, 2017a). As shown in Table 11.1, the increase in maximum air temperatures is also consistent with the increase in mean air temperature.

The ecosystems across Central Province considered to be most vulnerable to the projected 2040 increase in air and sea temperature (0.7°C) are marine ecosystems. This is primarily due to the increased risk of coral bleaching and its associated impacts on inshore reefs. The abundance of inshore reefs, offshore reefs and marine lagoons within Nggela Islands and Russell Islands makes these island groups more vulnerable to this climate change threat than Savo Island (which does not have any coral reefs). Subsequently, the communities on Nggela Islands and Russell Islands have a higher reliance on marine resources for food security and income generation. These communities are therefore more likely to be adversely impacted by coral bleaching events than Savo Island communities.

By 2100, however, the projected increase in air and sea temperatures by over 3°C poses a greater potential climate change risk to a broad range of ecosystem services. Reefs, marine lagoons and the marine open water will have increasing sensitivity to projected temperatures in 2100 and may have low adaptive capacity in the context of other 2100 climate change threats (compounding threats) such as ocean acidification. In 2100, the ecosystem services upon which the people of Nggela Islands and Russell Islands heavily depend may be highly vulnerable to temperature rise. These include, food provisioning (e.g. fish, crustaceans, clams etc), along with raw material provisioning (e.g. coral rock, lime and sand), biodiversity, coastal protection, and income generation (commercial sale of resources). Notably, the adaptive capacity of Russell Island marine ecosystems could be increased if the current trend of establishing LMMAs and MPAs continues. These LMMAs and MPAs remove an additional stressor to marine ecosystems by eliminating the anthropogenic stressor of overfishing. Savo Island communities will also be impacted by 2100, however, villages typically rely less on marine resources for food provision and income generation than resources from other ecosystems. Given the magnitude of temperature change, all other ecosystem services are expected to demonstrate high adaptive capacity.

Mangrove ecosystem services are predicted to be moderately to highly vulnerable to the projected temperature changes by 2100. 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 have higher sensitivities and lower adaptive capacities to water quality, which may be affected by temperature rise (linked with toxic absorption, salinity and dissolved oxygen) (BMT WBM, 2017a). Intertidal fauna (such as mangrove shells) may also be vulnerable to increased temperature during prolonged periods of low tide resulting in desiccation and spoiling (BMT WBM, 2017a). Communities on Nggela and Russell Islands will be more adversely impacted by these threats due to their higher reliance on mangrove resources. Disruption to mangrove ecosystem services by higher temperatures will not affect communities on Savo Island, which does not support mangrove ecosystems.

Habitat and biodiversity services provided by freshwater ecosystems are predicted to be vulnerable to the projected temperature change by 2100 due to their high sensitivity and low adaptive capacity to poor water quality, which may be affected by temperature rise (BMT WBM, 2017a). Similarly, terrestrial ecosystems are expected to become more affected by air temperature changes by 2100, with plantations and subsistence gardens in particular likely to become more vulnerable. Such ecosystems may experience decreases in crop yield, reductions in soil cohesion and stability, and an increased exposure to pests and disease (BMT WBM, 2017a). The vulnerability of both freshwater and terrestrial ecosystems would increase during prolonged dry periods (i.e. drought) (BMT WBM, 2017a). Communities which primarily rely on terrestrial and freshwater ecosystems across Central Province are therefore most likely to be impacted by disruptions to habitat and biodiversity services within these ecosystems. These include Gumu (Nggela Islands), Panueli (Savo Island), and Marulaon and Karumulun (Russell Islands).

11.3.2 Rainfall

Given the relatively intact forest, river banks and riparian areas of the three island groups, increases in total annual precipitation of 4% by 2040 are not predicted to be a high climate change threat to the ecosystem services of Central Province, particularly when attributed to extreme rainfall events in isolation. However, increases in total annual precipitation by up to 23.5% by 2100 could present a high climate change threat for communities which rely heavily on access to freshwater streams for drinking water (e.g. Gumu and Soka, Nggela Islands). For these communities, extreme wet periods cause flooding which makes the river/stream waters inaccessible and unsafe for drinking. The adaptive capacity of these communities is constrained by their ability to transition to other drinking water sources (e.g. receiving funding for more rainwater tanks). Increases in total annual precipitation are unlikely to significantly affect mangrove ecosystems, however, when these increases come in the form of extreme events (such as cyclones), their adaptive capacity to other climate change threats could become reduced due to damage.

Food provisioning services of cultivated land (i.e. plantations and gardens) are also likely to be highly vulnerable to larger increases in total precipitation and more extreme rainfall events by 2100. This is 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 (BMT WBM, 2017a).

11.3.3 Sea Level Rise

As sea levels continue to increase around the islands in Central Province, the vulnerability of ecosystems and their critical services to climate change also increase. By 2100, projected sea level rise potentially presents a very high threat to not only Central Province's ecosystem services, but the built settlements of its communities. At an ecosystem level, those which are potentially the most vulnerable to sea level rise increases from 2040 to 2100 and beyond are: fresh groundwater, freshwater swamps, sandy beaches and islands. Fresh groundwater ecosystems and services, including wells, surface expressions and springs, all have low adaptive capacity to saline intrusion (BMT WBM, 2017a). Groundwater is a vital ecosystem for communities within Central Province, with most communities relying on it as their primary source of water for uses such as cooking and bathing. Depending on groundwater connectivity, aquifer dimensions and local hydrological regimes, the risk of saline intrusion may impact groundwater sources much further inland.

The vulnerability of freshwater swamps to sea level rise is also high due to low adaptive capacity and high sensitivity to saltwater intrusion (BMT WBM, 2017a). Freshwater wetland ecosystem services which may be highly vulnerable to sea level rise are the provisioning of house materials (sago leaves) and food sources, including backup/emergency food provisions (e.g. swamp taro). Extreme events, such as drought and increased cyclone intensity may increase in the future (low confidence), adding more pressure on these essential services.

Rising sea levels of approximately 0.7 m by 2100 are expected to increase the vulnerability of ecosystem services by sandy beaches, islands and coastal areas. Ecosystem services most vulnerable to are the provision of land by sand islands (exemplified in the case of Karumulun) and the provision of sanitation areas. In the case of Savo Island, the ecosystem service most vulnerable to rising sea levels is provision of megapode laying fields by the sandy beach. The megapode fields have a high vulnerability to sea level rise due to their high physical exposure (location very close to the sea) and low adaptive capacity (very limited ability to relocate). The high vulnerability of the megapode fields to sea level rise results in subsequent high vulnerability for the people of Savo Island, who rely on sale of the megapode eggs as their primary source of income, as well as a key source of protein.

Mangroves are likely to be less vulnerable to rising sea levels due to their high adaptive capacity tomigrate landwards (BMT WBM, 2017a). However, increasing populations and subsequent expansion of built settlements adjacent to existing mangroves may pose a future threat by restricting the capacity of mangroves to migrate up shore.

While built settlements do not constitute ecosystem types, in the context of socio-ecological systems, it is important to note the vulnerability of communities themselves to rising sea levels. Many of the communities throughout Central Province are already observing rising sea levels, with the 0.7 m predicted increases by 2100 likely to have severe impacts on the ability of communities to function. Of particular concern are the communities of Soka, Toa, Vuranimala, Haleta, and Karumulun, which could see significant portions of their villages permanently inundated by 2100.

11.3.4 Ocean Acidification

Reefs are a prominent feature of the local marine environment surrounding Nggela and Russell Islands. Reefs and their dependant ecosystem services are vulnerable to ocean acidification (BMT WBM, 2017). Aragonite, a metastable form of calcium carbonate, is used by reef building corals and shell fish to build skeletons and hard shells (CSIRO, 2014). As oceans acidify the carbonate ion concentration in seawater decreases, making it harder for corals to grow (BMT WBM, 2017). For corals, aragonite 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).

Based on the projections, aragonite concentrations are likely to continue to decline until 2100 and beyond, at which point they may decline to values where coral reefs have not historically been found (< 3.0). High-latitude regions are the most vulnerable to these declines due to their naturally lower mean values (Bindoff *et al.*, 2019). The Equatorial and Eastern Pacific is therefore likely to become a hotspot of undersaturated aragonite conditions, and therefore lower concentrations. 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 Nggela and Russell Islands reef ecosystems are highly vulnerable to ocean acidification. Based on current projections, critical services considered highly vulnerable by 2100, 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 and clams at markets); 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). The impact of acidification on the health of reef and marine ecosystems for Nggela and Russell Islands is likely to be compounded by other stressors including coral bleaching, storm damage, water quality and overharvesting pressure and will be an important adaptive challenge.

11.3.5 Summary Socio-Ecological Systems Vulnerability

Based on the vulnerability assessment to climate threats, several ecosystem services of Nggela Islands (Table 11.3), Savo Island (Table 11.4) and Russell Islands (Table 11.5) are predicted to have high to very high vulnerability to climate change for both 2040 and 2100. Climate variables are shaded either green, yellow or red (corresponding to low, medium or high) to describe the severity of expected climate change threats on social and ecological systems.

Given that Nggela Islands communities are heavily dependent on the coast (with the exception of Gumu), based on the results of this vulnerability assessment, the key climate change threat to Nggela Islands ecosystems and their services for 2040 is sea level rise. Many of the ecosystem services vulnerable to this threat are critical provisioning services related to water supply (groundwater wells); food provisioning (crabs); raw material provisioning (building materials from beaches) and loss of sanitation area.

As illustrated in Table 11.3, many ecosystem services are predicted to be highly vulnerable to 2100 climate threats. The predicted 2100 air and sea temperature increases of 3.3°C, the rising sea levels of 0.7 m, 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 2100. The provision of freshwater from rivers and streams is likely to be highly vulnerable to increases in rainfall extremes, with flooding rendering the waterways inaccessible and unsafe for water provision to communities. For sandy beaches, islands and coastal areas already vulnerable to sea level rise in 2040, these threats will be exacerbated into 2100.

In the case of Savo Island, based on the results of this vulnerability assessment, the key climate change threat for 2040 is sea level rise due to its high threat to the megapode fields. The ecosystem services of the megapode fields vulnerable to this threat are critical provisioning services such as food provisioning (megapode eggs main source of protein and a large component of diet) and income generation (selling megapode eggs as one of the primary source of income).

As illustrated in Table 11.4, by 2100, the megapode fields are predicted to be highly vulnerable to a sea level rise of 0.7 m as existing threats are exacerbated. The predicted 2100 air and sea temperature increases of 3.3°C present moderate threats to marine resources (due to lower community reliance) and significant threats to garden/plantation resources (due to higher community reliance). Food provisioning services by crops are likely to be highly vulnerable to an increase in extreme rainfall events by 2100. Key ecosystem services provided by sandy beaches and coastal areas will also become highly vulnerable to sea level rise threats (0.7 m).

Finally, for the Russell Islands, based on the results of this vulnerability assessment, the key climate change threat for 2040 is sea level rise. Many of the ecosystem services vulnerable to this threat are critical provisioning services related to water supply (groundwater wells); food provisioning (freshwater swamps); raw material provisioning (building materials from beaches) and loss of sanitation area.

As illustrated in Table 11.5 many ecosystem services are predicted to be highly vulnerable to 2100 climate threats. The predicted 2100 air and sea temperature increases of 3.3°C, the rising sea levels of 0.7 m, 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 2100. Yields of coconut plantations are also likely to be highly vulnerable to increases in air temperature and extreme rainfall. This is a significant concern for the Russell Island communities who heavily rely on the sale of copra as a primary source of income. For sandy beaches, islands and coastal areas already vulnerable to sea level rise in 2040, these threats will be exacerbated into 2100.

The ecosystem services considered most vulnerable across Central Province are summarised below with the associated critical climate change threat:

- Food provision services, provided by reefs (vulnerable to rising temperatures, coral bleaching and ocean acidification), freshwater swamps (vulnerable to saltwater intrusion from sea level rise), cultivated gardens and plantations (vulnerable to extreme rainfall events causing soil erosion and waterlogged soils of cultivated land, as well as large increases in air temperature) and sandy beaches (vulnerable to sea level rise)
- Food provision services, as well as income generation, provided by megapode fields on Savo Island (vulnerable to sea level rise)
- Biodiversity, provided by reefs (vulnerable to coral bleaching due to rising temperatures and coral dieback associated with ocean acidification)
- Raw materials, provided by reefs (vulnerable to coral dieback associated with ocean acidification and coral bleaching) and freshwater swamps (vulnerable to saline intrusion by sea level rise)
- Water provisioning services from freshwater streams and groundwater wells (vulnerable to increases in extreme rainfall and saline intrusion by sea level rise respectively)

Table 11.3 Vulnerability of Ecosystem Services – Nggela Islands

Ecosystem	Ecosystem Service	2040*	2100				
		Sea Level Rise	Sea Level Rise	Increased Sea Temp	Increased Air Temp	Extreme Rainfall	Ocean Acidification
Terrestrial Forest	Food source				✓	✓	
	Raw materials (e.g. timber) and fuel				✓	✓	
	Timber export (income source)				✓	✓	
	Fresh water filtration				✓	✓	
	Biodiversity				✓	✓	
	Fresh groundwater replenishment				✓	✓	
	Medicine				✓	✓	
	Land for gardening		✓		✓	✓	
Freshwater swamp (wild taro area)	Food source – swamp taro, kangkung, mushrooms	✓	✓		✓	✓	
	Biodiversity	✓	✓		✓		
	Raw materials (e.g. sago)	✓	✓				
	Water quality and flood flow regulation	✓	✓			✓	
Mangroves	Raw materials (e.g. timber) and fuel		✓				
	Food source			✓			✓
	Biodiversity (e.g. fish breeding area)			✓			✓
	Coastline protection		✓				
	Carbon sequestration		✓	✓			✓

Ecosystem	Ecosystem Service	2040*	2100				
		Sea Level Rise	Sea Level Rise	Increased Sea Temp	Increased Air Temp	Extreme Rainfall	Ocean Acidification
Reefs	Fishing grounds and food provision			✓	✓		✓
	Income and revenue source			✓	✓		✓
	Raw materials (e.g. coral rock) and lime extraction			✓	✓		✓
	Habitat provision / biodiversity			✓	✓		✓
	Cultural values (shells etc.)			✓	✓		✓
	Seaweed and beche de mer (when not banned)			✓	✓		✓
	Coastal protection	✓	✓	✓	✓	✓	✓
	Recreation and leisure		✓	✓	✓		✓
	Supports marine food chain			✓	✓		✓
	Supports tourism industry			✓	✓	✓	✓
Rivers, streams, groundwater	Water source (drinking and domestic)				✓	✓	
	Water supply (irrigation)				✓	✓	
	Food provision				✓	✓	
	Biodiversity (e.g. fish breeding ground)				✓	✓	
	Supports aquaculture and fisheries				✓	✓	
Sandy beaches, islands and coastal areas	Sanitation area	✓	✓				
	Groundwater springs	✓	✓				
	Food and income source - crabs	✓	✓		✓		

Ecosystem	Ecosystem Service	2040*	2100				
		Sea Level Rise	Sea Level Rise	Increased Sea Temp	Increased Air Temp	Extreme Rainfall	Ocean Acidification
	Building materials	✓	✓				
	Land source (for housing, transport etc.)	✓	✓				
Gardens	Food source				✓	✓	
	Income and revenue source				✓	✓	
Plantations	Food source				✓	✓	
	Income and revenue source				✓	✓	
	Raw materials (e.g. sago)				✓	✓	
Marine (other)	Food provision			✓	✓		✓
	Income and revenue source			✓	✓		✓
	Habitat provision / biodiversity			✓	✓		✓
	Climate and atmospheric regulation			✓	✓		✓

* Based on the 2040 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 temperature, ocean acidification and an increase in extreme rainfall events.

Table 11.4 Vulnerability of Ecosystem Services – Savo Island

Ecosystem	Ecosystem Service	2040*	2100				
		Sea Level Rise	Sea Level Rise	Increased Sea Temp	Increased Air Temp	Extreme Rainfall	Ocean Acidification
Megapode field	Cultural significance	✓	✓				
	Food and income source. Money to improve living standards.	✓	✓	✓	✓		
	Adjacent forest important for bird rest and roost				✓	✓	
	Solving community issues – *social value*	✓	✓				
Sandy beaches, islands and coastal areas	Sanitation area	✓	✓				
	Building materials (inc. income source)	✓	✓				
	Recreation	✓	✓				
	Copra drying area	✓	✓				
	Land source (for housing, transport etc.)	✓	✓				
Gardens	Food source				✓	✓	
	Income and revenue source				✓	✓	
Plantation	Food source				✓	✓	
	Income and revenue source				✓	✓	
	Sanitation				✓		
Marine	Food source			✓	✓		✓
	Income and revenue source			✓	✓		✓
	Habitat for marine species			✓	✓		✓

Ecosystem	Ecosystem Service	2040*	2100				
		Sea Level Rise	Sea Level Rise	Increased Sea Temp	Increased Air Temp	Extreme Rainfall	Ocean Acidification
	Climate and atmospheric regulation			✓	✓		✓

* Based on the 2040 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 temperature, ocean acidification and an increase in extreme rainfall events.

Table 11.5 Vulnerability of Ecosystem Services – Russell Islands

Ecosystem	Ecosystem Service	2040*	2100				
		Sea Level Rise	Sea Level Rise	Increased Sea Temp	Increased Air Temp	Extreme Rainfall	Ocean Acidification
Terrestrial Forest	Food source				✓	✓	
	Raw materials (e.g. timber) and fuel				✓	✓	
	Income source (timber milling)				✓	✓	
	Fresh water filtration				✓	✓	
	Biodiversity				✓	✓	
	Fresh groundwater replenishment				✓	✓	
	Medicine				✓	✓	
	Land for gardening / plantation		✓		✓	✓	
Freshwater swamp / river / groundwater	Food source	✓	✓		✓	✓	
	Income source	✓	✓				
	Water source (inc. emergency drinking)	✓	✓			✓	
	Raw materials (e.g. sago and sticks)	✓	✓				
	Biodiversity	✓	✓		✓		
	Water quality and flood flow regulation	✓	✓			✓	
Mangroves	Food source			✓			✓
	Biodiversity (e.g. breeding area)			✓			✓
	Carbon sequestration		✓	✓			✓
	Coastline protection		✓				

Ecosystem	Ecosystem Service	2040*	2100				
		Sea Level Rise	Sea Level Rise	Increased Sea Temp	Increased Air Temp	Extreme Rainfall	Ocean Acidification
	Raw materials		✓				
Reefs	Food provision			✓	✓		✓
	Income and revenue source			✓	✓		✓
	Raw materials (e.g. coral rock) and lime extraction			✓	✓		✓
	Habitat provision / biodiversity			✓	✓		✓
	Cultural values (shells etc.)			✓	✓		✓
	Coastal protection	✓	✓	✓	✓	✓	✓
	Recreation and leisure		✓	✓	✓		✓
	Supports marine food chain			✓	✓		✓
	Supports tourism industry			✓	✓	✓	✓
Sandy beaches / coastal areas	Sanitation area	✓	✓				
	Gravel and sand for building materials	✓	✓				
	Land source (for housing, transport etc.)	✓	✓				
Gardens	Food provision				✓	✓	
	Income and revenue source				✓	✓	
Plantation	Income and revenue source				✓	✓	
	Food source				✓	✓	
	Raw materials				✓	✓	

Ecosystem	Ecosystem Service	2040*	2100				
		Sea Level Rise	Sea Level Rise	Increased Sea Temp	Increased Air Temp	Extreme Rainfall	Ocean Acidification
Marine (other)	Food source			✓	✓		✓
	Income and revenue source			✓	✓		✓
	Habitat provisions / biodiversity			✓			✓
	Climate and atmospheric regulation			✓	✓		✓

* Based on the 2040 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 temperature, ocean acidification and an increase in extreme rainfall events.

12 ESRAM Outcomes

Central Province communities are heavily reliant on ecosystem services for their health and well-being and livelihoods. However, the vulnerability of Central Province's social and ecological systems to human threats such as the over-exploitation of resources are likely to be increasing. The growing population will place further pressure on ecosystem services, while shifts away from traditional regulatory systems and a loss of respect for cultural traditions will significantly increase the vulnerability of ecosystems and communities. The direct and indirect impacts of climate change, specifically sea level rise, acute and chronic coastal erosion 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 both people and ecosystems.

The following section provides a summary of the vulnerabilities of ecosystem services to climate and non-climate related threats and their impact on the resilience of Central Province's ecosystems and communities. The ESRAM outcomes are presented in three broad ecosystem types: freshwater (rivers, streams, swamps and groundwater), coastal and marine (mangroves, reefs, sandy beaches and islands, megapode field and marine waters) and terrestrial (forests, gardens and plantations). Outcomes are also summarised in Table 12.1.

12.1 Resilience of Ecosystem Services to Human Induced and Climate Change Impacts

12.1.1 Freshwater Ecosystems and Services

Freshwater ecosystems provide important ecosystem services to Central Province, particularly during times when essential services relied upon daily by residents are limited e.g. water supply by groundwater wells and spring-fed streams during prolonged dry periods, and food and habitat provision by swamps which provide swamp taro utilised during food shortages. Additionally, streams and rivers which support freshwater fauna are used to either supplement marine derived protein (as in most Nggela and Russell Island communities) or as the primary protein source (in the case of Gumu). The exception to this is Savo Island, where seasonal streams are occasionally used for domestic water use only, since volcanic activity dries up the streams. Existing non-climate threats to freshwater ecosystems include, modified river and creek banks and altered riparian vegetation from stream side gardens, contamination of rivers and streams by chemicals (such as those used to treat mosquito nets), and increased sedimentation and contamination by illegal logging companies.

Projected impacts 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 freshwater swamps are likely to be vulnerable to sea level rise by 2040. More extreme wet/dry seasonal cycles (i.e. from more extreme rainfall events combined with increased temperatures) present a significant threat to the water provisioning services of rivers and streams, as well as food provisioning services of freshwater swamps. More frequent flooding as a result of more extreme rainfall events will affect the accessibility and quality of fresh water for communities on Nggela, while hotter dry seasons may dry up freshwater swamps. Freshwater ecosystem services likely to be highly vulnerable to human induced threats and sea level rise are the provision of drinking and domestic water supply by rivers, streams and groundwater wells, biodiversity and habitat supported by freshwater swamps, and food security and raw material provisions by freshwater swamps (swamp taro and sago).

Saltwater intrusion of groundwater wells is likely to be a critical issue for communities where wells are located in close proximity to the coast (e.g. Vuranimala, Soka, Panueli and Karumulun). At all four of these communities, groundwater is used as the primary source of domestic water and (in some cases) secondary source of drinking water (typically second to either rainwater tanks or rivers/streams). Of the eight focus communities, five relied on rainwater tanks as the primary source of drinking water (Toa, Haleta, Panueli, Marulaon and Karumulun). The heavy dependence on rainwater tanks, and groundwater wells which are currently vulnerable to climate threats (i.e. more extreme wet/dry cycles and sea level rise), are likely to force communities to seek alternative means in sourcing drinking water for their survival. Potential options may include installing larger (and more) rainwater tanks and improving rainwater harvesting systems (collection, storage and distribution of rainwater from roofs), as well as investigating additional wells and springs throughout the island. Three of the five communities relied on freshwater rivers/streams as their primary source of drinking water (Soka, Gumu and Vuranimala). These systems are vulnerable to potential shifts in wet/dry cycles under climate change, with more extreme rainfall (and overall increases in rainfall totals) potentially increasing the frequency of flooding and reducing the availability of safe drinking water for reliant communities. Potential adaptation options are similar to above and could include diversifying drinking water supply through either rainwater tank installation or investigation of more groundwater wells.

Based on their current condition, rivers and streams are likely to be resilient to the projected impacts of climate change due to the relatively intact terrestrial forests and minimal clearing of stream banks. However, some communities have already observed reductions in streamflow from adjacent vegetation clearing. To sustain this key resilience feature, particularly with an increasing population across all island groups, sustainable clearing practices must be implemented across the province (especially for Nggela Islands) and practices such as clearing on steep slopes and riparian areas 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 rainfall and associated run-off.

The increased sedimentation and contamination of rivers and streams by illegal logging activities was identified as a critical issue on Nggela Islands, particularly for the communities of Gumu and Haleta, which are located near areas where illegal logging is known to occur. The waters of the Mbetitina and Nggumu rivers are crucial for Gumu's resilience to future human and climate threats, with the community having limited alternative water sources available (the project team identified a small number of rainwater tanks and did not observe any groundwater wells in the vicinity of the village). The Central Province government have already taken steps to reduce the adverse impacts of logging on local ecosystems by refusing to grant new business licenses since 2019, however, illegal logging in the northern parts of Nggela Islands persists. Compliance with licenses needs to be enforced more strongly by the Central Province government (either with National or International support) to reduce the prevalence of illegal logging in Nggela.

The existing 'back-up' services provided by freshwater ecosystems during current food and water supply shortages are critical for building resilience across all island groups to both future climate and non-climate change impacts. Forward planning for cultivation in freshwater swamps will need to accommodate both the growing population and lengthy yield times (approximately 10 years for swamp taro) to ensure future yield amounts are sufficient. To continue the provision of food and water security services with the projected increase in temperature and rainfall, and overall frequency of natural hazards, while sustaining a growing population, effective management practices must be introduced to protect and enhance these ecosystems services.

12.1.2 Coastal and Marine Ecosystems and Services

Coastal and marine resources play a critical role in sustaining the well-being and livelihood of Central Province residents, particularly across Nggela and Russell Islands. Fishing is the primary source of income for many communities along the Nggela coastline due to their proximity to Honiara and Tulagi markets. Fishing also presents a significant source of income for communities in Russell Islands, while Savo Island residents primarily harvest marine resources for subsistence purposes only. Marine resources therefore supply daily protein and nutrients, generate cash income, provide building materials, protect communities and the coastline from natural hazards and extreme weather events, and provide cultural services.

The current condition of the marine environment surrounding Central Province is mixed. It has been suggested by both the literature (MFMR/WorldFish, 2022; Sulu, 2010; Tafea and Babeu, 2007) and recent surveys (courtesy of WCS) that the in-shore marine areas and associated reefs around Nggela Islands are in poor health. However, for more detailed results on the condition of Nggela reefs refer to the forthcoming WCS Biological Survey report. This is widely attributed to a combination of overharvesting and use of destructive fishing techniques, which have been used to fulfil growing market demands for inshore fisheries resources (e.g. dynamite fishing). The current condition of the marine environment surrounding Savo Island and Russell Islands is unknown, however, similar threatening processes such as unsustainable harvesting of marine resources, and the direct physical destruction of coral reefs from the collection of coral products, is likely to be reducing the health of coral reefs and marine offshore areas. Several anecdotal indications suggest that unsustainable harvesting of marine resources is occurring across all islands in Central Province. Verbal reports by local residents at all eight communities which indicate the reduction in resource abundance include: a reduced abundance of reef fish, residents forced to fish further away from villages (i.e. offshore fishing) and a reduced abundance of bigger fish. As the population continues to grow across all three island groups, these threats will increase.

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. Fishermen from neighbouring provinces which visit the in- and off-shore waters of Russell and Nggela Islands are also likely contributing to overharvesting and physical destruction of coral reefs (from destructive fishing techniques). Impacts to biodiversity can have implications on the stability and resilience of marine ecosystems that enables them to maintain functionality over a range of environmental conditions, and thus providing resilience to a changing climate (BMT WBM, 2017b). 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. Some communities are already taking important steps to managing resources sustainably, with Marulaon and Karumulun routinely implementing temporary harvesting bans to allow specific resources to recover. The two Russell Islands communities also have a complex network of MMAs and MPAs which have been developed to protect ecosystems and conserve resources.

In addition to overharvesting, the community on Savo Island (Panueli) recognised that poor waste management and sanitation practices are beginning to have effects on the surrounding marine environment. Two communities (Soka and Panueli) also noted that the large volume of plastic and other pollution (due to the close proximity to Honiara) entering the inshore marine environment, is concerning for marine fauna. Solid waste and human and animal waste impact on multiple components of the coastal and marine ecosystem including water quality, sediment quality, and the structure, composition and condition of flora and fauna communities. Other key non-climate threats identified by communities included sedimentation from illegal logging activities (Gumu and Haleta) and oil spills (Haleta).

The compounding threats of climate change will exacerbate these human induced impacts. Marine ecosystems are likely to be highly vulnerable to the projected temperature increase due to coral reefs having high sensitivity and low capacity to adapt to changes in sea temperature (BMT WBM, 2017b). The projected 3.3°C increase in sea temperature by 2100, coupled with coral bleaching, overexploitation and pollution, is likely to result in most provisioning ecosystem services of coral reefs and open waters becoming highly vulnerable to these changes. These services include: food and trade provision (supplying daily protein and micronutrients through fish, molluscs, crustaceans), habitat (essential feeding, breeding, spawning, cleaning and aggregation habitat) and biodiversity, income generation (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 2100 and beyond. The impact of acidification on the health of reef and marine ecosystems is likely to be compounded by other stressors including coral bleaching, storm damage, water quality and increased fishing pressure driven by population growth (BMT WBM, 2017b). The people of Central Province (particularly in Nggela and Russell Islands) are likely to be required to adapt to alternative ecosystems for provisional services by 2100.

Coastal erosion on beaches and sand islands from the combined impacts of coastal hazards (storm surges, extreme/king tides etc.) and rising sea levels is also a critical issue for many Central Province communities (all except for Gumu). Nggela coastlines are dominated by white coral beaches, with all communities (except Gumu) having a strip of sandy beach adjacent to built settlement areas (i.e. separating the settlements from the sea). Narrow sandy beaches also surround the entirety of Savo Island, while mixed sand/gravel beaches are present along the southern coastlines of Marulaon and Karumulun Islands (Russell Islands). Sandy beaches are most highly valued by the communities as a source of food and income via seasonal crab harvests (‘crab areas’), sanitation areas (due to close proximity to villages), open spaces for copra drying and a source of sand and gravel (i.e. coral rubble) for building materials.

Land availability provided by beaches and sand islands is decreasing across Central Province as a result of acute and chronic coastal erosion which is likely to have been exacerbated by the removal of shoreline vegetation and the modification of shorelines to make space for settlements. Karumulun is already experiencing the effects of sea level rise, with large portions of the island already washed away and destroyed over the years. Projected sea level increases of 0.7m by 2100 present a critical threat to communities like Karumulun which have very little available land capital and low elevations (equating to a very low adaptive capacity). One resident from Karumulun noted that “when we have high tides, the water bubbles up through the crab holes in the ground”. Soka, Toa, Vuranimala, Haleta, Marulaon and Karumulun are all highly vulnerable to projected sea level rise due to their low elevations and proximity to the coast. In Marulaon, rising sea levels and associated chronic coastal erosion have started impacting the burial ground, with many graves close to being washed into the sea. For sandy beaches, islands and coastal areas already vulnerable to sea level rise in 2040, threats will be exacerbated into 2100.

Coastal erosion on beaches and sand islands from various coastal hazards (storm surges, extreme/king tides etc) combined with rising sea levels is also impacting on Savo Island’s megapode laying fields. Savo Island does not have any coral reefs and is particularly exposed to the high wave energies of the open ocean. As a result, the beaches on the island undergo severe erosion. The laying fields are located on the warm sands of Savo Island’s northern coastline (warmed by a nearby subsea volcano). The close proximity of the fields to the coastline and lack of ability for them to move or migrate elsewhere, combined with the adjacent high wave energies, makes the fields very vulnerable to sea level rise and coastal erosion. The megapode fields provide crucial ecosystem services for Savo Island, including food provision (eggs are the primary source of protein), income generation (selling the eggs at market is a main source of income) and cultural services. Climate change will act as a compounding threat to existing overharvesting pressures on megapode populations, particularly in the face of population growth. If megapode eggs are no longer able to be used as an income source, alternative income sources will be required which could potentially exacerbate existing unsustainable harvesting of marine resources. The services provided by megapode fields year-round are therefore critical for building resilience across Savo Island to both future climate and non-climate change impacts.

Mangrove forests are currently abundant along rivers and coastlines in Nggela and Russell Islands and appear to be in good condition. However, concentrated clearing for the provision of building materials and fuel without replanting 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 associated village expansion.

The projected increase in sea temperature and the impacts of ocean acidification by 2100 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 (BMT WBM, 2017b). 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 hazards such as tsunamis and tropical cyclones, as well as from coastal erosion. The sustainable management of mangroves will also continue to provide essential habitat to intertidal fauna communities, in turn contributing to food security for Nggela and Russell Island residents.

Marine ecosystems are arguably the most vital ecosystem to the people of Nggela Islands (followed closely by Russell and Savo Islands); however, they are likely to be the most vulnerable to both human and climate induced impacts. Increasing population growth and overharvesting of marine resources will continue to push the local marine ecosystem threshold to the point where resources may become exhausted. In terms of economic valuations, the value of fisheries is estimated to be USD $6,880 (2024) and SBD $57,680 (2024) per person each year (Albert *et al.*, 2015). Based on the estimated population of Central Province (30,326), total fisheries are valued at USD $208,642,880 (2024) and SBD $1,749,203,680 (2024) per annum. The heavy reliance on marine resources for community function and livelihoods within Central Province, coupled with the high economic value of fisheries, strongly highlights the need for sustainable harvesting of marine resources and protection and effective management of marine ecosystems.

12.1.3 Terrestrial Ecosystems and Services

Terrestrial forests of Central Province 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 (hunting), medicine, 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 overharvesting (either for timber harvest or clearing land for gardens). 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.

Gardens and plantations are essential for food provision and income generation among all eight focus communities. Gardens provide the staple vegetation and fruit crops (e.g. sweet potato, cassava and taro) while plantations provide tree crops (e.g. coconut, betel nut and sago) that are highly versatile and are heavily relied upon by the communities. On Nggela, it is common for fishermen to engage in subsistence gardening as an additional livelihood activity (Sulu, 2010). As a result, selling gardening produce at the markets is also a large component of income for many communities, particularly those situated on rivers. For example, selling garden and plantation produce is Gumu's main source of income, with the community being one of the primary suppliers of produce to Tulagi market. Panueli are also highly reliant on the sale of produce, which is the primary source of income alongside selling megapode eggs. Russell Island communities are especially reliant on plantations for income generation, with the island group' extensive history of coconut plantations leaving a lasting legacy. Coconut plantations dominate most of the islands within the Russell group and the selling of copra remains many communities' primary source of income (e.g. Marulaon). Key non-climate threats to both gardens and plantations are: unsustainable harvesting (e.g. tall trees for building purposes and cutting of young coconuts) which undermines plant health, stability and yield; destruction by pests (e.g. African Snail in Savo Island); encroachment from expanding villages from an increasing population, excessive weed growth, theft of garden produce and illegal logging practices.

In terms of food, building and medicinal provisions, terrestrial forests and gardens are essential to the survival of Central Province residents, particularly if marine food resources (or megapode eggs) are limited, income generation is low and the population continues to increase. As a result, 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 3.3°C by 2100 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. Terrestrial forests on Nggela and Savo are likely to be more resilient to the projected increases in temperature due to their high level of intactness which sustains cooler temperatures within forest ecosystem.

The projected increase in total annual rainfall (potentially via increased extreme events) by 2100 is likely to impact on 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. These could all result in reduced crop yields across gardens and plantations. 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 Central Province'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 impacts, management measures will need to be implemented (e.g. replanting programs, allocation of protected areas, stronger enforcement of logging regulations and sustainable clearing, harvesting and cultivation practices) (BMT WBM, 2017b). 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 Central Province's food security, and providing regulating services such as climate regulation, prevention of soil erosion, primary productivity and maintaining stream water quality.

12.2 Conclusions

While Central Province is highly vulnerable to a changing climate, and is already experiencing several impacts from climate change, human induced threats may present a greater risk to the livelihoods of some local communities and ecosystem health. There are significant opportunities to improve community practices and promote the sustainable use of ecosystems to reduce environmental degradation and conserve critical ecosystem services for future generations. Findings from this ESRAM assessment indicate that the priority areas in most urgent need of support through ecosystem-based responses, in the context of sustaining ecosystems and ecosystem services, are:

- **Nggela Islands** – reefs and inshore marine areas which have been heavily impacted by destructive fishing methods and intensive overharvesting.
- **Savo Island** – megapode laying fields
- **Russell Islands** – offshore marine areas, coconut plantations, Karumulun Island, and existing MMAs and MPAs (to further strengthen these initiatives).

Table 12.1 Ecosystem and Socio-Economic Resilience Assessment Summary table

High Level Ecosystem Type	Most Vulnerable Ecosystem Services	Human and Non-Climate Stressors	Potential Climate Change Stressors	Focus Areas	Priority
Freshwater (swamps, groundwater, rivers and streams)	• Drinking water supply (rivers and streams) • Domestic water supply (groundwater) • Food and income provision by freshwater swamps (swamp taro and sago) • Food provision by rivers/streams (eels, prawns etc.) • Habitat and biodiversity (freshwater swamps) • Raw material provision by freshwater swamps (sago leaves)	• Population growth • Modified river and creek banks and altered riparian vegetation from stream side gardens • Contamination of rivers and streams by chemicals (such as those used to treat mosquito nets) • Increased sedimentation and contamination by illegal logging companies	• Saltwater intrusion of groundwater wells and freshwater swamps from sea level rise • Increases in rainfall (particularly more extreme rainfall events) increasing frequency of flooding • Increases temperatures drying out freshwater swamps	Swamps: Nggela Islands Groundwater: Vuranimala, Soka, Panueli and Karumulun Rivers/streams: Soka, Gumu and Vuranimala	**High**
Coastal and Marine (mangroves, reefs, marine waters, sandy beaches and islands)	• Provision of food, trade and income generation from local fisheries (fish, molluscs, crustaceans etc) provided by reefs, marine waters, mangroves and beaches • Provision of habitat and biodiversity provided by reefs, marine waters and mangroves • Provision of income generation (sale of megapode eggs) provided by sandy beaches on Savo Island	• Population growth • Depletion of marine resources and loss of biodiversity from unsustainable harvesting • Destructive fishing methods • Physical destruction of coral reefs for the collection of coral products.	• 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) • Shift in marine ecosystem structure due to rise in sea temperature • Altered capacity for oceans to regulate climate	Mangroves: Nggela and Russell Islands Reefs: Nggela Islands (Soka, Toa, Haleta, Vuranimala) Marine waters: Nggela Islands	**Very High**

High Level Ecosystem Type	Most Vulnerable Ecosystem Services	Human and Non-Climate Stressors	Potential Climate Change Stressors	Focus Areas	Priority
	• Provision of raw materials (coral rock and lime production) provided by reefs • Coastal hazard protection by the attenuation and buffering of wave and storm energy by reefs	• Pollution from poor sanitation and waste management • Clearing of coastal vegetation	from increased sea temperatures • Acute coastal erosion of sand islands and beaches from coastal hazard events (exacerbated by sea level rise) • Chronic coastal erosion from sea level rise • Permanent inundation of sand islands	and Russell Islands Sandy beaches: Panueli megapode fields and Karumulun	
Terrestrial (forests, plantation and gardens)	• Habitat and biodiversity • Provision of food provided by terrestrial forests, gardens and plantations • Generation of income from the sale of produce/products from terrestrial forests, gardens and plantations • Provision of raw materials (timber, fuelwood and building materials) provided by terrestrial forests and plantations	• Population growth • Land clearing and overharvesting for timber (including by illegal logging practices) • Unsustainable harvesting of gardens and plantations • Destruction of gardens and plantations by pests and diseases (e.g. African Snail) • Excessive weed growth in gardens and plantations • Encroachment from expanding villages • Theft of garden produce	• Soil erosion, sedimentation and landslip from extreme rainfall events. • Reduction in crop yield and soil cohesion and stability, and an increase in invasive species due to increase in temperature	Forests: Gumu and Haleta (near illegal logging) Plantations: Marulaon and Gumu Gardens: Panueli and Gumu (high reliance)	**Moderate**

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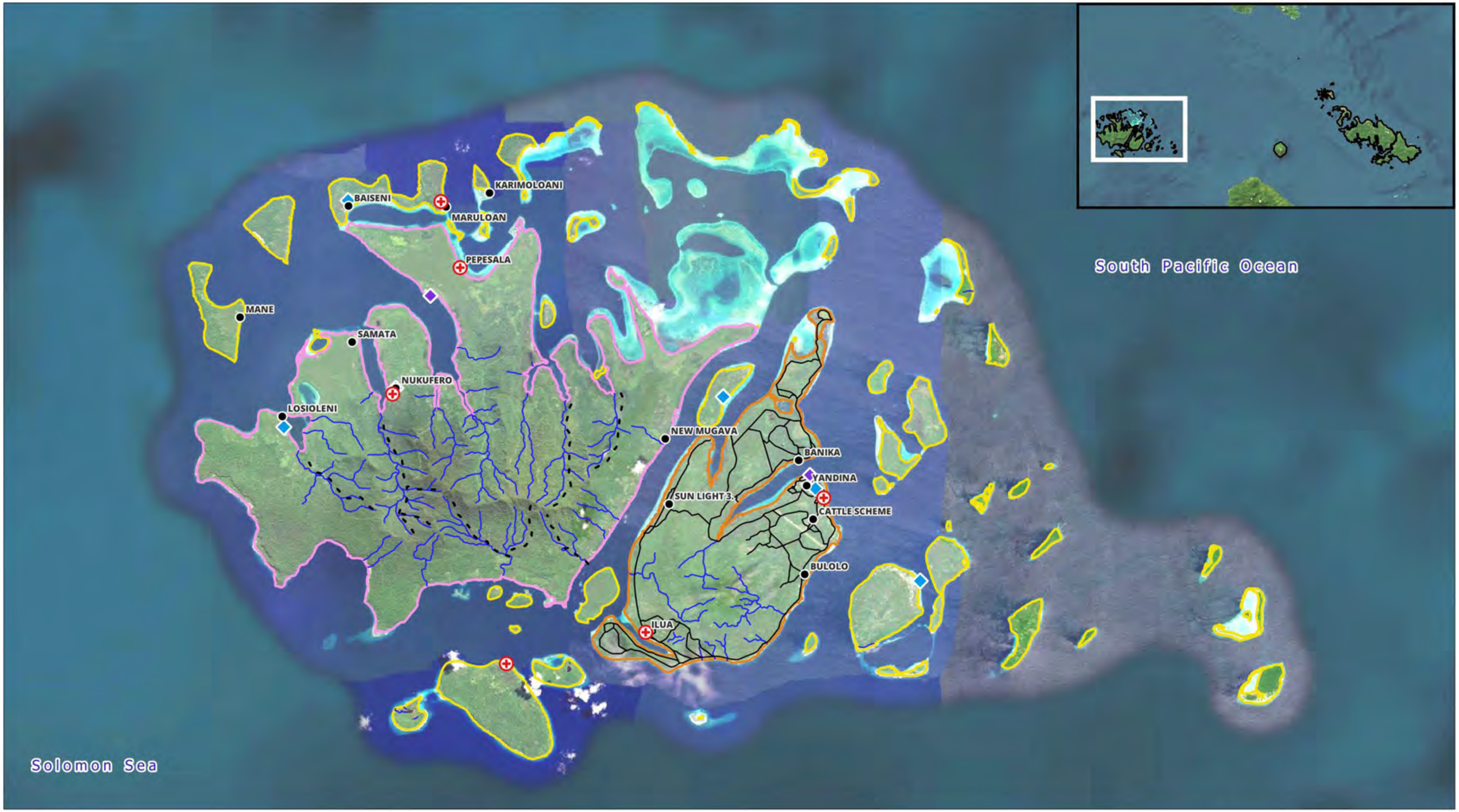
Annex A Preliminary Mapping



LEGEND

Settlement	Road
Health Facility	Watercourse
Wharf	Lovukol Ward
Education Facility	Mbanika Ward
Logging road	Pavuvu Ward

Title:

Russell Islands, Central Province

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Figure: A-1

Rev: A

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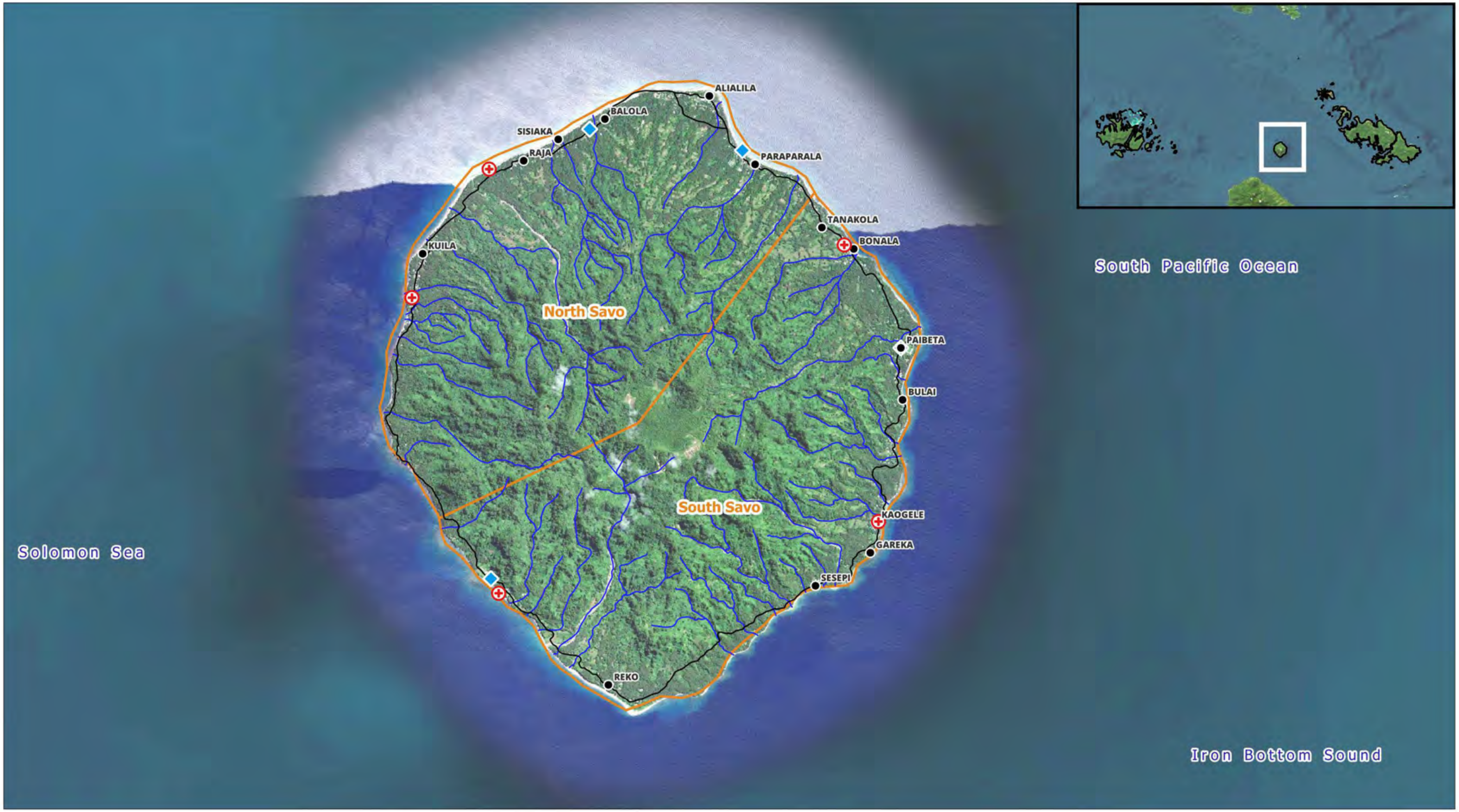

LEGEND

Settlement	Road
Health Facility	Watercourse
Education Facility	Ward

Title:

Savo Island, Central Province

Figure: **A-2**

Rev: **A**

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LEGEND

●	Provincial Capital	- - -	Logging road
●	Settlement	—	Road
⊕	Health Facility	—	Watercourse
◆	Wharf	☐	Ward
◆	Education Facility		

Title:

Nggela Islands, Central Province

Figure: A-3

Rev: A

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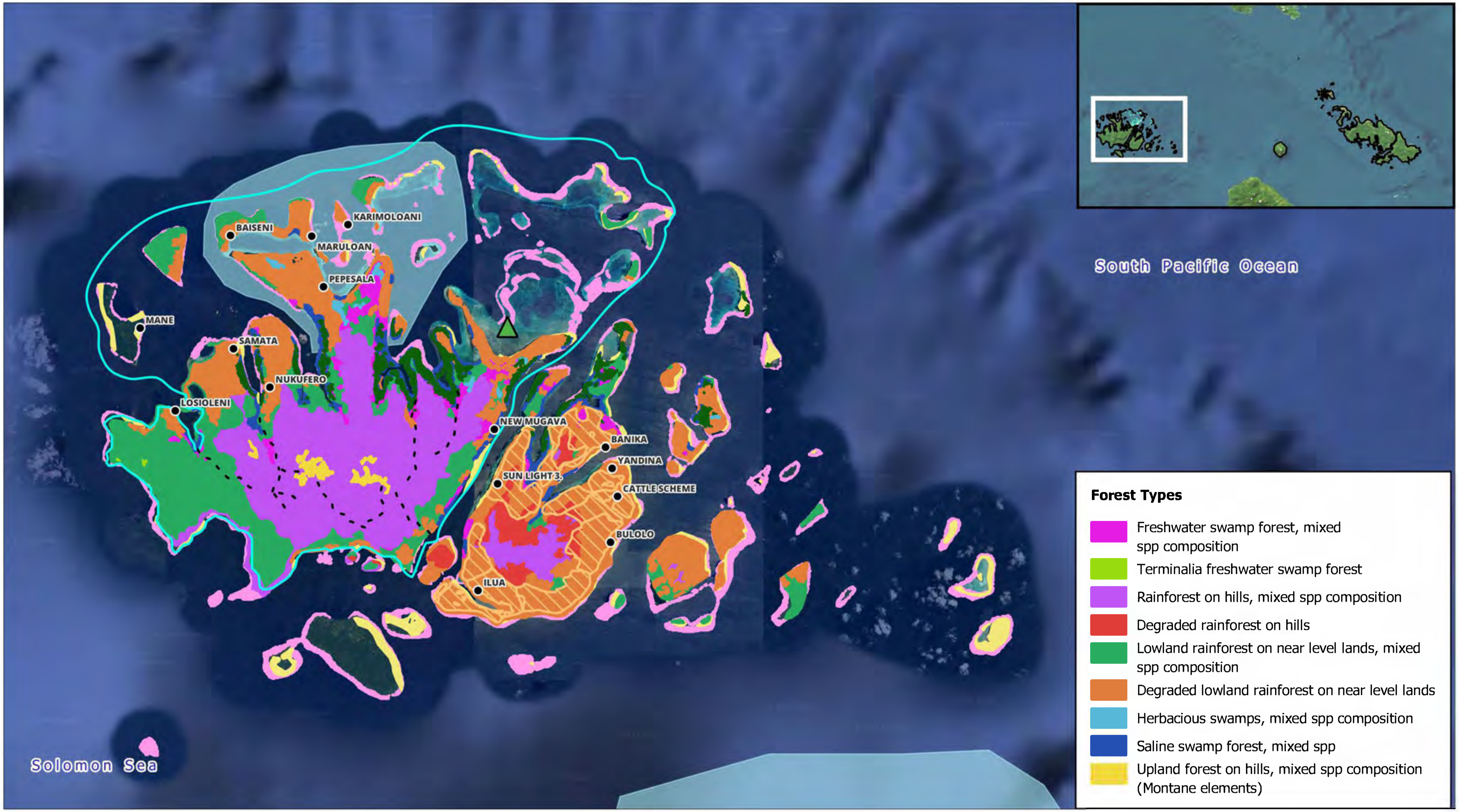

Title:

Draft Ecosystem and Land Use Mapping, Russell Islands

Figure: A-4

Rev: A

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LEGEND

- Settlement
- Terrestrial forest (Brandt et al., 2023)
- Coral reef (WCMC, 2021)
- Special and Unique Marine Areas

Title:

Draft Ecosystem and Land Use Mapping, Savo Island

Figure: **A-5**

Rev: **A**

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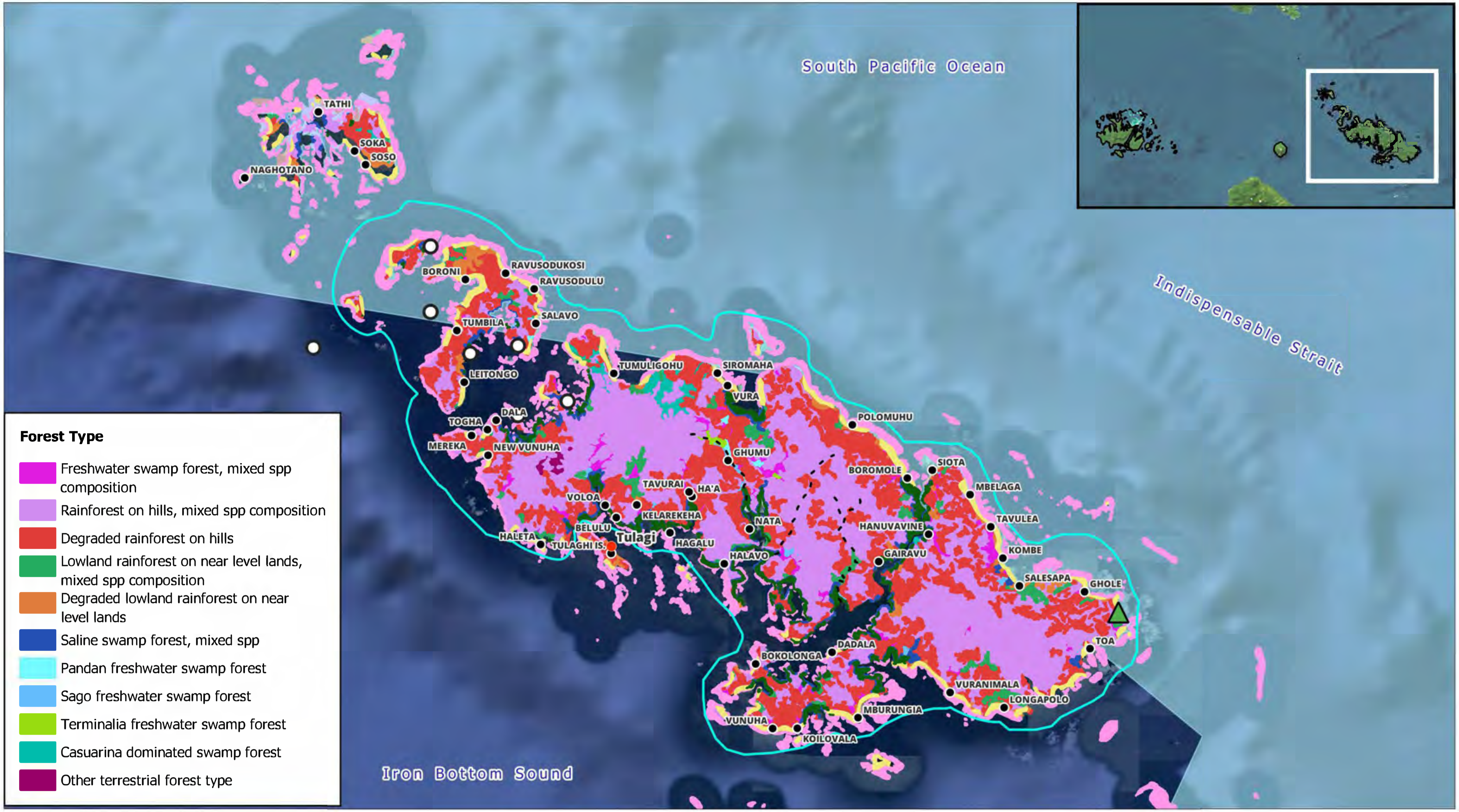

LEGEND

- Provincial Capital
- Settlement
- Seaweed farm
- Protected Areas
- Logging road
- SI KBAs
- Mangroves (GMW, 2020)
- White beach (approx.)
- Coral reef (WCMC, 2021)
- Special and Unique Marine Areas

Title:

Draftt Ecosystem and Land Use Mapping, Nggela Islands

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N 0 5 10 km

Figure: A-6

Rev: A

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Annex B Photographs of Community Consultations

Figure B.1 Participants at Soka Workshop, 25th November 2024

Figure B.2 Participants at Gumu Workshop, 26th November 2024

Figure B.3 Participants at Toa Workshop, 27th November 2024

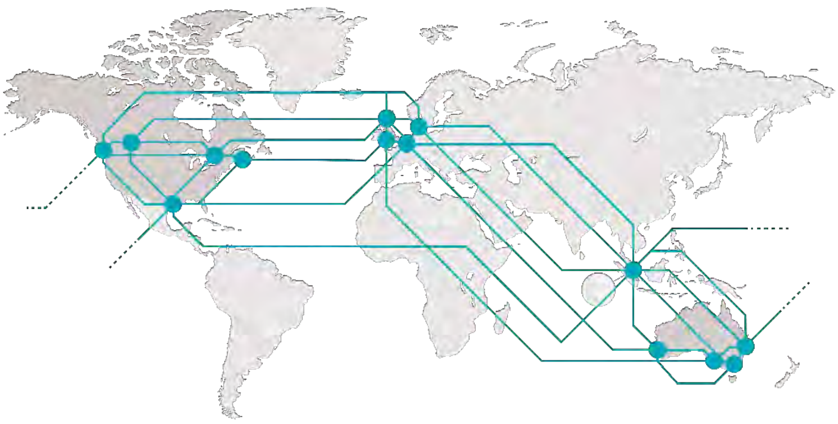
Figure B.4 Participants at Vuranimala Workshop, 28th November 2024

Figure B.5 Participants at Haleta Workshop, 29th November 2024 (workshop was located offsite in Tulagi due to village event conflicts)

Figure B.6 Participants at Panueli Workshop, 3rd December 2024

Figure B.7 Participants at Marulaon Workshop, 5th December 2024

Figure B.8 Participants at Karumulun Workshop, 5th December 2024



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Level 5
348 Edward Street
Brisbane
QLD 4000
Australia
+61 7 3831 6744

Registered in Australia
Registered no. 010 830 421
Registered office
Level 5, 348 Edward Street,
Brisbane QLD 4000 Australia

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