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SOLOMON ISLANDS

Ecosystem and Socio-economic Resilience Analysis and Mapping

TO LEAD IS TO SERVE

SPREP
Secretariat of the Pacific Regional Environment Programme

BMT WBM

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

This report produced by BMT WBM for the Secretariat of the Pacific Regional Environment Programme (SPREP) presents Volume 1 (of three volumes) prepared as part of the Solomon Islands Ecosystems and Socio-economic Resilience Analysis and Mapping (ESRAM) to assess and prioritise climate change-related ecosystem-based adapation options for selected locations in Solomon Islands. Volume 1 provides the generic project background and methodology relevant to all three volumes, together with the high level national scale assessment.

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All photographs are credited to Beth Toki unless stated otherwise.

Key project partners

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List of Abbreviations

ACMCA	Anarvon Community Marine Conservation Area
AR5	Fifth Assessment Report of the IPCC
CBRM	community-based resource management
EbA	ecosystem-based adaptation
EBA	endemic bird area
EBSA	ecologically and biologically significant areas
EEZ	exclusive economic zone
ENSO	El Niño-Southern Oscillation
ESRAM	Ecosystem and Socio-economic Resilience Analysis and Mapping
EVRI	Environmental Valuation Reference Inventory
GCM	Global Climate Model
GIS	Global Information Systems
GPS	Global Positioning System
IBA	important bird areas
KBA	key biodiversity areas
MHWM	mean high water mark
MPA	marine protected area
NM	nautical miles
PEBACC	Pacific Ecosystem-based Adaptation to Climate Change
PV	present value
R2R	ridge-to-reef
RCP	Representative Concentration Pathway
SPC	The Pacific Community
SOPAC	Pacific Islands Applied Geoscience Commission (now the Geoscience Division) of SPC
SPREP	Secretariat of the Pacific Regional Environment Programme
TBL	triple Bottom Line
TEV	total economic valuation
TNC	The Nature Conservancy
UNCLOS	United Nations Convention on the Law of the Sea
VandA	vulnerability and adaptation

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Executive Summary

Project overview

This project forms part of the Solomon Islands component of the *Pacific Ecosystem-based Adaptation to Climate Change* (PEBACC) project. PEBACC is a five-year project funded by the German Government. It is implemented by the Secretariat of the Pacific Regional Environment Programme (SPREP) in three participating countries (Fiji, Solomon Islands and Vanuatu) to explore and promote ecosystem-based options for adapting to climate change. The key outputs of the PEBACC project are:

(1) ecosystem and socio-economic resilience analysis and mapping (ESRAM) study – baseline study for adaptation planning at national, provincial and community levels;

(2) ecosystem-based adaptation (EbA) options assessment – EbA options analysed, prioritised and plans developed;

(3) implementation plans – EbA plans implemented with demonstrated benefits; and

(4) communications and outreach products developed to promote integration of EbA options into climate change policies, plans and projects.

The ESRAM component (Output 1) study is the subject of the present report. The ESRAM study will inform subsequent EbA phases of the PEBACC project involving the identification of EbA options for strengthening the resilience of Solomon Islands to the effects of climate change. The following framework was used to undertake the ESRAM study.

Task 1 Ecosystem baseline and threat assessment

- Identify the current state of ecosystems, trends and drivers of change with root causes, scenarios, governance factors.
- Identify ecosystem types, ecosystem services and threats.
- Identify ecosystem services that are valued by the community.
- Map key ecosystems and related ecosystem services, including high-use areas and/or major threats based on existing spatial data.

Task 2 Ecosystem valuation

- Undertake a 'total economic valuation' to define the economic value of key ecosystems services relevant to the ESRAM study.

Task 3 Condition and threat analysis

- Assess the vulnerability of ecosystems services to the effects of climate change based on climate change projections.
- Identify the ecosystem services most vulnerable to future climate and non-climate threats and effects.
- Recommend EbA options to strengthen the resilience of key ecosystem services.

While ESRAM considers three geographic locations/scales, this Volume 1 report is the national scale assessment. This is a broader (higher-level) exercise than the local and city scale assessments, as appropriate to this spatial scale. Volume 1 presents:

(1) general ESRAM methodology – a description of the general ESRAM assessment approach used for the three scales/locations in Solomon Islands; and

(2) national ESRAM – the results of the national scale ESRAM assessment.

The results of the Wagina Island and Honiara ESRAM assessments are presented in Volumes 2 and 3, respectively.

National ESRAM outcomes

Well-managed and healthy ecosystems are critical for the provision of essential services to maintain the health, well-being and livelihoods of all Solomon Island communities and economies. The vulnerability of social and ecological systems to human activities, such as logging, agriculture, pollution and the over-exploitation of marine resources throughout Solomon Islands, is increasing. As one of the fastest growing populations in the world, these activities will only intensify and have an increased detrimental effect on the communities and economies of Solomon Islands. The direct and indirect effects of climate change and their interactions with human-induced threats increases the vulnerability of critical ecosystem services and reduces the resilience of social and ecological systems.

Freshwater ecosystem services

Freshwater ecosystems provide essential services to many Solomon Island households. The key anthropogenic threats to freshwater ecosystems are an increase in sedimentation of stream and river systems from logging and land-clearing practices, pollution of water catchments from inappropriate solid waste and sanitation practices, rapid population growth, and urbanisation. The key climate threats to freshwater ecosystem services are an increase in extreme rainfall events and sea-level rise. The key ecosystem services most vulnerable and in need of protection, restoration and enhancement to build their resilience under future climate conditions are:

- provision of water supply (for drinking, domestic and irrigation purposes) provided by groundwater, rivers, streams and lakes;
- provision of food for both subsistence and commercial purposes (eels and other fish, molluscs, crustaceans, etc.) provided by rivers, streams, lakes, wetlands and swamps;
- habitat provision (supporting biodiversity and food sources) provided by streams, rivers, wetlands, lakes and swamps;
- income generation (fisheries, aquaculture and bottled water) provided by streams, rivers, wetlands, lakes and groundwater;
- provision of recreational activities (swimming) provided by streams and rivers; and
- water purification by wetlands, lakes and swamps.

The high reliance on freshwater resources for many households, particularly low-income households, combined with the reduced water quality and a rapid population growth rate, are critical issues for building the nation's resilience to future climate change effects. If effective measures are not implemented to conserve freshwater resources and improve water quality issues, households that solely rely on freshwater ecosystems services for their health and well-being and livelihoods (e.g. food and water supply), will need to adapt to alternative means to strengthen their resilience to the future effects of climate change. If not managed effectively, the potential economic loss of freshwater ecosystems (e.g. freshwater lakes, rivers, wetlands) is estimated at USD 15,512 (2015) or SBD 121,282 (2015) per hectare per annum.

Coastal and marine ecosystems and services

Increasing habitat destruction, pollution and over-exploitation of marine resources for both subsistence and commercial use has resulted in severe decline of marine biodiversity and ocean health, and the depletion of important food and commercial species. The rapidly increasing population and inadequate environmental regulations are intensifying the rate of marine ecosystem degradation. The climate change projections likely to have the greatest effect on marine and coastal ecosystem services are an increase in sea and air temperatures and associated ocean acidification and coral bleaching, an increase in extreme rainfall events and sea-level rise. The key ecosystem services most vulnerable and in need of protection, restoration and enhancement to ensure resilience under future climate conditions are:

- provision of food (supplying daily protein and micronutrients through fish, including pelagic fish, turtles, octopus, clams, beche-de-mer, trochus, molluscs and crustaceans) provided by coral reefs, mangroves, marine waters, seagrass and macroalgae (seaweed);
- supporting habitat (essential feeding, breeding, spawning, cleaning and aggregation habitat) and biodiversity provided by coral reefs, mangroves, beaches, marine waters, seagrass and macroalgae;
- income and revenue generation (fishing, seaweed, coral, lime extraction and tourism) provided by coral reefs, marine waters and macroalgae;
- provision of raw materials (timber, fuelwood, coral rock and lime production) provided by mangroves and coral reefs;
- hazard protection, including wave attenuation by coral reefs, seabed stabilisation by marine macroalgae, and shoreline and coastal protection by mangroves;
- cultural practices, values and identity (shell money, ornaments and decorations) provided by seagrass, macroalgae and coral reefs;
- provision of *kastom* medicine provided by seagrass and mangroves; and
- regulating services (carbon sequestration, climate and atmospheric regulation, primary production, etc.) provided by mangroves, marine waters, coral reefs, beaches, seagrass and marine macroalgae.

Marine and coastal ecosystem services are central to the livelihoods and well-being of a large portion of Solomon Island communities and economies. Marine and coastal ecosystem resilience needs to be enhanced by improving water quality, reducing coastal development pressures and sustainably managing fisheries resources. A balance between meeting the subsistence food needs of households and maximising economic benefits through export and sales of marine products is needed to build social and economic resilience.

The potential economic loss of marine and coastal ecosystems and all ecosystem services (e.g. coral reefs, coastal systems, and coastal wetlands, including mangroves) is estimated to cost USD 295,052 (2015) or SBD

2,306,888 (2015) per hectare per annum. Utilising the estimated total coverage of mangroves in Solomon Islands of 65,000 ha (Sulu *et al.* 2012), the loss of mangroves and their ecosystem services is equivalent to an economic loss of USD 579,345,000 (2015) or SBD 4,529,395,000 (2015). Based on the estimated seagrass cover of 10,000 ha (Sulu *et al*. 2012) throughout Solomon Islands, the loss of ecosystems services provided by seagrass would equate to a loss of approximately USD 296,700,000 (2015) and SBD 2,319,750,000 (2015).

Terrestrial ecosystems and services

Logging and agricultural activities, coupled with a rapid population growth, are the key threats faced by the nation's terrestrial ecosystem services, while threats from mining and infrastructure activities are likely to increase in the future. The climate change projections likely to have the greatest impact on terrestrial ecosystem services are an increase in extreme rainfall events and an increase in air temperature. The increased vulnerability of terrestrial ecosystems may be expressed by a reduction in local biodiversity and species structure, and sensitivity to other threats, such as pest and disease and prolonged dry periods. 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, plantations and gardens;
- provision of water supply, produced by forests and mountains and supported by vegetation, soils and microorganisms;
- supporting habitat and biodiversity by terrestrial forests;
- provision of raw materials and income generation (building, fuel and commercial purposes);
- erosion control and land stability;
- protection from natural hazards and extreme weather events provided by terrestrial forests;
- cultural services such as cultural items, values, practices, identity and heritage (traditional tools, ornaments, costumes, weaving, handicrafts and traditional currency); and
- regulating services (regulation of water supply and quality, primary productivity, nutrient cycling, soil fertility and stability, and carbon sequestration) provided by terrestrial forests.

The clearing of forests will continue to reduce the resilience of social and ecosystem systems by reducing the provision of essential ecosystem services. Forest degradation, clearing and change in land use reduces the resilience of both humans and ecosystems to future climate and non-climate threats. As the frequency and intensity of climate-related disasters increase with global climate change (Munang *et al.* 2013), the resilience of ecosystems and human societies against the effects of climate change will continue to decrease with further environmental degradation.

The potential economic loss of terrestrial ecosystems (e.g. tropical forests and grasslands) and their ecosystems is estimated to cost USD 4,675 (2015) or SBD 36,553 (2015) per hectare per annum. Based on the estimated forest cover of 2,150,000 ha in 2015, this would equate to a loss of approximately USD 6,884,300,000 (2015) and SBD 53,829,550,000 (2015).

Ecosystem-based adaptation options

Through sustainable resource management, ecosystem-based adaptation integrates biodiversity and ecosystem services into an adaptation strategy. It is envisioned that EbA will be incorporated and implemented in both policy and on-ground adaptation actions, providing a test case and model for other Pacific nations (or other scales/locations within the participating countries). An ecosystem-based adaptation approach is particularly relevant to the economies and communities of the Pacific Islands, which are heavily reliant on local land and sea resources for maintaining national, provincial and local economies and community livelihoods and socio-cultural values. In this respect, maintaining healthy and well-functioning ecosystems will be crucial to building community resilience and reducing vulnerability to the effects of climate change.

By highlighting ecosystem service vulnerabilities, opportunities can be identified to protect and restore critical ecosystems and their services, and retain and build on the strengths of social systems and effective governance structures. Based on the vulnerable ecosystem services identified, high level EbA options have been proposed to protect, restore and strengthen ecosystems to increase the resilience of Solomon Island social and ecological systems.

1 Introduction

1.1 Pacific Ecosystem-Based Adaptation to Climate Change Project

1.1.1 Background

This project forms part of the Solomon Islands component of the *Pacific Ecosystem-based Adaptation to Climate Change* (PEBACC) project. PEBACC is a five-year project, funded by the German Government. It is implemented by the Secretariat of the Pacific Regional Environment Programme (SPREP) in three participating countries (Fiji, Solomon Islands and Vanuatu) to explore and promote ecosystem-based options for adapting to climate change.

Ecosystem-based adaptation (EbA) is an ecosystem-focussed approach to building the resilience of linked social and ecological systems to the negative effects of climate change. Through sustainable resource management, ecosystem-based adaptation integrates biodiversity and ecosystem services into an adaptation strategy. When delivered effectively, EbA can be cost-effective and contribute to biodiversity conservation, while generating social, economic and cultural co-benefits (CBD 2009).

An ecosystem-based adaptation approach is particularly relevant to the economies and communities of the Pacific Islands, which are heavily reliant on local land and sea resources for maintaining national, provincial and local economies and community livelihoods and socio-cultural values. In this respect, maintaining healthy and well-functioning ecosystems will be crucial to building community resilience and reducing vulnerability to the effects of climate change.

1.1.2 Study components and outputs

Figure 1-1 shows the key components of the PEBACC project, which are:

(1) ecosystem and socio-economic resilience analysis and mapping (ESRAM) study – baseline study for adaptation planning at national, provincial and community levels;

(2) EbA options assessment – EbA options analysed, prioritised and plans developed;

(3) implementation plans – EbA plans implemented with demonstrated benefits; and

(4) communications and outreach products developed to promote integration of EbA options into climate change policies, plans and projects

(SPREP 2016).

The ESRAM component (Step 1) study is the subject of the present report. The ESRAM study will inform subsequent EbA phases of the PEBACC project, involving the identification of ecosystem-based adaptation options for strengthening the resilience of Solomon Islands to the effects of climate change. It is envisioned that EbA will be incorporated and implemented in both policy and on-ground adaptation actions, providing a test case and model for other Pacific nations (or other scales/locations within the participating countries). Both the EbA options assessments and implementation plans will be presented as stand-alone reports separate to this ESRAM study.

The ESRAM study will be followed by: a detailed EbA options assessment (step 2); the development of implementation plans for selected demonstration sites (step 3); and on-ground EbA implementation works (step 4) (see Figure 1-1). Both the EbA options assessments and implementation plans will be presented as stand-alone reports, separate from the ESRAM reports (i.e. Volumes 1, 2 and 3).

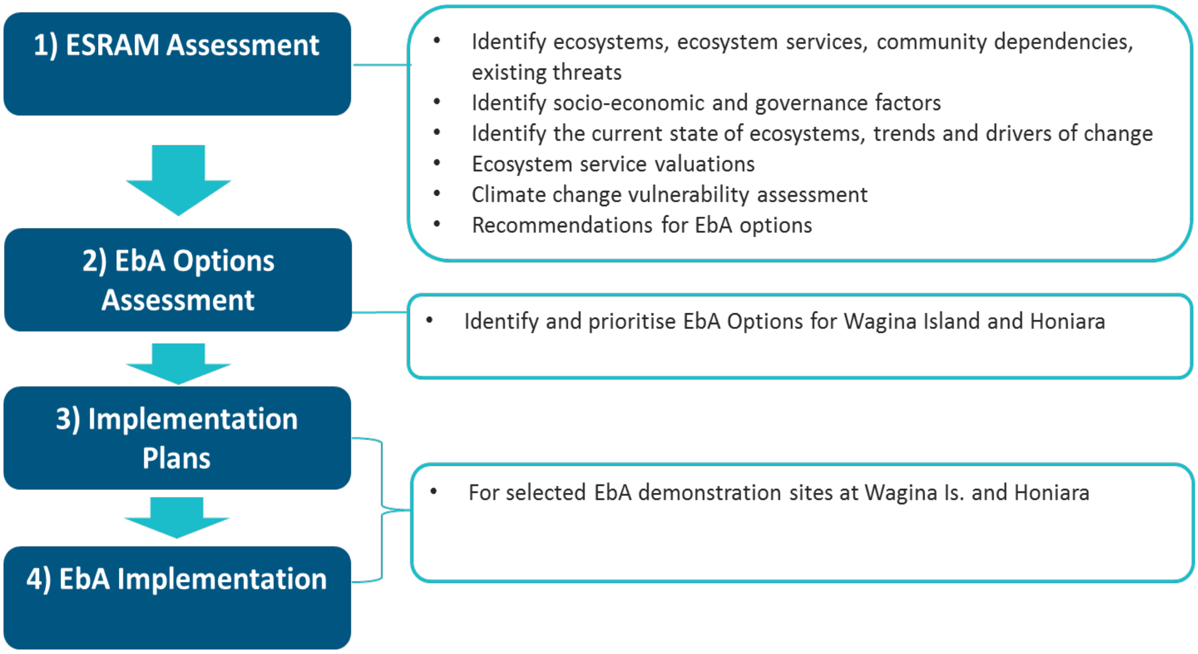


Figure 1-1 Position of ESRAM study in the broader PEBACC process

1.2 Aims and objectives

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

The species objectives of the ESRAM study are listed below.

1. Identify ecosystem types, ecosystem services and threats in the context of:
   - ecosystem types present, in the context of the relevant ecosystem services;
   - the present condition or health of the ecosystems, based on existing information if available and/or recent observations (qualitative or opportunistic) throughout the course of the assessment;
   - key ecosystem services in terms of direct community dependencies;
   - the role of ecosystem services in providing socio-ecological resilience;
   - critical ecosystem linkages or dependencies; and
   - the main existing threats to an ecosystem and/or ecosystem service.
2. Map key ecosystems and related ecosystem services, including high-use areas and/or major threats based on existing spatial data.

3. Identify the current state of ecosystems, trends and drivers of change with root causes, scenarios and governance factors.
4. Undertake a 'total economic valuation' to define the economic value of key ecosystems services relevant to ESRAM.
5. Assess the vulnerability of ecosystems services to the effects of climate change, based on climate change projections and other existing threats.
6. Provide broad recommendations regarding strategic EbA options.

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

1.3 Volume 1 report scope

While ESRAM considers three geographic locations/scales, this Volume 1 report is the national scale assessment. It is a broader (higher-level) exercise than the local and city scale assessments, as appropriate to this spatial scale.

Volume 1 presents:

- general ESRAM methodology – A description of the general ESRAM assessment approach used for the three scales/locations in Solomon Islands; and
- national ESRAM – The results of the national scale ESRAM assessment.

The results of the Wagina Island and Honiara ESRAM assessments are presented in Volumes 2 and 3 respectively.

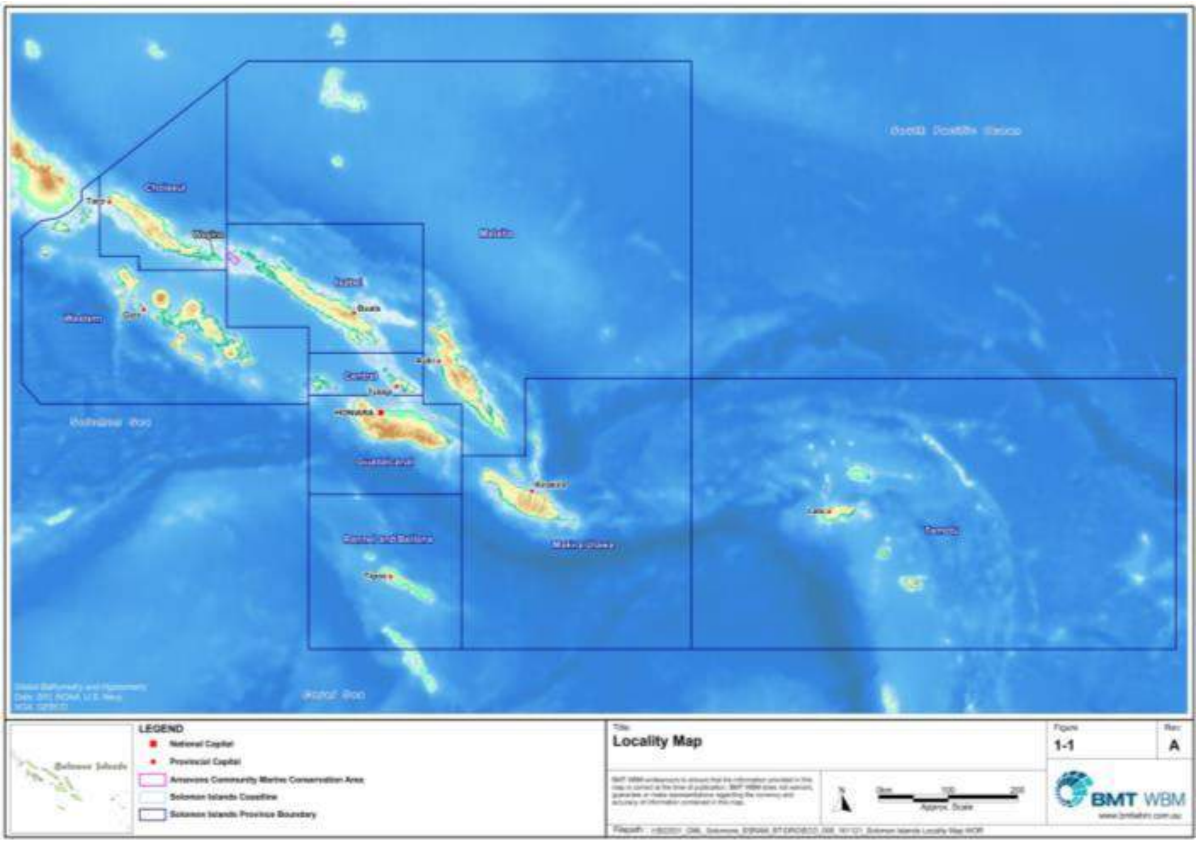


Figure 1-2 Locality map

1.4 Ecosystem services context

There is an urgent need for Solomon Islands and other small island nations to strengthen their resilience to the effects of climate change. As part of this process, it is important to focus on the opportunities and resilience provided by protecting and restoring ecosystem services that underpin national development agendas and community livelihoods.

Ecosystem services are the benefits, or services, that people obtain from ecosystems to sustain and support human well-being (Travers *et al.* 2012; Millennium Ecosystem Assessment 2005). Ecosystems provide a diverse range of services for communities and economies across the globe. As the demand for these services increases through global drivers such as population growth, urbanisation, increased consumption and increased global connections (Biggs *et al.* 2012), ecosystems are under increasing stress to continue to provide the services humanity depends upon.

The Millennium Ecosystem Assessment (2005) categorises ecosystem services into four types (see Table 1-1 for further examples of ecosystem services):

- provisioning services – the products obtained directly from ecosystems, such as food, water, fuels, medicines and fibres;

- regulating services – the benefits obtained from the regulation of ecosystem processes, such as water regulation, erosion control, regulation of climate cycles and pollination;
- cultural services – the largely non-consumptive benefits obtained from ecosystems, such as spiritual, religious and aesthetic well-being.
- supporting services – supporting services encompass the main ecosystem processes that underpin all other services, such as soil formation, photosynthesis, primary production, nutrients, and water cycling. Supporting services make it possible for the ecosystems to provide the above services.

The linkage to and dependence on the natural world is complex and introduces the concept of social-ecological systems, which is defined by Berkes and Folke (1998) as complex, integrated systems in which humans are part of nature. One approach to better understand the dynamics of social-ecological systems is the 'resilience' thinking approach (Folke 2006). The United Nations Framework Convention on Climate Change (IPCC 2007) defines resilience as '*The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change'.* Resilience describes the degree to which the system is capable of self-organisation, learning and adaptation (Holling 1973; Gunderson and Holling 2002; Walker *et al.* 2004). A resilience-thinking approach attempts to investigate how these interacting social-ecological systems can best be managed to ensure a sustainable and resilient supply of the essential ecosystem services on which humanity depends (Biggs *et al.* 2015).

Managing ecosystems to conserve and improve ecosystem health is crucial for sustaining the various ecosystem services important to human well-being. When resilience is strengthened, social-ecological systems can maintain their structure and function. When resilience is reduced and a social-ecological system becomes vulnerable, a system may be affected by disturbances that previously would not have negatively influenced the system. This disturbance may cause the basic structure and function of a social-ecological system to alter and the ecosystem services that once benefited humans become diminished (Resilience Alliance 2017).

The Millennium Ecosystem Assessment (2005) reports that approximately 60% of all ecosystem services and up to 70% of regulating services are being degraded or used unsustainably. A major compounding factor to human induced ecosystem degradation is climate change, which increases the frequency and intensity of climate-related disasters, and exacerbates ecosystem degradation (Munang *et al.* 2012). These detrimental changes to ecosystems and the effect on the provision of ecosystem services weaken the resilience of vulnerable ecosystems and societies. Communities around the world are already vulnerable to the impacts of climate related hazards. Munang *et al.* (2012) reports that the number of disasters linked to natural hazards continues to rise, while in recent times (1975–2008), over 2.2 million people globally have lost their lives in natural hazard-induced disasters (excluding epidemics), with associated economic losses at approximately USD 1,527.6 billion (UNISDA 2009).

There is growing evidence that ecosystem services are critical to human society resilience, i.e. how linked social-ecological systems can deal with shocks and stressors (Carabine 2015). Carabine (2015) defines human resilience to include four outcomes: (1) providing basic needs for health and well-being, (2) supporting livelihoods; (3) building social capital, stability and security; and (4) reducing exposure to natural hazards and enhancing adaptive capacity in a changing climate.

Table 1-1 presents the four ecosystem service types (provisioning, regulating, cultural and supporting) and how these ecosystem services contribute to the human resilience outcomes listed above.

Table 1-1 Summary of ecosystem services' contribution to human resilience outcomes (Carabine 2015)

Ecosystem Service Resilience	Provisioning Services	Regulating Services	Cultural Services	Supporting Services
Basic needs, health and well-being	• Food production by agro-ecosystems underpins food security • Food production (protein) by aquaculture and fisheries • Forests and mountains produce water used to support agriculture • Water supply supported by vegetation, soils and microorganisms • Fuel and fibre for shelter, cooking and heating • Biochemicals with medicinal value derived from a range of ecosystems • Crop genetic diversity increases and sustains food production and quality	• Climate regulation by oceans, forests • Carbon storage in soils, vegetation and oceans • Soil biodiversity regulates soil ecosystem for primary production and nutrient cycling • Water regulation and purification • Pollination by animal vectors • Biological control of crop, livestock and human diseases • Health benefits from air and water purification	• Foster sense of place of intrinsic value to all societies • Cultural identity and well-being • Traditional ecological knowledge enables use of resources and survival • Food preferences linked to food provision, wild foods as important reserves • Relatively intangible in general • Culture can mediate access to resources creating winners and losers • Psychological/health benefits from access to green open spaces in urban areas	Primary production, nutrient cycling and soil formation – which underpin all ecosystem services and is therefore critical to all human resilience outcomes
Livelihoods	• Fisheries and agro-ecosystems vital to livelihoods and economies across the world • Sustainable livelihoods supported by natural capital • Fibre and fuel products that generate income (e.g. timber, biofuels, etc.), but values vary • Natural resources are basis of industry, manufacturing, trade, medicine and tourism • Health and wellbeing from access to green open space	• Water provision, pollination and soil quality are all crucial for food security but often do not accrue financial benefits for small-scale farmers and pastoralists • Biological control of agricultural pests reduces economic losses • Species and biodiversity can act as bio-indicators of environmental stress	• Cultural status linked to biodiversity and can enable or impede livelihood opportunities • Institutions and norms have evolved in cultures closely linked to environments • Such cultural diversity can be of tourism value • Nature-based tourism and recreational value are basis of many livelihoods • Aesthetic value of ecosystems contributes to use of open spaces and other nature-based facilities	

	can increase economic productivity • Biodiversity often yields high-value incomes from tourism and related activities • Freedom of choice to pursue livelihoods			
Social capital, stability and security	• Declines in ES can lead to violent conflict and social turmoil if scarce • Food security and human security are linked • Green open spaces in urban areas can reduce crime and aggression • Natural resource access and management has evolved with institutions particular to systems	• Climate change and breakdowns in climate regulation services are increasingly becoming security problems • Environmental change can impact on social cohesion and institutions • Regulation of disease ecology prevents breakdown of social order/stability • Many customs and institutions have been established to manage regulating ES	• Natural resource markets can shape social relationships at local and global levels • Demands for natural resources are shifting through urbanisation, etc. • Recreational, spiritual, mental health and amenity values	
Reduced exposure and enhanced adaptive capacity	• Strong and sustainable livelihoods build resilience to recover from disasters • Diverse food products resilient to shocks, e.g. pest outbreaks, drought • Fibre and fuel can be a cause of disaster risk, e.g. wildfire in shifting landscapes • Provision of food, water and energy important for enhancing adaptive capacity in a changing climate	• Ecosystems can act as barriers or buffers to extreme events and natural hazards • Economic losses and deaths can be reduced by provision of such ES • Regulating ES is also core to adapting to long-term stresses e.g. climate change	• Perceptions and responses to natural hazards influenced by cultural and social factors • Cultural factors and traditional ecological knowledge can reduce risk and build adaptive capacity	

2 ESRAM methodology

2.1 Study approach

The three Solomon Island ESRAM studies (national, local, city) follow the generic methodology described in this chapter and summarised in Table 2-1. This generic methodology has been adapted for each of the different spatial scale/location contexts, depending on factors such as geographic extent, stakeholder engagement requirements and community/population size. Additional and/or specific methods relevant to a scale/location are detailed in the respective ESRAM reports.

Table 2-1 Study tasks

Task and Component	Methodology Section
Task 1 Ecosystem baseline and threat assessment	
• Identify the current state of ecosystems, trends and drivers of change with root causes, scenarios, governance factors	2.2.1
• Identify ecosystem types, ecosystem services and threats	2.2
• Identify ecosystem services that are valued by the community	2.2.2
• Map key ecosystems and related ecosystem services, including high-use areas and/or major threats based on existing spatial data	2.2.3
Task 2 Ecosystem valuation	
• Undertake a 'total economic valuation' to define the economic value of key ecosystems services relevant to ESRAM	2.3
Task 3 Condition and threat analysis	
• Assess the vulnerability of ecosystem services to the effects of climate change based on climate change projections	2.4
• Identify the ecosystem services most vulnerable to future climate and non-climate threats and impacts	2.5
• Recommend EbA options to strengthen the resilience of key ecosystem services	2.5

2.2 Ecosystem baseline and threats assessment

The initial step in the ESRAM assessments was to establish an inventory and understanding of the ecosystems and key ecosystem services to be assessed with respect to climate change and other non-climate drivers. Information for this component was derived from a combination of sources described in the following sections.

2.2.1 Review of existing literature

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 Solomon Islands concentrates primarily on the ecosystems and/or ecosystem components that are deemed to be of key conservation value. These ecosystems or ecosystem components include:

- vertebrate terrestrial fauna and avifauna (i.e. birds and mammals), especially endemic fauna (e.g. Filardi *et al.* 2007; Pikacha 2008; Pikacha *et al.* 2012).
- areas identified as a high priority for environmental protection due to factors such as a pristine condition, unique nature, high biodiversity and/or the presence of endemic fauna (e.g. Halpern *et al.* 2013; Moseby *et al.* 2012; Pollard *et al.* 2013).

Often, these two topics interact to further restrict the scope of the available literature. The result is that, even for environmental components that have been studied on numerous occasions, the geographic coverage of available information may still be very limited and there are often extensive gaps in knowledge and context for other locations. Conversely, where national scale documents exist among the environmental literature (e.g. Pacific Horizon Group 2008; Sulu *et al.* 2012; Albert *et al.* 2013; Lavery *et al.* 2016), they are typically of a very broad and generic nature. The *Solomon Islands Marine Assessment* (Green *et al.* 2006) is a notable exception, detailing marine survey results throughout the country in a national scale report.

Ecosystem components of direct economic importance (e.g. to fisheries or forestry industries) are also captured in the literature. Remaining information gaps relate to major ecosystem components, both biological and physical, that contribute to ecosystem services. Key examples where there is a notable paucity of country-specific information include:

- invertebrate fauna;
- groundwater ecosystems;
- phytoplankton / zooplankton;
- deep sea habitats and communities;
- physico-chemical environmental drivers (i.e. of ecosystem processes and biological communities); and
- unconsolidated (i.e. non-reef) seabed habitats and associated communities.

The smaller scale locations that will be focused on as part of the present project (i.e. Wagina and Honiara) are rarely mentioned in the environmental literature, in part due to the factors described below.

(1) Honiara – Being the national capital, Honiara is highly developed and most environmental values are highly modified or degraded. For this reason, environmental assessments tend to focus on less disturbed locations elsewhere, or in locations subject to specific industry developments, such as logging and mining (e.g. Morrison *et al.* 2007; SMM 2012; Envi-Green Pacific 2012; Golder Associates 2014).

(5) Wagina Island – Being isolated from both the provincial capital Taro and priority terrestrial conservation locations throughout Choiseul Province, Wagina has largely been overlooked by the environmental literature. With the exception of marine works associated with the nearby Anarvon Marine Conservation Area (Green *et al.* 2006), the main environmental assessments to have focused on Wagina Island are the environmental impact assessment(s) relating to the mining development presently proposed for the island (Envi-Green Pacific 2012; Envi-Green Pacific 2013).

2.2.2 Stakeholder workshops

In addition to sourcing existing information, in-country work was generally in the form of stakeholder consultation workshops and a field component, noting that the format of these varied between assessments (Table 2-2).

Table 2-2 Overview of stakeholder participation and field approaches

ESRAM	Consultation	Field
National	One-day workshop with key stakeholders, primarily national government representatives (who are generally tertiary qualified, directly involved in environmental work and regularly consulted on environmental issues), to identify key ecosystems, services and threats on a broad national scale	Nil
Honiara	Workshop with key stakeholder representatives (e.g. national government, community, local council and local projects) to identify key ecosystems, services and threats, and undertake interactive mapping activities	Site inspections at communities near Mataniko River, Vura District, White River, Independence Valley, Win Valley, waterfront areas of Honiara and other points of interest (i.e. as identified during the workshop activities). Included informal discussions with local community members on an opportunistic basis
Wagina Island	Workshops with each of the four communities to identify key ecosystems, services and threats, and undertake interactive mapping activities	Most detailed field component: • site inspections and guided tours of villages and surrounds • collection of GPS data for spatial validation • field surveys for mapping and qualitatively assess condition • locating water wells (mapping survey and water quality testing) • additional opportunistic observations

Dedicated workshops with representative stakeholders were the primary means of stakeholder participation and engagement for informing the ESRAM assessments. Overall, six workshops were undertaken as follows:

- National – one workshop with key stakeholder representatives (mainly national government);
- Wagina Island – four workshops, one 'community level' workshop at each of the four villages on the island; and
- Honiara - one workshop with a variety of key stakeholder representatives.

The field methodology specific to each of the Honiara and Wagina Island assessments is detailed in the respective report volumes (2 and 3). The workshops had multiple broad objectives, as listed below.

- Provide follow up on earlier PEBACC meetings hosted by SPREP.
- Advise attendees about the ESRAM study and its part in the broader PEBACC project.

- Provide some awareness of ecosystems, ecosystem services and climate change. Source information and local knowledge from attendees to inform the ESRAM assessments, with a particular focus on:
  - identifying ecosystems;
  - documenting key ecosystem services in terms of the community's direct dependence on their local land and sea resources, including ascertaining the relative value of resources to the community (i.e. which resources are essential and/or valued most); and
  - undertaking interactive mapping exercises (primarily at Honiara and Wagina Island workshops) to spatially document ecosystem services, with a particular focus on high-use areas..
- Identify existing threats to the ecosystems and/or ecosystem services.
- Identify additional information sources not already obtained/consulted.

The Honiara and national workshops were facilitated by Dr Simon Albert (University of Queensland) and Dr Beth Toki (BMT WBM), while the Wagina Island workshops were jointly facilitated by David Boseto (Ecological Solutions Solomon Islands) and Dr Tammy Tabe. All workshops allocated a large proportion of time to participatory activities, whereby attendees had opportunities to inform the assessment directly. For these activities, the stakeholder representatives were assigned to groups (four groups per workshop) to discuss, document and map the required information. This worked particularly well for the Honiara and Wagina Island workshops, where each group was able to focus on either a defined geographic area or an ecosystem type. Workshop participants for all three locations provided invaluable input to all workshop activities, particularly the spatial documentation of ecosystem services.

Further information on the attendees and specific objectives of workshop(s) for each assessment are provided in the relevant report volume.

2.2.3 Mapping

Maps were generated to identify the key ecosystems and related ecosystem services, including high use areas and/or major threats, where possible. Maps were produced in MapInfo Professional v12 using the following data sets:

- national government ministries and the SOLGEO spatial data sets;
- interactive mapping outputs from the stakeholder workshops (i.e. manual mapping directly on high resolution satellite imagery, which was subsequently digitised);
- remote sensing – using publicly available satellite imagery to remotely digitise ecosystems (e.g. forest extent, rivers) where existing data were not available, inadequate or required fine-tuning;
- field surveys and on-ground validation – for Honiara and Wagina Island, location data were collected using a hand-held GPS (e.g. locations of specific points of interest, community uses, threats, land marks, ecosystem types and boundaries); and
- Additional GIS data sources, such as local and regional projects (e.g. UN-Habitat, MACBIO).

2.3 Economic valuations

2.3.1 Economic approach

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

Ecosystem valuations can assist resource managers to deal with the effects of market failures (i.e. inability of a market to reflect the full social costs or benefits of goods or services), by measuring their costs to society, in terms of lost economic benefits (King and Mazzotta 2000). These costs to society can then be imposed on those who are responsible, or can be used to establish the value of actions to reduce or eliminate environmental impacts.

Typically, the framework used to identify the full range of ecosystem service values is known as 'total economic valuation' (TEV). 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. 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 2012). The latter is generally associated with existence value, which is the satisfaction one receives from the sole contemplation of the existence of an entity (Kareiva 2012). For example, a person who has never visited and never intends to visit the Great Barrier Reef can still obtain satisfaction from knowing it exists.

A simple conceptualisation of the TEV framework is shown in Figure 2-1.

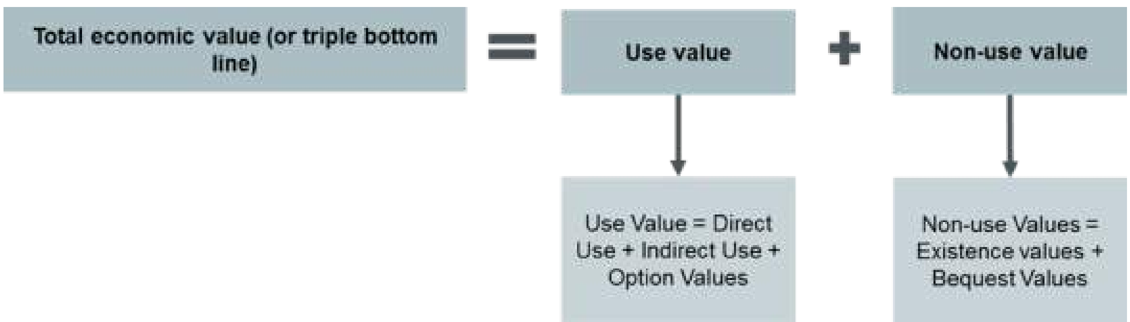


Figure 2-1 Categories for total economic valuation

For non-use values, there are two broad approaches for determining values: revealed preference and stated preference. Revealed preference methods utilise prices from related services or products to estimate non-use values, while stated preference methods utilise survey methods to outline people's preferences (and willingness to pay) for social and environmental changes. Both of these methods require significant resources and time to implement, and it is not always possible to adopt these methods in practice. A common way to overcome these limitations is to use 'benefit transfer'.

Benefit transfer in its simplest form uses ecosystem values calculated for one locality to estimate the values for another (similar) locality. 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).

Both the TEV framework and benefit transfer have underpinned the ecosystem service valuation methodology used for this project. To do this, a relatively straightforward framework was utilised to identify, describe and value (where possible) the ecosystem services. The same methodology was used across the three spatial scales considered in the project, with different inputs used as appropriate. An overview of the approach is shown in Figure 2-2.

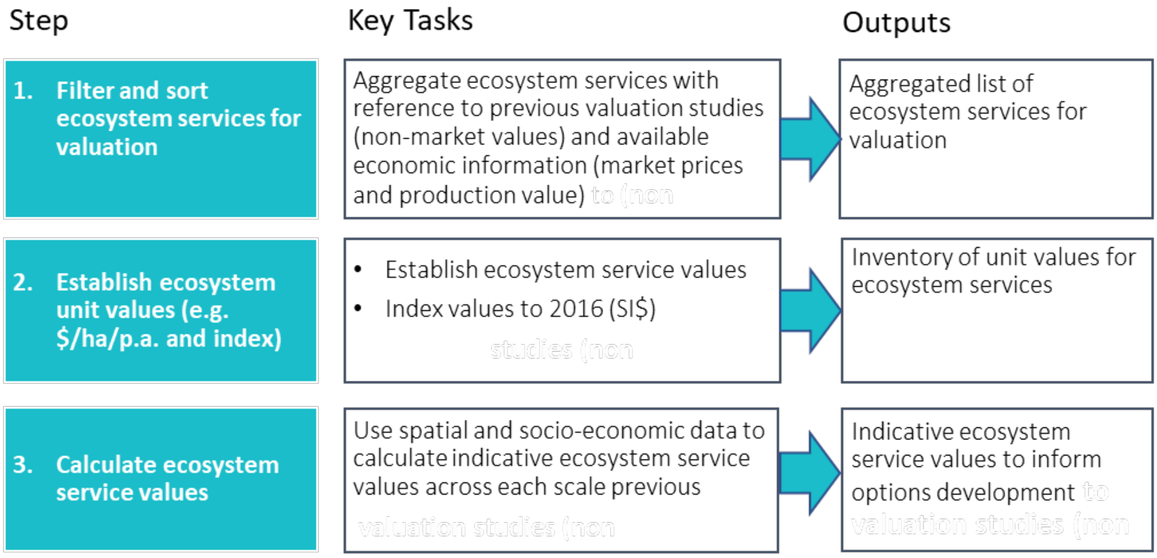


Figure 2-2 Overarching methodology for economic valuations

2.3.2 Step 1: Filter and sort ecosystem services

Before valuing the ecosystem services, it was necessary to filter and sort the services to assist with the valuation process. This was done to help consolidate the valuation requirements and to better reflect that scope of the project.

The sorting process was guided by ecosystems present at each scale, the identified services, available valuation studies (for non-use values), and local economic information where available (e.g. market prices and production data for market values).

2.3.3 Step 2: Establish ecosystem unit values

Once the ecosystem services were appropriately filtered and considered, an inventory of ecosystem unit values was developed. Values were developed based on local inputs and valuation studies (benefit transfer).

To maximise the accuracy and appropriateness of inputs within the project scope and timeline, a 'bottom-up, top down' approach was adopted to selecting values. This essentially meant that, where possible, local scale data and information were used for establishing unit values in the first instance (i.e. 'bottom-up'). Where local level figures were not available, figures from other locations and global averages were identified for benefit transfer (i.e. 'top-down') to fill gaps. Values were presented in 2015 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, the United Nations Operational Rates of Exchange were used.

This approach helped to maximise the coverage of ecosystem values to ecosystem services whilst favouring local values. Additionally, more recent and robust information sources were favoured, with each input being considered on a case-by-case basis.

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. Furthermore, due to the different ways in which different studies capture and produce data, there may be duplication between values. Where this occurs, values for the same or overlapping ecosystem services have been presented alongside each other for each of the three geographic scales.

Where 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.

The data from de Groot *et al.* were sorted by removing all studies that contained values from countries ranked as 'High Income' countries by the World Bank, as of September 2016, and removing studies that were published prior to 1990. The median values were then calculated for the remaining studies.

2.3.4 Step 3: Calculate ecosystem service values

The next step of the process was to generate indicative values for ecosystem services at the target scale. This was done at a high-level, based on the inventory of values developed in the previous step, as well as the spatial and population data from other sections of the ESRAM report.

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 must be noted that values may be more or less accurate in reality. The following passage summarises the need for and trade-offs in using benefits transfer:

> *Although the use of high-quality primary research to estimate values is preferred in most cases, the realities of the policy process, particularly time and budget constraints, often dictate that benefit transfer is the only feasible option. Given these realities, benefit transfer has become a central component of virtually all large-scale benefit-cost analyses. Hence, while benefit transfers are subject to a variety of potential errors, the literature increasingly recognizes the need for the resulting information* (Johnston *et al.* 2015: 20).

2.4 Climate change assessment

2.4.1 Current and future climate projections

A summary of the current climate for Solomon Islands was based on the assessments by Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) and sourced from:

- the Australian Bureau of Meteorology and CSIRO (2011). Climate Change in the Pacific: Scientific Assessment and New Research, Volume 2: Country Reports; and
- the Australian Bureau of Meteorology and CSIRO (2014). Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports.

The climate projections for Solomon Islands for this assessment (Australian Bureau of Meteorology and CSIRO [2014]) are based on the very high IPCC emissions scenario Representative Concentration Pathways (RCP) 8.5, the highest scenario of the 5th Assessment Report, for the short term (2030) and longer term (2090).

To identify immediate potential threats and vulnerabilities of ecosystems services, the 2030 timeframe was selected and 2090 chosen for long-term planning. For adaptation planning purposes, particularly for long term, i.e. 2090, the RCP 8.5 emission scenario was chosen for this assessment because it provides the worst case scenarios for projected climate change. In addition, it should be noted that greenhouse gas emissions are currently tracking at the higher end of the emissions scenarios. Building ecosystem resilience to worst-case climate induced changes is likely to lead to significant co-benefits to community livelihoods and the environment.

The latest global climate model (GCM) projections and climate science findings for Solomon Islands indicate:

- very high confidence that El Niño and La Niña events will continue to occur in the future, but it is not clear whether these events will change in intensity or frequency;
- very high confidence that annual mean temperatures and extremely high daily temperatures will continue to rise;
- very high confidence that sea level will continue to rise;
- very high confidence that ocean acidification is expected to continue;
- very high confidence that the risk of coral bleaching will increase in the future;
- high confidence that more extreme rain events will occur;
- low confidence that annual rainfall is projected to increase slightly;

- low confidence that drought is projected to decrease slightly;
- low confidence that December–March wave heights are projected to decrease; and
- low confidence that there will be no significant changes projected in June–September waves.

Refer to Appendix B for further information on the data sets used by PACCSAP for Solomon Islands, as well as further information on emission scenarios.

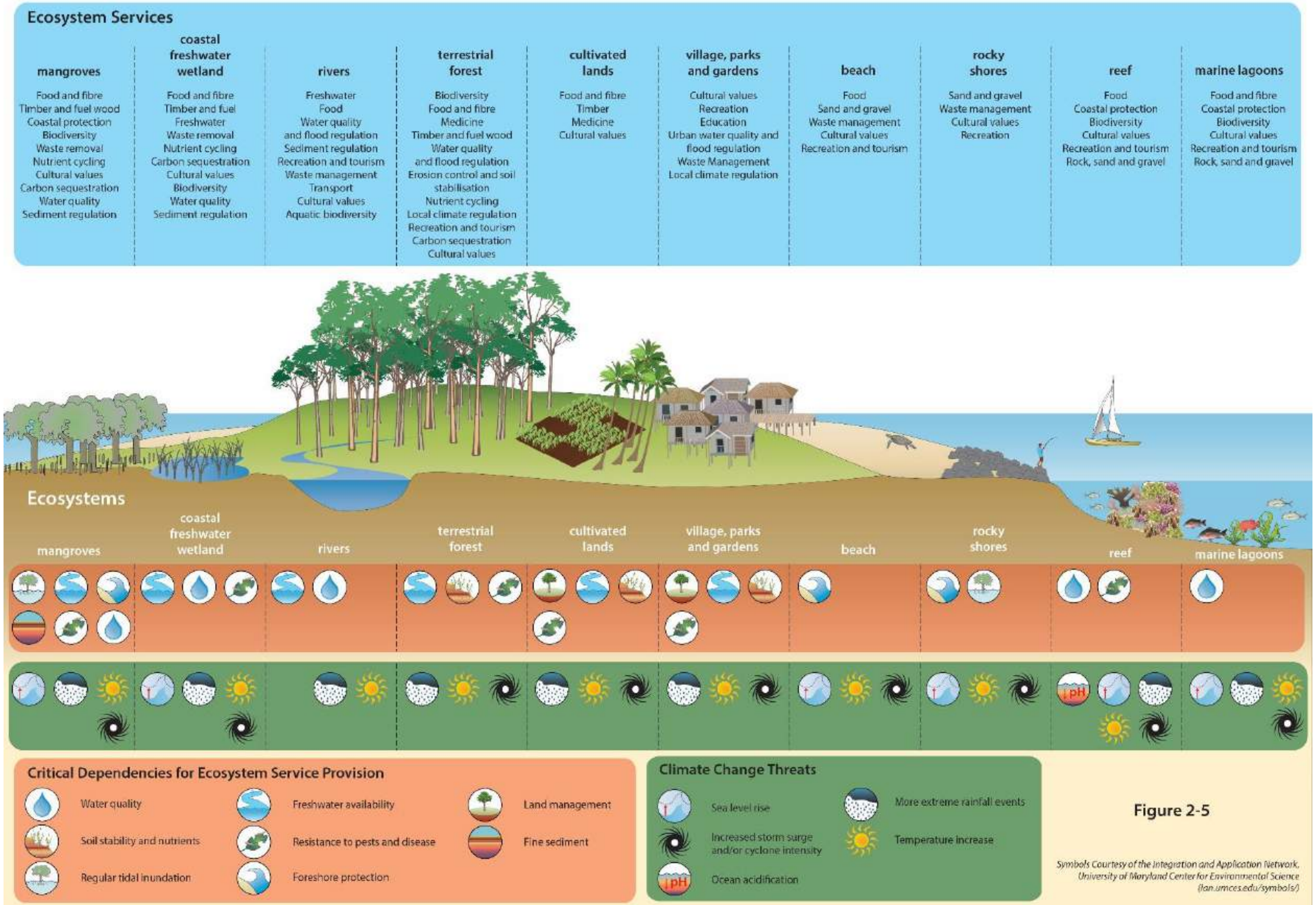


Figure 2-3 Ecosystems and their services for the Solomon Islands

2.4.2 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. The vulnerability of ecosystems to climate change is the degree to which ecosystems are susceptible to the adverse effects of climate change, which is a function of its exposure to climate stimuli, sensitivity of the service to these stimuli, and its adaptive capacity to climate change, as defined below (IPCC 2007).

- **Exposure** refers to the nature and degree to which an ecosystem is exposed to significant climatic variations or threats.
- **Sensitivity** refers to the degree to which an ecosystem is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g. coral bleaching in response to temperature rise) or indirect (e.g. seagrass dieback due to sedimentation from extreme rainfall events).
- **Adaptive capacity** refers to the ability of an ecosystem to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

A climate change vulnerability assessment was undertaken, based on exposure, sensitivity and adaptive capacity of key ecosystem services to potential climate change threats identified for Solomon Islands. This assessment was based on the process presented in Figure 2-4 and outlined below.

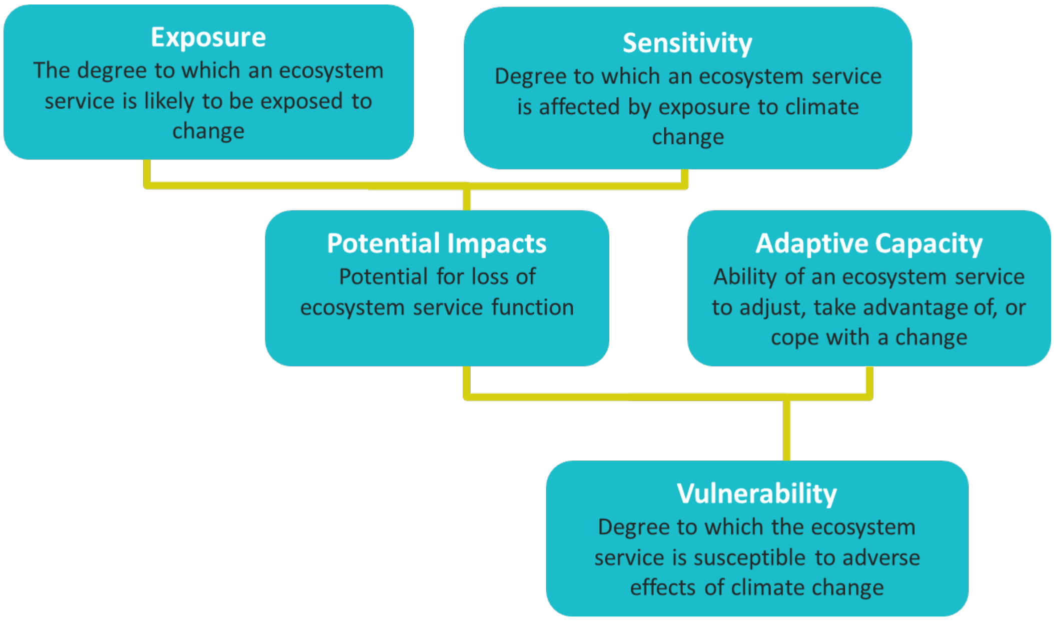


Figure 2-4 Climate change vulnerability assessment conceptual framework

(1) Identification of provisioning, regulating, supporting and cultural ecosystem services

(2) For each climate change threat, the vulnerability of each ecosystem service was evaluated. In order to do this, each ecosystem service was given a score between 1 and 3 for exposure and sensitivity (1 = low, 2 = moderate, 3 = high).

(3) The exposure and sensitivity ratings were used to calculate the potential impact of the climate change threat to each ecosystem service, where:

Potential Impact = Exposure x Sensitivity

(4) The adaptive capacity of the ecosystem service to the climate change threat considered the vulnerabilities of both natural and human systems and the links between them, and was scored between 1 and 3, where:

1 = ecosystem service has a high adaptive capacity to climate change threat (e.g. food gardens can be readily relocated inland in response to sea-level rise)

2 = ecosystem service has moderate adaptive capacity to climate change threat (e.g. saltmarsh has some adaptive capacity to migrate with sea-level rise)

3 = ecosystem service has low adaptive capacity to climate change threat (e.g. reef has low adaptive capacity to aragonite concentrations <3)

(5) The product of the potential impact ranking and adaptive capacity was calculated to determine the overall vulnerability of the ecosystem service to the climate change threat, where:

Vulnerability = Potential Impact x Adaptive Capacity

Ecosystems services that scored 18 or more are predicted to be highly to very highly vulnerable to the specified climate change variable for 2030 and/or 2090. The results of the vulnerability assessment were used to identify adaptation management options.

This vulnerability assessment has used a similar approach to the assessment undertaken in the *Solomon Islands National Report: TA7394-REG: Strengthening the capacity of developing member countries to respond to climate change* (International Centre for Environmental Management 2012).

2.5 ESRAM study outcomes

The resilience of ecosystem services to human-induced and climate change impacts was assessed, based on the information obtained from the tasks outlined above, including: the current state of ecosystems; social-economic and ecological trends; drivers of change and environment consequences, scenarios, and governance factors; key ecosystems and ecosystem services utilised by Solomon Island communities and economies; and the economic value of ecosystem services.

Based on these findings, recommended EbA options were compiled in order to guide the adaptation and management of ecosystem services vulnerable to the existing and future impacts of climate-related and human-induced threats identified at the national scale. Potential key stakeholder groups and organisations were also identified to support, enable and implement EbA options.

3 National scale ESRAM – context

This chapter provides relevant context for the national scale ESRAM assessment, including:

- additional methodology, primarily providing further stakeholder workshop details and grouping of ecosystem services for valuation; and
- information about the national setting, such as the national socio-economic profile, introduction to local biodiversity and conservation, national governance and climate change governance.

3.1 Specific methodology

The following reports provide the primary existing information that forms the underlying basis and understanding for ecosystems at a national scale in this assessment, and the current state of ecosystems, trends and drivers of change, scenarios and governance factors (see Section 4). The reports listed below should be referred to for further context and information.

- Solomon Islands State of the Environment Report 2008 (Pacific Horizon 2008)
- Freshwater biotas of the Solomon Islands (Polhemus *et al.* 2008)
- Solomon Islands Forest Life – Information on biology and management of forest resources (Lavery *et al.* 2016)
- State of the Coral Reefs of Solomon Islands (Sulu *et al.* 2012)
- Solomon Islands Marine Life: information on biology and management of marine resources (Albert *et al.* 2013)
- State of Conservation In Solomon Islands – Country Report 2013 (SPREP 2016)
- Solomon Islands Marine Assessment (Green *et al.* 2006)

The dedicated stakeholder workshop for this assessment provided the primary means for focussing the scope of the assessment (i.e. stakeholder liaison and participation during the workshop was used to identify what the 'key' ecosystems and ecosystem services were). Objectives specific to the national ESRAM stakeholder workshop were to:

- acquire inputs and advice from representative key stakeholders, especially representatives from national government ministries;
- define the focus of the assessment – i.e. what are the 'key' ecosystem services and where are they most important?
- identify key existing threats at the national scale; and
- identify available existing information and data for further informing the assessment (e.g. existing spatial data sources).

The stakeholder workshop was held in Honiara on 9 August 2016 and was attended by 26 participants representing the following organisations:

- Ministry of Environment, Climate Change, Disaster Management and Meteorology

- Ministry of Fisheries and Marine Resources
- Ministry of Forestry and Research
- Ministry of Infrastructure and Development
- Ministry of Development, Planning and Aid Coordination
- Solomon Island Community Resilience to Climate and Disaster Risk Project (CRISP)
- Solomon Island Water Sector Adaptation Project (UNDP)
- Prime Minister's Office
- UN-Habitat project
- Solomon Islands National University
- Ecological Solutions SI
- SPREP
- WWF-Pacific.

Participants comprised both males (62%) and females (38%) as per Table 3-1, and all were actively involved in contributing to the workshop's participatory activites. In terms of statistical representation, the sample size of 26 participants is considered small and unreliable.

Example photographs of groups participating in these activities on the day are shown in Figure 3-1, while a full list of the attendees is provided in Appendix A.

Table 3-1 Summary of stakeholder workshop attendees, 9 August 2016

Aspect	Workshop detail
Number of participants	26
Male proportion	62% (16)
Female proportion	38% (10)

3.1.1 Grouping of ecosystem services for valuation

Workshops for identifying national scale ecosystem services identified over 100 different services. Furthermore, many of these services are highly critical for segments of the populace and would lead to serious consequences if lost.

Due to the quantum of services listed and the scale at which they are being considered (i.e. national) it was determined that it was not feasible to provide values for each service. This was primarily due to the available information on ecosystem values not adequately matching the specificity of services identified, as well as the fact that individual service values were likely to be highly variable across the country (e.g. the ocean as a food source may be relied upon to different extents in different areas and may be utilised differently, thus changing the value of the service in different locations within Solomon Islands).

To overcome this, it was determined that the most appropriate method for capturing the values for as many listed ecosystem services as possible was to use global median values.

To achieve this, representative ecosystems were grouped to match the biomes defined in the global median values used for the project (see de Groot *et al.* 2012). This was done to avoid duplication, whilst ensuring as many of the ecosystems described above were considered. The revised list of ecosystems selected for valuation includes:

- coral reefs
- coastal systems
- coastal wetlands
- freshwater lakes and rivers
- inland wetlands
- tropical forests
- grasslands.

The ecosystems and services that could not be assessed were groundwater and plantations/gardens. Groundwater, while an exceptionally important ecosystem service, has been poorly captured in past ecosystem valuation studies and there is not a reliable global value that can be applied in the same manner as other ecosystem services (see Greibler and Avramov 2013 for further information). While groundwater values can be readily broadly defined (e.g. drinking water supply, water purification), relevant information was not available or applicable to the national scale, and was also not representative of the full range of ecosystem services from groundwater (see Brink *et al.* 2011).

Plantations and gardens provide a range of services and products to humans, and can also perform ecosystem services, such as regulation of soil and water quality. However, at the same time, agricultural practices (including crops and gardens) can also cause ecosystem disservices, e.g. contaminating water and increasing sedimentation run-off. The exact value of these types of systems are therefore a function of the services and disservices they provide and vary greatly, depending on the land-use type and the natural environment it is replacing. It is not feasible to provide a high-level value that could be applied to cultivated land across Solomon Islands.

Despite this, the project team considered, where plausible, the economic benefits of agricultural production in weighing up the costs and benefits in the options assessment phase of the project.

Figure 3-1 Stakeholders at the national workshop conducting participatory activities in groups (photographs courtesy of Simon Albert)

3.2 Geographic setting

Solomon Islands is an island state, located in the south-west Pacific Ocean and spread across the third largest archipelago in the South Pacific (SPC 2008; Pollard *et al.* 2014). Located between 5-12°S and 152-170°E, the archipelago comprises a double chain of approximately 1000 islands extending over 1450 km in a south-eastern direction (Mueller-Dombois and Fosberg 1998; Filardi *et al.* 2007). It includes seven major islands groups (Guadalcanal, Malaita, Makira-Ulawa, Isabel, the New Georgia Group, Rennell and Bellona, and Choiseul), and over 900 smaller islands, islets, atolls and cayes (Filardi *et al.* 2007).

Being an island state, the nation has a relatively small land area of around 28,785 km^2 and an extensive total marine area of around 1.3 million km^2 (Gough *et al.* 2010; Pollard *et al.* 2014).

Nine of the larger islands exceed 900 m in elevation (Guadalcanal 2450 m, Kolombangara 1768 m, Isabel 1250 m, Rendova 1063 m, Malaita 1280 m, New Georgia 1006 m, Vangunu 1124 m, Makira 1040 m, Choiseul 970 m) (Filardi *et al.* 2007).

The volcanic islands are mostly steep, with river systems that are usually short (<100 km) and watershed areas that vary in size, depending on local terrain and topography (Gehrke *et al.* 2011; Boseto *et al.* 2016).

3.3 National socio-economic profile

The population of Solomon Islands in 2014 was approximately 609,800, with a rapid annual growth rate of 2.07% (SPREP 2016). The UN classifies Solomon Islands as a 'Least Developed Nation' with most people living in coastal villages, practising a subsistence lifestyle, and retaining customary ownership of their land and shallow seas.

The population can be divided into urban and rural residents. Approximately one-fifth (102,030) of the population during 2009 was classified as urban dwellers (2009 census data), of which over 70% resided in the capital city of Honiara. With an annual urban growth rate of 4.7%, it is anticipated that by 2020 approximately 25% of the Solomon Island population will be living in urban areas if the present trend continues (UN-Habitat 2012). While urbanisation in Solomon Islands is a relatively recent phenomenon, the predicted urban growth rate is expected to present confronting challenges, such as urban poverty, unemployment, housing, environmental risk, land administration, and infrastructure provision and maintenance (UN-Habitat 2012).

Poverty in Solomon Islands is widespread and characterised by a lack of access to essential services and income-earning opportunities (Solomon Islands Government Ministry of Development Planning and Aid Coordination 2013). In 2013, Solomon Islands had an estimated GDP per capita of USD 3,400 (SPREP 2016). Income distribution is inequitable, with rural expenditure levels significantly below expenditure levels in urban areas. Similarly, social indicators, although improving, are among the worst in the region (*ibid*). Employment rates are somewhat unclear. The 2009 census reports a rate of only 2.0% unemployment but, under the census definition, the 'employed' include subsistence workers, who make up more than 50% of the workforce (*ibid*).

With more than 80% of the labour force engaged in subsistence agriculture and fishing (Filardi *et al.* 2007) in rural communities, the need for high-income generation is low. However, cash is still required for essential items (e.g. transportation, school fees, manufactured goods – machetes, axes, fishing line, fish hooks) and valued luxuries (e.g. boats, mobile phones, flashlights, radios, coffee, sugar, rice, biscuits). Cash is also needed for church contributions and special occasions. For cash requirements, the rural economy is typically dependent on producing a small number of commodities, including fresh fruit, coconut, cocoa, timber, as well as fish and marine products (ARDS 2007; Feinberg 2010; Abernathy *et al.* 2014).

More broadly, the main industries are agriculture, fishing, forestry and mining, and most manufactured goods and petroleum products are imported. According to the 2009 census:

> *Natural resources include fish, forests, gold, bauxite, phosphates, lead, zinc, and nickel. Agriculture products include cocoa beans, coconuts, palm kernels, rice, potatoes, vegetables, fruit; timber; cattle, pigs; and fish. The main industries are fish (tuna), mining, timber, palm oil, and tourism. (Census Report 2009: 2)*

Timber, copra, fish, palm oil and cocoa are the most significant exports, with increasing interest and prospecting in the mining industry over the last decade. Timber exports generate 60–70% of total foreign export earnings (from royalties), and it is estimated that one in six Solomon Islanders are employed by the industry (Filardi *et al.* 2007). Timber was the main export product until 1998, when world prices for timber from tropical forests declined (SPREP 2016). Logging fell by 3.0% in 2013 but still recorded the country's third largest annual harvest (*ibid*). This rate of extraction and its heavy reliance on logging previously harvested forests appears unsustainable, and logging is expected to decline at an average annual rate of 8% in the medium term (ADB 2014). Exploitation of fisheries offers prospects for export and domestic economic expansion. Tourism, particularly diving, is an important service industry for Solomon Islands, but growth in tourist numbers is hindered by lack of infrastructure and security concerns (SPREP 2016).

According to the Food and Agriculture Organization of the United Nations, improving sustainable agriculture and rural development is an important means to improving resilience and reducing vulnerability to natural disasters and climate change (FAO 2016). Solomon Islands has a similar Human Development Index ranking to that of nearby countries, such as Vanuatu and Kiribati, and is categorised in the low human development category (UNDP 2015).

Since the conflicts in the late 1990s and early 2000s, Solomon Islands has recovered well, but the economy continues to face several challenges. Exports remain commodities-based and logging rates are considered to be unsustainable (SOE Report 2008; SPREP 2016; Kabutaulaka 2000, 2006).

3.4 Biodiversity and conservation

Solomon Islands is renowned as a global biodiversity hotspot, characterised by exceptional patterns of inter-island diversity and high degrees of endemism, both within the region and on individual islands (Filardi *et al.* 2007; Conservation International 2013). It has the second highest terrestrial biodiversity in the Pacific (exceeded only by Papua New Guinea), with an estimated 5,599 described species, including: 2,597 plants, 245 birds, 75 mammals, 87 reptiles, 19 amphibians, and 777 fish and 1,799 invertebrate species, as per the IUCN Red List (Menazza and Balasinorwala 2012).

Solomon Islands is also part of the Coral Triangle, the global centre of marine biodiversity that comprises 76% of the world's corals and 37% of the world's coral reef fish species, in an area that covers less than 2% of the planet's oceans (TNC 2008).

While basic taxonomic and distribution data are lacking for many taxa (Filardi *et al.* 2007) and it is likely that many species remain undescribed, the following is noted from the existing literature.

- Patterns of avian endemism are particularly noteworthy and have received the most attention (*ibid*). While at least 163 species of breeding land birds, including 72 endemic species, are known (Ciamond and Mayr 1976), an additional 62 bird species are represented by unique sub-species on different islands throughout the country (Morrison *et al.* (2007). Overall, the Solomon group's endemic bird area (EBA) has the greatest number of restricted range bird species of all the world's EBAs. Further, most of the larger islands have their own endemic species and/or subspecies (Filardi *et al.* 2007).
- Other taxonomic groups also reveal high endemism; more than half of the known palm and orchid species are endemic, as are 75% of climbing Pandanus species, 21% mammals and there is high reptile and amphibian endemism – over 80% of all frogs are endemic (Filardi *et al.* 2007).
- Tetepare Island deserves a special mention from a biodiversity and conservation perspective. It is the largest uninhabited island in the South Pacific, totalling 18 square km, retaining >96% of its old growth rainforest, and supporting several endemic and rare species (Moseby *et al.* 2012). The island is recognised as an area of international biological and conservation significance by those who have carried out biological surveys there (e.g. Read and Moseby 2006; Keppel 2007; Jenkins and Boseto 2007), and it supports important refuge populations for species of international conservation significance (Jenkins and Boseto 2007).

The rich biological diversity and high endemicity of Solomon Islands is most likely due to the area's geographical complexity (Conservation International 2013). Numerous tectonic events between the Pacific and Australian tectonic plates formed a diverse range of islands of varying age and isolation (Meuller-Dubois 1998). The islands have never been in land contact with the Asian or Australian continents, or New Guinea Island, allowing a unique tropical rainforest flora and fauna to evolve with high levels of endemism (Furusawa *et al.* 2014).

Throughout Solomon Islands, environmental and natural resource management is predominantly community based, in line with the local customary tenure and governance system. Approximately 87% of the land is classified as 'customary land'. The land and nearshore sea is both owned and managed by traditional genealogical groups, such that rural communities themselves have autonomy over their natural resources and the right both to close or to provide resource access (Abernathy *et al.* 2014; Furusawa *et al.* 2014).

Tribal chiefs have the responsibility to manage both land and marine resources for the benefit of the tribe, traditionally involving decisions over when to close fishing access to reefs and where to use land for farming and dwellings (Aswani 1999). More recently, communities have been leasing rights to fisheries or timber, primarily to companies from Malaysia, China and Japan (Halpern *et al.* 2013). Given the customary tenure system, formal conservation initiatives are most commonly in the form of community-based resource management (CBRM). More than 350 communities are known to have carried out some sort of CBRM (Govan *et al.* 2015).

Government policies also recognise the value of CBRM, even for achieving objectives associated with climate change. For example, the Solomon Islands National Plan of Action for the Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (SI-NPOA CTI), and subsequently the Inshore Fisheries Strategy (2010–2012), both recommend CBRM as the basis of resource management to achieve a variety of goals covering climate change vulnerability and adaptation, ecosystem approaches, food security, management of key species and habitats, and appropriate use of protected areas (Govan *et al.* 2015).

In terms of protected areas, a relatively small proportion of the country is protected by formal protected areas, with 28 land based and 24 marine protected areas formally recognised (PIPAP 2016). The Pacific Islands Protected Areas Portal (PIPAP 2016) states that 2.21% (644 km^2) of the total land area of Solomon Islands is protected, while 0.12% (1,926 km^2) of the total marine area is protected (WDPA 2013). The largest managed areas include (Figure 3-2):

- East Rennell World Heritage Area (87,500 ha);
- Anarvon Community Marine Conservation Area (16,187 ha); and
- a notable network of marine protected areas in Temotu Province.

All other managed areas are typically small scale CBRM areas (Figure 3-2), which generally aim to achieve sustainable resource use and secure resources for future exploitation (Halpern *et al.* 2013; Abernathy *et al.* 2014).

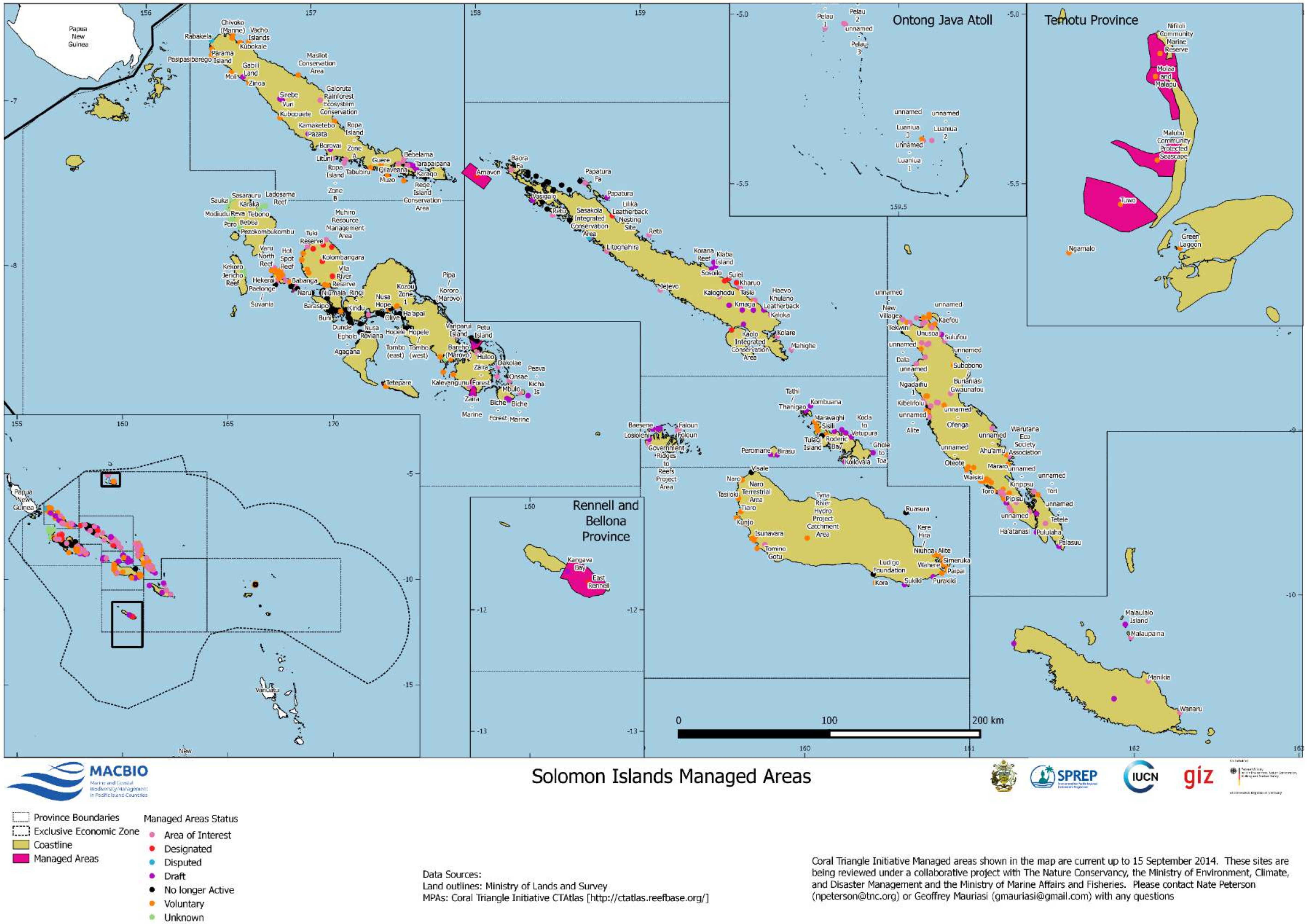


Figure 3-2 Managed areas in Solomon Islands (image courtesy of MACBIO)

While the total area of protected and/or otherwise formally managed areas remains small, there has been considerable recent investment in identifying areas of conservation significance for the purposes of informing future conservation planning and development decisions. In particular, the following have been identified at the national scale (Figure 3-4 and Figure 3-5).

- Key Biodiversity Areas (KBAs). KBAs are sites that contribute to the global persistence of biodiversity, including vital habitat for threatened plant and animal species in terrestrial, freshwater and marine ecosystems (BirdLife International 2017).
- Ecologically and Biologically Significant Areas (EBSAs). EBSAs are areas which, through scientific criteria, have been identified as important for the healthy functioning of our oceans and the services that they provide (CBD Secretariat 2012).
- Important Bird and Biodiversity Areas (IBAs). IBAs are KBAs identified for birds, using internationally agreed criteria applied locally by experts (BirdLife International 2017).

These are predominantly terrestrial areas of significance, and together encompass a large proportion of the total land area. Further information on individual KBAs, EBSAs and IBAs is provided in the Solomon Island Government's National Biodiversity Strategic Action Plan (NBSAP) (Pauku and Lapo 2009) and supporting documents such as Filardi *et al.* (2007).

In the context of climate change and EbA, these significant areas are likely indicative of high value or intact ecosystems that provide a range of ecosystem services at the national scale (i.e. services in addition to those relating to biodiversity and conservation). They provide a starting point for considering future adaptation and resilience-building initiatives, particularly where these significant areas coincide with areas of high resource use or other existing/future threats.

Future conservation efforts, including those associated with EbA initiatives, should continue to consider a 'ridge-to-reef' approach, which is already recognised as a holistic conservation strategy that is appropriate in Solomon Islands. This approach focused on the importance of biological and physical interactions and linkages between ecosystems (see example in Figure 3-3). This could include, for example, the need to restrict terrestrial vegetation clearing to reduce sediment run-off to a nearby marine protected area (MPA). Its importance is also highlighted by freshwater fish. Since amphidromy is the dominant life history strategy for freshwater fish in Solomon Islands (i.e. 25% of species rely on access to move between fresh and saline waters), conserving adequate ecological links between freshwaters and estuarine/marine waters is critical (Jenkins and Boseto 2007; Jenkins *et al.* 2008).

Figure 3-3 Example of ridge-to-reef benefits (SPREP 2014)

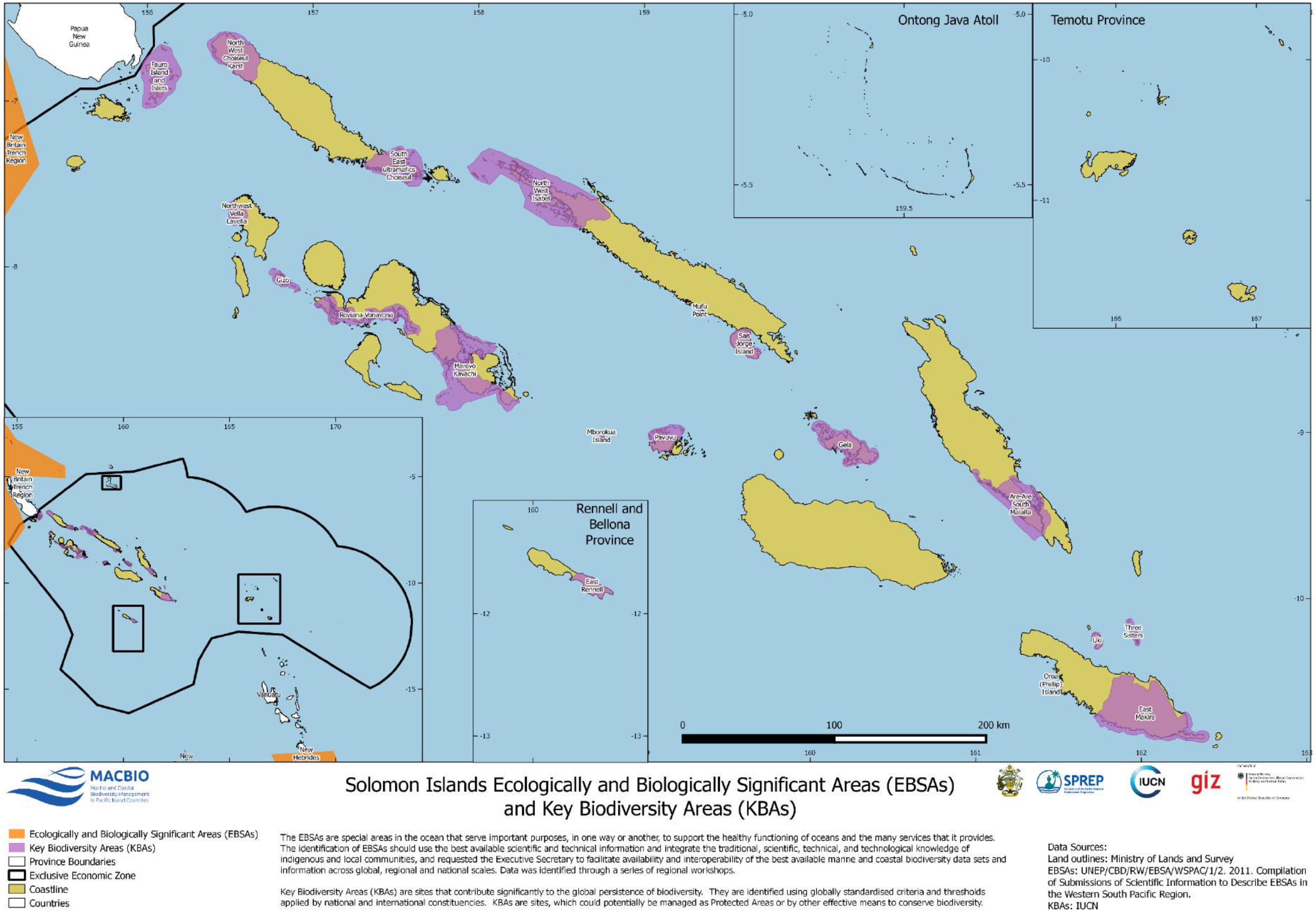


Figure 3-4 Key Biodiversity Areas (KBAs) and Ecologically and Biologically Significant Areas (EBSAs) (image courtesy MACBIO)

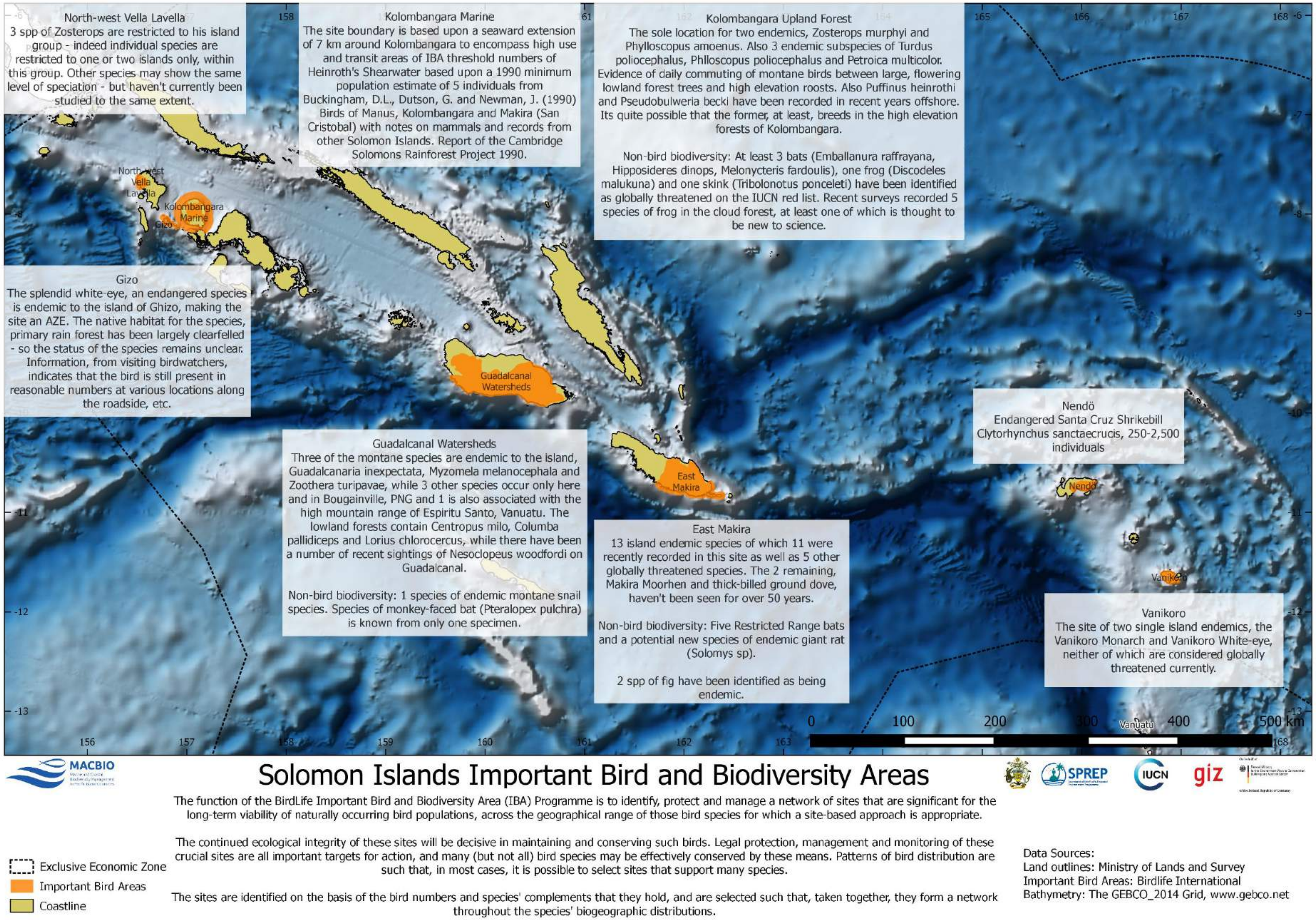


Figure 3-5 Important bird areas (IBAs) (image courtesy MACBIO)

3.5 National governance

Governance in Solomon Islands is split between formal state institutions and traditional and community institutions. Formal state governance is led by a national, democratically elected parliament of 50 members, each representing a single geographically defined electorate (Roughan and Wara 2010). Executive government is derived from this parliament through a process of coalition formation and the election of a prime minister who then appoints a cabinet. There are nine provinces and each provincial government is elected through area elections. A matrix of customary authority, church-based institutions and locale-specific community bodies forms the main context for local level governance, the exact nature and makeup of which varies considerably across all provinces (*ibid*).

Effective institutional administrations are imperative for environmental management and enforcement of environmental legislation and policies. While governmental and inter-governmental institutions have been established in Solomon Islands to govern and protect the management of ecosystems, an update of environmental legislation is urgently needed. SPREP (2016) reports that the region is hindered by the lack of capacity and resources to develop, monitor and enforce environmental legislation, which is delayed by bureaucratic processes. The need for an institutional overhaul is intensified by the projected rapid population increase over the coming decades and the increase in economic and social development.

Improved integration and coordination of legislation, policies, strategies and programmes amongst national and sub-national institutions and non-governmental institutions is also needed. Mataki (2011) reports that the barriers to integration and better coordination are formed by the fragmented and sectoral-based legislative and institutional frameworks and ‘turf protection’, as well as lack of disciplinebased training of government officials. Due to capacity limitations at the local level, and the scale and complexity of socio-ecological issues affecting Solomon Islands, actions to better manage ecosystems and strengthen community resilience will benefit significantly from being aligned to national and sectoral policies.

The national governance framework for Solomon Islands in terms of environmental threats facing the country are outlined in Table 3-2.

Table 3-2 National governance framework (SPREP 2016)

Threats	Legal Framework	Institutional Arrangements	Strategy/Plans/Comments
Land use and land-use change	Town and Country Planning Act [Ch 154]	The Ministry of Lands and Survey is responsible for the administering of land. The Town and Country Planning Board is responsible for regulating and providing approvals for proposed plan requests and building approvals. A local planning scheme (LPS) is submitted to the minister by the board and upon approval is published in the gazette. The LPS is to assist in the selection of, or to define sites for, particular purposes, whether by the	National Climate Change Policy 2012–2017 National Biodiversity Strategy and Action Plan (NBSAP) Solomon Islands National Development Strategy 2011–2020 National Adaptation Program of Action (NAPA) Pacific Mangroves Initiative, National Solid Waste Management Strategy. The Ministry of Lands and Survey is responsible for the administering of land. The

Threats	Legal Framework	Institutional Arrangements	Strategy/Plans/Comments
		carrying out of development thereon or otherwise.	Constitution of Solomon Islands explicitly recognises customary law and states that it will have effect as part of the law of Solomon Islands.
Environmental effect of developments and activities	No legislation specifically relating to the EIA process. The primary piece of legislation concerning EIAs is the Environment Act and the Environment Regulations 2008	The Ministry of Environment is responsible for regulating the Environment Act, including the overseeing of the EIA process for any development proposals. The Director of Environment and Conservation assesses the EIA report, letters and comments and decides whether or not to grant the mining, logging or whatever development proposal is before him. The director's decision may be appealed against by the proponent to the Environment Advisory Committee (EAC) within 30 days of notice of decision. Proponents may further appeal the Environment Advisory Committee's decision to the Minister of Environment.	NBSAP Solomon Islands National Development Strategy 2011–2020 National Solid Waste Management Strategy Landowners have a right to be given a copy of the EIA report, if logging or mining will affect their land or community. The thrust of the Environment Act is on the procedures of EIAs. It is a requirement of the act that all prescribed developments are required to undergo an EIA, for which development consent is required. The Solomon Islands EIA guideline has been prepared by the Environment and Conservation Division with the aim of simplifying the procedures of EIA outlined in the act and accompanying Environment Regulations 2008. This was to provide basic advice and guidance on the EIA process for government officers, planners, developers, resource owners and those involved in processing development proposals.
Pollution and waste management	No legislation specific to pollution or waste management. The key relevant legislation includes Environment Act 1998 and the Environment Regulations 2008	The Director of Environment is mandated to receive applications for licences to discharge waste or emit noise, odour or electronic magnetic radiation. The director may revoke or suspend the licence, if satisfied that there has been a breach of any of the conditions of the licence issued. Under the Environment Act, the minister may make regulations on matters pertaining to the effectiveness of the act that include matters pertaining to pollution and waste management. The director may serve abatement notices for non-	Japanese Technical Cooperation Project Promotion for Regional Initiative on Solid Waste Management (JPRISIM) National Climate Change Policy 2012–2017 NBSAP Solomon Islands National Development Strategy 2011–2020, National Adaptation Program of Action (NAPA) National Solid Waste Management Strategy There is a substantial lack of policy, strategy and government initiative and commitment to tackling Solomon islands' pollution

Threats	Legal Framework	Institutional Arrangements	Strategy/Plans/Comments
		compliance of provisions of a pollution abatement notice. Environment inspectors may serve stop notices to persons not complying with any of the requirements contained in the pollution abatement notice.	and waste problems. There is a poor level of domestic wastewater disposal and solid waste management, which is the primary source of pollution to the marine environment. At least 75% of sewage flows through a piped collection system directly into the sea without treatment, reflecting the level of waste management in the country.
Deforestation and mining	Forest Resources and Timber Utilisation Act Forest Resources and Timber Utilisation Protected species Mines and Minerals Act 1996 Mines and Minerals Regulations 1996	Legislation specific to mining is the Mines and Minerals Act 1996 and the Mines and Minerals Regulations 1996. The government department with primary responsibility for administration of the mineral sector is the Department of Mines and Energy. The government department with primary responsibility for administration of the mineral sector is the Department of Mines and Energy, which is responsible for prescribing appropriate procedures and granting tenements, primarily in the form of permits, licences, and leases. . The Ministry of Environment, Climate Change, Disaster Management and Meteorology also plays an important role in the mineral sector because of its role in overseeing mineral sector developers' compliance with the environmental components of the regulatory framework. The Minerals Board advises the Minister for Mines on issuance of mineral permits, licences and leases. The Minerals Board assists with negotiations, determination of access arrangements and fees, and compensation for damage. The provincial government is responsible for granting business licences to development proponents. Loggers must first get development consent from the Ministry of Environment and a logging licence from the Ministry of Forestry.	MESCAL POWPA Solomon Islands Code of Logging Practice National Climate Change Policy 2012–2017 NBSAP Solomon Islands National Development Strategy 2011–2020 National Adaptation Programme of Action (NAPA) Clean Development Mechanism (CDM) Pacific Mangroves Initiative National Solid Waste Management Strategy. Forests cover 79% of the land in Solomon Islands and are all privately owned. Solomon Islands' forestry industry faces the challenges of unsustainable logging and the unregulated conversion of forests to other land uses. A decline of harvestable logs has resulted in mining now being seen as the mainstay of the economy.
Climate change and	Legislation specific to disaster impacts is the National Disaster Act.	The National Disaster Act supported by the National Disaster Plan established the	National Climate Change Policy 2012–2017

Threats	Legal Framework	Institutional Arrangements	Strategy/Plans/Comments
disaster impacts	Other primarily related legislation include the National Disaster Council Act. There is no legislation specific to climate change but related primary legislation includes the Environment Act and Environment Regulations	National Disaster Council (NDC). The NDC is supported by the National Disaster Management Office (NDMO) under the Ministry of Home Affairs. The NDC and NDMO are responsible for disaster preparedness and response. Disaster risk reduction is also the responsibility of the NDC. Data on geological hazards are produced by the Geo Hazards Unit of the Ministry of Mines and Energy. Climate data are produced by the Metrological Division of the Ministry of Environment, Conservation and Metrology.	NBSAP Solomon Islands National Development Strategy 2011–2020 National Disaster Plan Regional Islands Framework for Disaster Risk Reduction and Disaster Management 2005–2015 Coping with Climate Change in the Pacific Island Region (CCCPIR) Pacific Island Framework for Action on Climate Change 2006–2015 (PIFACC) NAPA CDM

3.5.1 Climate change governance

The Solomon Islands Government is party to the United Nations Framework Convention on Climate Change (UNFCCC) and the 2015 Paris Agreement. Additionally, in the Pacific region, the government is a signatory to the Framework for Pacific Regionalism and the Framework for Resilient Development in the Pacific (FRDP). At the national level, there is no legislation specific to climate change, although related legislation includes the Environment Act and Environment Regulations. There is legislation specific to disaster impacts – the National Disaster Act – while other related legislation includes the National Disaster Council Act.

The government's commitment to climate change is demonstrated through the National Climate Change Policy 2012–2017. The policy, launched in June 2012 by the Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM), was developed by several Solomon Island government ministries and supporting organisations. The policy provides a framework for a national approach to addressing the adverse effects of climate change, adaptation, and achieving sustainable development. The institutional arrangements for the implementation of the National Climate Change Policy are shown in Figure 3-6. Several other national level documents address climate change issues, including the Solomon Islands National Development Strategy 2011–2020 (MDPAC 2011); and the Solomon Islands National Biodiversity Strategy and Action Plan (Pauku and Lapo 2009).

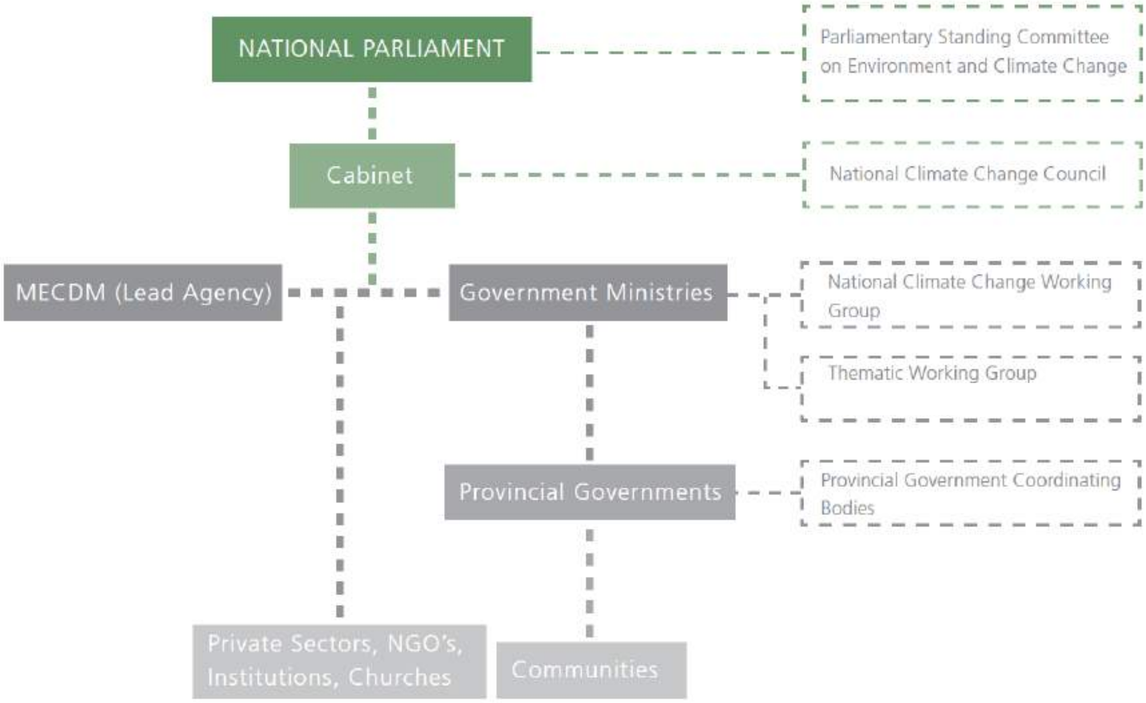


Figure 3-6 Institutional arrangements for the implementation of the National Climate Change Policy (Source: Rodil and Mias-Cea 2014)

Difficulties to adaptation and mitigation of climate change in Solomon Islands include a lack of governmental commitment, a lack of policy and institutional framework, poor coordination and links, a lack of data capacity, and budgetary constraints. The Global Climate Change Alliance[1] (GCCA 2012), which leads the Solomon Islands Climate Assistance Program (SICAP), provided an evaluation of the lessons learned and recommendations gathered from their time in supporting the implementation of the national climate change policy, as listed below.

- Capacities in the Ministry of Environment (particularly in the Climate Change Division) remain overstretched and addressing these capacity constraints has been slower than anticipated (in the context of the recruitment freeze of public servants). The appointment of the new Permanent Secretary at the Ministry of Environment (July 2013) has improved the leadership and momentum of climate change activities in the ministry.
- Timely access to general budget support funds has proved difficult for the Ministry of Environment, with resulting delays in planned activities. The budget allocated to climate change actions is unknown.
- The large number of actors (ministries, donors, NGOs) and broad definition of the 'climate change' sector (encompassing adaptation, mitigation, disaster management, environment) poses challenges for effective coordination.

[1] The GCCA is an organisation established by the European Union (EU) in 2007 to strengthen dialogue and cooperation with developing countries, in particular least developed countries (LDCs) and small island developing States (SIDS).

- Ownership and leadership by the government, political commitment and an action-oriented matrix of reform priorities to assess progress and structure the policy dialogue are important success factors.
- The target of drafting appropriate guidelines for managed human resettlement that was included within SICAP was too ambitious. Human resettlement or relocation is a delicate issue. Cultural aspects, physical infrastructure (education and health services, elderly care, trauma counselling) and political concerns are factors that play a role and require consideration and involvement of wider authorities. It is obviously a lengthy process that should be taken forward holistically.

GCCA's recommendations:

- Ongoing vulnerability assessment to identify and rank affected, high-risk communities according to risk related criteria. Determining a realistic costing of climate change adaptation measures, including relocation. Drafting guidelines for human resettlement projects, after nation-wide consultations, including safeguard standards, to minimise risks of conflict due to resettlement.
- Ongoing strengthening of capacity in the Climate Change Division of the Ministry of Environment.
- Drafting a matrix of action and deliverables in the climate change sector as a tool for the Ministry of Environment's Climate Change Working Group.

4 Current state, trends, drivers of change and environmental consequences

The greatest current threat to ecosystems stem from human activities (SPREP 2016). These threats include habitat loss; invasive species; urban, agricultural and industrial pollution; and over-exploitation of natural resources. The direct and indirect effects of climate change and their interactions with human-induced threats will only intensify the risks to ecosystems.

This sections explores the current state of ecosystems, trends, drivers of change (non-climatic) and the environmental consequences of these changes at a national level.

4.1 Current state of ecosystems and national trends

As discussed in Section 3.4, Solomon Islands is globally recognised as a biodiversity hotspot, with extraordinary patterns of inter-island diversity and high degrees of endemism (Filardi *et al.* 2007; Conservation International 2013) and the second highest terrestrial biodiversity in the Pacific (exceeded only by Papua New Guinea). As part of the Coral Triangle, Solomon Islands contributes to the global centre of marine biodiversity that comprises 76% of the world's corals and 37% of the world's coral reef fish species (TNC 2008).

The SPREP *State of Conservation in Solomon Islands – Country Report 2013* (SPREP 2016) provides a high-level summary of the current state, pressures and threats facing ecosystems and native species, and trends predicted as of 2013 (see Table 4-1).

Table 4-1 Summary of current state of ecosystems and native species in Solomon Islands (SPREP 2016)

			Status			
Topic	Section	Indicator	State	Pressures and threats	Trend	Data quality
ECOSYSTEMS						
Terrestrial	1.1	Forest cover	Good	Fair	Deteriorating	Medium
Freshwater	1.2	Freshwater ecosystems	Good	Fair	Mixed	Low
Coastal	1.3.1	Coral reef	Fair	High	Deteriorating	Medium
	1.3.2	Mangrove ecosystem	Good	Fair	Mixed	Medium
	1.3.3	Seagrass beds	Good	Fair	Mixed	Medium
Marine	1.4.1	Ocean health	Fair	Poor	Deteriorating	Medium
	1.4.2	Utilised species	Fair	Fair	Deteriorating	Medium

NB: The status of 'High' for 'Pressure and threats' on 'Coral reef' is believed to be incorrectly rated.

Data quality listed in Table 4-1 provides an estimate of the amount and quality of the data that were used to assess the trend for each indicator.

In Table 4-1, the status of each ecosystem is rated good, fair or poor for its current state and for the pressures and threats it faces. . A trend for each indicator is then presented and ranges from 'mixed', indicating that some aspects have improved and some have worsened, 'deteriorating', indicating the state of biodiversity has worsened, and 'improving', indicating the state of biodiversity has improved.

In terms of the current state of Solomon Island ecosystems, all indicators investigated by SPREP (2016) were rated as being in a good to fair state. As reflected in the Solomon Islands unique and high level of biodiversity and endemism, ratings of fair or poor indicate a reduction in ecosystem biodiversity and habitat. Furthermore, all ecosystem indicators are reported to be deteriorating or mixed, i.e. some aspects are improving, and some are deteriorating.

The following section provides further information on the current state of Solomon Island ecosystems and the projected future trends.

4.1.1 Forests

4.1.1.1 Forest types

Solomon Islands has six distinct forest types and approximately 5,000 plant species (Pauku 2009). The forest types vary in extent across each province, but the species mix is generally uniform between the islands (Whitmore 1969). The six vegetation types are described below (adapted from MFEC 1995).

- **Grassland and other non-forest areas** comprise mainly herbaceous species. The predominant species include *Imperata cylindrica, Dicranoptera linearis* and *Themeda australis*. Examples of commonly occurring species are *Mimosa invisa, Morinda citrifolia*, *Saccharum spontaneum*, *Polygala paniculata* and *Timonius timon*. Some of these species (e.g. *M. invisa*) are also very common in disturbed areas.
- **Saline swamp forests** are subject to tidal influence as they are found in estuaries and foreshores. Examples of commonly occurring species are *Barringtonia asiatica, Calophyllum inophyllum, Casuarina equisetifolia, Terminalia catappa, Intsia bijuga, Inocarpus fagifer, Pandanus spp., Barringtonia racemosa* and species of mangroves.
- **Freshwater swamp and riverine forests** are typically found in poorly drained soil at low altitudes with little micro-relief. Species such as *Inocarpus fagifer, Mextroxylon salomonense, M. sagu, Barringtonia* racemosa are found here, although some important timber species are also present (e.g. *Terminalia brassii* and *Dillenia salomonensis*).
- **Lowland rainforests** include forests at altitudes up to 5 m–70 m, often with complex structure due to the high number of species in upper or hill forest and patches of freshwater swamp forest. Natural disasters such as cyclones and human activities often disturb this forest type, as evident in a high incidence of re-growth and secondary species. Commonly occurring species in this vegetation are timber species, such as *Campnosperma brevipetiolata, Dillenia salomonensis, Endospermum medullosum, Parinari salomonensis, Terminalia calamansanai, Schizomeria serrata, Maranthes corymbosa, Pometia pinnata, Gmelina moluccana, Elaeocarpus sphaericus* and *Vitex cofasus*. Most indigenous fruit trees are also found in this forest, including *Canarium spp, Syzygium malaccensis, Magnifera minor, Spondius dulce, Barringtonia procera, B. edulis, Artocarpus altilis, Gnetum gnemon*, and *Burkella obovata*.

- **Hill forests** occur at altitudes of 400–600 m and on well-drained soils. They exhibit a complex structure, with varying tree heights and canopy density. Some species in the lowland forest are also present here, as well as those species commonly found in the montane forest. Species forming this forest include *Pometia pinnata, Gmelina moluccana, Elaeocarpus sphaericus, Campnosperma brevipetiolata, Dillenia salomonensis, Endospermum medullosum, Parinari salomonensis, Terminalia calamansanai, Schizomeria serrata, Maranthes corymbosa,* and *Vitex cofasus*. Fruit tree species such as *Canarium spp., Gnetum gnemon* and *Artocarpus altilis* are also present.
- **Montane forests** occur at altitudes above 600 m, on ridge tops and mountain summits, but can be found in lower elevations under harsher conditions. These are characterised by a dense and compact canopy with small, light tree crowns. Species in this forest type are *Callophyllum kajewskii, Callophyllum pseudovitiense, Eugenia spp., Dacrydium spp., Pandanus spp., Racembambos scandens* and ferns.

The forest types and their area of coverage (ha) and percentage of land area of each province are presented in Table 4-2.

Table 4-2 Area coverage of forest types per province (Source: MFEC 1995)

Province	Guadalcanal		Central		Malaita		Isabel		Western		Makira		Renbell		Temotu	
Forest type	Area (ha)	% land area	Area (ha)	% land area	Area (ha)	% land area	Area (ha)	% land area	Area (ha)	% land area	Area (ha)	% land area	Area (ha)	% land area	Area (ha)	% land area
Montane	51,204	9.6	174	0.3	6,612	1.6	10,164	2.5	22,044	4.4	11,204	3.5	-	-	512	0.6
Hill	401,936	75.1	38,765	61.3	354,544	84.4	325,667	78.7	351,436	69.9	265,466	80.4	23,120	33.1	56,500	65.3
Lowland	58,844	11.0	13,546	21.4	20,144	4.8	17,812	4.3	53,312	10.6	14,996	4.5	2,200	3.1	6,076	7.0
Freshwater and riverine	10,100	1.9	2,700	4.3	10,705	2.5	25,216	6.1	39,888	7.9	9,096	2.8	280	0.4	200	0.2
Saline swamp	1,328	0.2	3,112	4.9	9,992	2.4	17,852	4.3	10,544	2.1	908	0.3	188	0.3	2,504	2.9
Grassland (and other non-forest areas)	10,920	2.0	212	0.3	4,016	1.0	8,215	2.0	18,756	3.7	8,610	2.6	528	0.8	8,172	9.4

The total area presented in Table 4.2 does not match the total area of the country, as not all islands are surveyed and different methods are used (FRIS–ERM-S). Choiseul excludes Rob Roy and Wagina islands (approximately 15,500 ha).

In 2010, forests covered approximately 77% of Solomon Island's land area, which is down from 80% in 1990 (FAO 2010) (Table 4-3). This reduction in forest cover is reported to be mostly non-commercial forest because the bulk of the commercial forest has now been logged (Pacific Horizon 2008). While most of the lowland area of Solomon Islands has been logged or converted to plantations, the montane and cloud forests are still relatively intact (*ibid*).

Table 4-3 Change in forest cover over time in Solomon Islands (SPREP 2016)

Total Land Area (1,000 ha)	Forest (1,000 ha) 1990	Forest (1,000 ha) 2000	Forest (1,000 ha) 2005	Forest (1,000 ha) 2010
2,890	2,324	2,268	2,241	2,213

Existing threats to forest cover is dominated by economic activities, including logging and agriculture, while mining and infrastructure development activities (roads and settlements) currently present less of a threat (SPREP 2016). The spread of invasive species and natural disasters are also likely to cause increased levels of forest degradation (*ibid*). SPREP (2016) rates the current state of forests as good, while the status of pressures and threats is rated as fair. Trends relating to both the state of forests and pressures that threaten forests are projected to deteriorate (*ibid*).

4.1.2 Freshwater ecosystems

Freshwater ecosystems include rivers, lakes, swamps, groundwater and wetland systems. Major rivers (30-40 km) are present in Choiseul and Guadalcanal, but the most common freshwater habitats are steep-gradient rocky mountain streams located on all islands (SPREP 2016). Major streams and rivers typically terminate in long estuaries that form vital nursery habitats for marine fish and crustaceans (Polhemus *et al.* 2008). Some areas contain extensive coastal lowlands that support complex habitats, ranging from tall, closed-canopy freshwater swamp forests to florally diverse mangrove swamps (SPREP 2016) while a high diversity and endemism exist in freshwater invertebrates (Polhemus *et al.* 2008). SPREP (2016) rates the current state of freshwater ecosystems as good, while the status of pressures and threats is rated as fair.

Solomon Islands ES

River, lake and wetland systems are experiencing a reduction in freshwater species richness from threatening processes such as flow alteration (e.g. logging and commercial plantation activities causing siltation), barriers (e.g. dam construction), habitat and water quality degradation (due to siltation), introduction of invasive species (e.g. tilapia, water hyacinth) and overharvesting (*ibid*). Trends relating to both the state of freshwater ecosystems and pressures that threaten these ecosystems are projected to improve in some aspects, and worsen in others (*ibid*).

4.1.3 Coral reefs

Solomon Islands' coral reef systems span an area of 575,000 ha (*ibid*) and includes a diverse range of reef types, such as narrow fringing reefs, rare double barrier reefs, patch reefs and atolls (Sabetian and Afzal 2004). Sites surveyed in Turak (2006) indicate that the overall condition of most reefs and coral communities in Solomon Islands is good, with reef degradation low to moderate at most sites. Coral communities found in very sheltered inlets in the fjord-like coastlines were unique, had high species richness, typically contained high living coral cover and in 2006 were generally in good health, with hard coral cover of between 35 and 45% (*ibid*). In 2007, however, an earthquake and tsunami resulted in extensive reef damage and some shallow reefs received irreparable damage. SPREP (2016) rates the status of the state of coral reefs as fair, while the status of pressures and threats is rated as good.

SPREP (2016) reports that 71% of Solomon Island reefs are considered to be at medium or higher threat level from local factors, including: watershed-based pollution/sedimentation from developments such as mining; vegetation clearance for agriculture and forestry; marine pollution (ports, oil terminals, shipping channels, agricultural pesticides and fertilizers, sewage from residential/tourist centres); coastal development (cities, settlements, airports and military bases, mines, tourist resorts); and destructive fishing and overfishing.

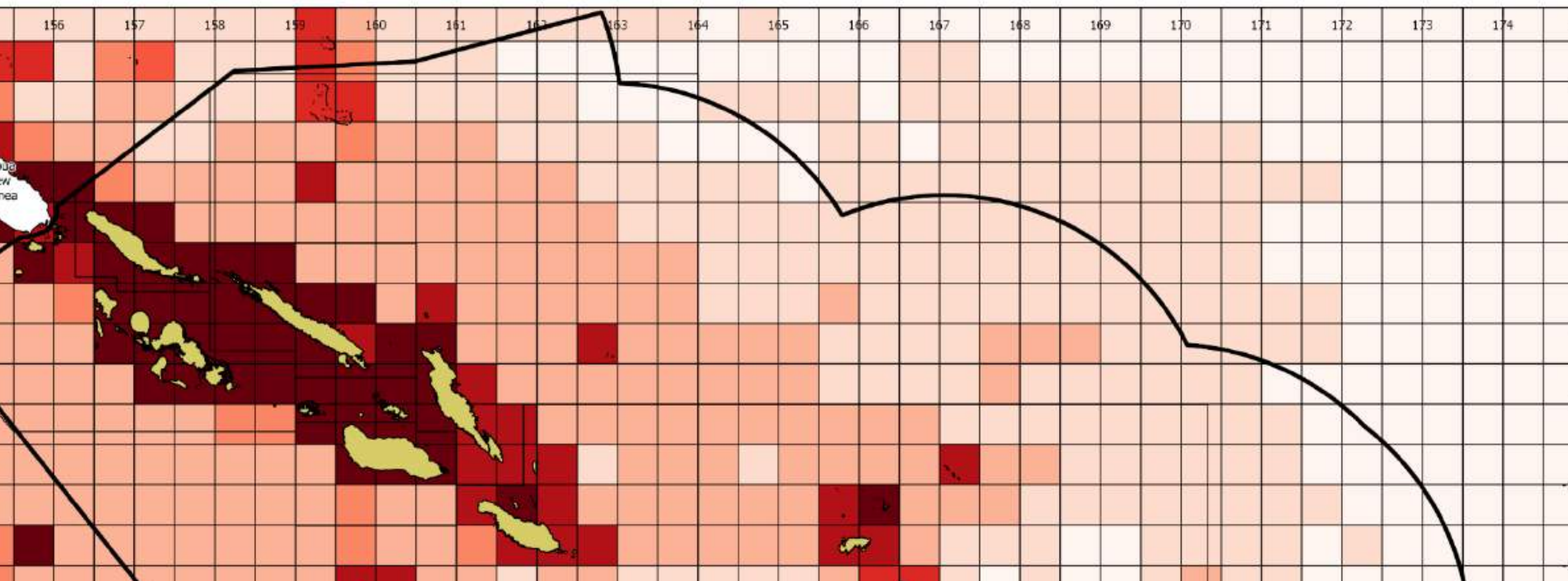
One of the most critical issues facing Solomon Islands and its marine resources is the rapid population growth rate, coupled with the high dependence on marine resources for ecosystem services such as food and income (SPREP 2016). If population growth and deforestation continue at high rates, threats to coral reefs are expected to increase significantly. Trends relating to both the state of coral reefs and the pressures that threaten coral reefs are projected to deteriorate (*ibid*).

4.1.4 Mangroves

Mangroves are prevalent throughout Solomon Islands, particularly in the western group of islands. Mangrove species are dominated by *Rhizophora* and *Bruguiera* while *Lumnitzera* is also common. Mangroves are of great significance to the livelihoods of many Solomon Island communities and economies. SPREP (2016) rates the status of the state of mangroves as good, while the status of pressures and threats is rated as fair.

Unlike terrestrial forests, mangroves have not been commercially exploited to date, but they are increasingly under threat from conversion to other land uses from urban development and mining (SPREP 2016). Over-harvesting of mangroves for fuelwood, timber extraction for building materials and herbal medicines, overharvesting of fish and invertebrate resources, and logging are also major threats (*ibid*). Converting mangroves to other land uses and the over harvesting of mangroves increases coastal erosion, reduces mangrove species richness and threatens fish and invertebrate spawning grounds. This results in ecosystem changes and affects the provisioning and regulating ecosystem services that many communities rely on (e.g. habitat for food sources, coastal protection, water regulation, shelter).

Table 4-4 presents the trend in the decline in mangrove forest cover over time from 1990 to 2010. Trends relating to both the state of mangroves and the pressures that threaten mangroves are



4.1.5 Seagrass

Solomon Islands has an estimated area of 10,000 ha of seagrass beds spread across the coastal intertidal flats around the country (Sulu *et al*. 2012). Ten species of seagrass have been recorded in Solomon Islands (Short *et al.* 2007; Ellis 2009). Seagrass is of high importance to fish and invertebrates in the provision of food and nursery grounds, including for endangered species such as green sea turtle (*Chelonia mydas*) and dugong (*Dugong dugon*). Seagrass is also of commercial importance to artisanal fisheries (SPREP 2016). SPREP (2016) rates the status of the state of seagrass as good, while the status of pressures and threats is rated as fair.

At a local level, seagrass is likely to be affected by coastal development, pollution from inadequate waste and sanitation management, overharvesting of coral and fisheries, coastal erosion, flooding, and the sedimentation of rivers due to mining, logging and agricultural activities (*ibid*). Trends relating to both the state of seagrass and the pressures that threaten seagrass are projected to improve in some areas and in others are likely to deteriorate (*ibid*).

4.1.6 Ocean health

The Pacific Ocean is the largest ecosystem in the world. The coastal and marine environments of Oceania sustain numerous activities that underpin local, sub-national, national and international economies and provide livelihoods and food security for millions of people (SPREP 2016). Marine ecosystems are continually being devastated by habitat destruction, pollution, climate change and overfishing, with the latter activity believed to be the greatest human-induced threat to ocean health in the region (*ibid*). Over-exploitation has reduced many fish stocks throughout the Pacific and caused ecological shifts that reduce biodiversity and productivity. By-catch during commercial fishing activities and live capture and harvesting for the aquarium trade contribute to these effects (*ibid*). SPREP (2016) rate the status of the state of ocean health as fair, while the status of pressures and threats is rated as poor.

Human activities that alter the marine environment by affecting water quality, such as sedimentation from mining or agricultural practices, are likely to make it unsuitable for marine life that require precise environmental regulation. In addition to oil and gas extraction, most pollution in the ocean originates from industry, agriculture or domestic sources on land (*ibid*). Marine invasive species are also an increasing threat to marine ecosystems. Trends relating to both the state of ocean health and the pressures that threaten ocean health are projected to deteriorate (*ibid*).

4.2 Drivers of change

The following section further explores the non-climatic drivers of factors contributing to the change in ecosystem condition, biodiversity and habitat. In the absence of recent information and data, all information presented in this section is sourced from Solomon Islands State of the Environment Report 2008 (SOE 2008) and the SPREP Solomon Island Country Profile and Virtual Environment Library, unless stated otherwise.

4.2.1 Population pressures

A rapidly increasing population has seen a considerable intensification of land use in Solomon Islands over the past 30 years. The population estimate in 2014 was approximately 609,800 with an average annual population growth rate of 2.07% (SPREP 2016). The annual population growth rate has declined over the last couple of decades; 1986–1999 experienced a 2.8% growth and from 1999–2009 a lower growth rate of 2.3% was recorded. Based on 2006 statistics, 41.5% of the population was estimated to be under 15 years old (Solomon Islands National Statistics Office 2006). The high proportion of young people indicates that the population growth rate will continue to be high, further increasing population pressures and subsistence use intensification.

Despite a declining growth rate, the population size continues to rapidly increase and is one of the highest growth rates in the world (SPREP 2016). A population growth scenario for Solomon Islands based on the average annual population growth rate of 2.07% (2014) is presented in Figure 4-1. It is estimated that the population will double (1,219,600) by 2048 and reach almost two million by 2070 and almost three million by the end of the century.

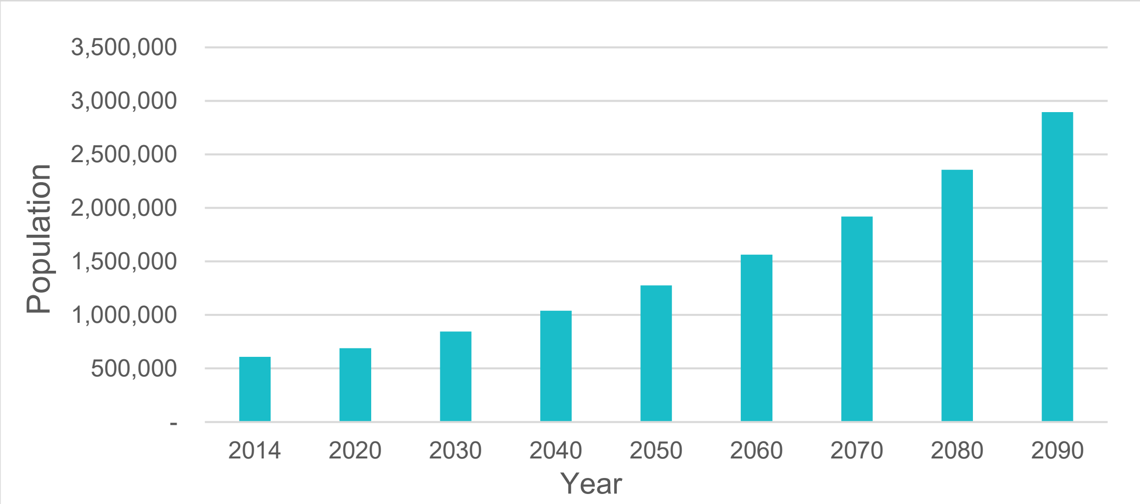


Figure 4-1 Projected population estimates for Solomon Islands (2.07% annual growth rate)

Urbanisation is another contributing factor to environmental change, with an estimated 20% of the population living in urban areas. The annual urban growth rate is 4.7% and if the present trend continues, 25% of the Solomon Island population will be living in urban areas by 2020 (approximately 152,450 people).

4.2.2 Subsistence use intensification

In the past and in areas of low population density, shifting cultivation maintains soil fertility by means of long fallow periods,15–25 years, but in many locations, they are typically 5–9 years and as short as 1–4 years in some places where high population densities exist (e.g. more than ten people per square km (Mackay 1988). The reduced fallow periods, and often extended cropping periods, have produced food for the growing population, but this is also resulting in a reduction of soil fertility, with consequent reduction in crop yields. This is now becoming a major problem in many small islands (including Wagina Island in Choiseul Province).

Increasing pest and disease issues pose a threat to subsistence food production and are often associated with more intensive land use. Widespread logging has also reduced potential food garden areas in some locations, while a lack of labour due to young population migrating to urban areas is another issue facing subsistence food production.

The pressure to farm cash crops has driven the introduction of harmful farming practices, such as extensive land clearing, intensification of land use and inappropriate soil cultivation. The occupation of most flat arable lands by cash crops is also pushing subsistence cropping onto marginal areas especially steep lands. About 63% of the total land area (28,000 square km) in Solomon Islands comprises steep lands (> 20% slope) which are used for shifting cultivation by smallholders. Intensified and constant cultivation of marginal sloping lands is unsustainable and is responsible for soil erosion, loss of soil fertility, an increase in pest and diseases, a decline in crop yield, and widespread land degradation (Cheatle 1987). The SOE report (2008) indicates that there are few, if any, widespread and quantitative data on soil erosion rates, the extent and severity of land degradation, the decline in soil fertility, and the sustainability of current cropping systems in Solomon Islands.

4.2.3 Commercial plantations

Solomon Islands' agriculture sector exports are largely palm oil, palm kernels, copra and cocoa. They are key measured contributors to the country's gross domestic product (GDP). The agriculture sector accounts for approximately 50% of GDP (SPREP 2013). Copra and cocoa production are dominated by smallholder production, with average farm size ranging from 0.1 to around 10 ha.

As demonstrated in Section 4.1.1, forests covered approximately 77% of Solomon Islands' land area in 2010, which is down from 80% in 1990 (FAO 2010). The conversion of large areas of land, mostly fertile coastal lands, into commercial plantations, is a significant threat to biodiversity. This form of land change adds pressure on land resources by displacing domestic food gardening and, if not managed properly, will pollute river systems and coastal marine ecosystems due to excessive run-off and siltation during heavy rains. If not properly managed, these all have considerable potential to affect the country's rapidly growing population.

4.2.4 Urbanisation

Urbanisation is recognised as one of the principal causes of environmental change. Around 20% of the population is classified as urban dwellers (2009 census data), of which over 70% reside in the capital city of Honiara. If the adjoining urban areas of Guadalcanal are included, 'greater Honiara' represents 82% of the urban population of Solomon Islands. With an annual urban growth rate of 4.7%, it is anticipated that, by 2020, approximately 25% of the Solomon Island population will be living in urban areas if the present trend continues (UN-Habitat 2012). The national and urban population increase is placing severe stress on public services and utility companies, which are struggling to provide essential services (health and education) and maintain regular supplies (water, electricity and waste collection services).

4.2.5 Mining

Open-pit mining has been limited to date to the Gold Ridge Mine on Guadalcanal. Open-pit mining can have a severe impact on the surrounding environment, due to deforestation and earth removal for the pit and ancillary earthworks, and also on the riverine drainage systems in the area, which are the potential receiving environment for contaminated run-off.

In July 2015, following Tropical Cyclone Raquel, which brought extreme rainfall to the region, the Solomon Islands government declared the Gold Ridge Mine a disaster area, with the tailings dam close to overflowing, resulting in an environmental catastrophe. The unseasonably heavy rain filled the Gold Ridge tailings dam to within 20 cm of full capacity, which threatened to rupture and result in arsenic, cyanide and heavy metals-laden tailings to flow downstream and potentially severely affect residents and ecosystems.

There are no mines currently in operation in Solomon Islands, although there are proposals for new mines throughout Isabel and Choiseul Provinces, including a proposed bauxite mine on Wagina Island.

4.2.6 Logging

There are several resources within the environment that are being exploited at unsustainable rates, but the most pressing is the country's forest resource. A critical situation exists with the forests of Solomon Islands; of all activities threatening the terrestrial biodiversity, logging is considered the leading threat. SPREP (2016) describes the current condition of biodiversity, habitat and ecosystems as good, while the status of pressures and threats to forests is rated as moderate.

Logging has played a central role in the economy of Solomon Islands for decades. Large scale commercial wood harvest from primary forests started in the 1960s and, until the 1980s, most logging took place on state land (Kabutaulaka 2000, 2006). Beginning in the early 1980s, exploitation shifted to customary land (which makes up approximately 90% of the total land area in Solomon Islands). An influx of multinational companies followed and the number of logging licences issued increased rapidly (TEEBcase 2012).

By the mid-1990s, timber exports contributed to approximately half the country's export revenue and a third of government revenue (Montgomery 1995; Fraser 1997). The sustainable harvest rate for Solomon Islands was estimated to be 325,000 cubic metres per year, but in the 1990s, actual logging rates reached double this amount (or 700,000 cubic metres per year) (Kabutaulaka 2000, 2006). The timber harvest increased to 1 million cubic metres in 2004, which equates to four times the sustainable harvest levels (SPREP 2016). Although the amount of timber exported continued to increase, government revenues decreased. Between 2002 and 2005, exports doubled while the contribution of logging revenue to government income fell from 16% in 2002 to 13% in 2004 (Tokaut 2006). SPREP (2016) estimates that forest cover has reduced by 4% from 1990 to 2013 (an additional 1% reduction from the 2010 figures presented in Section 4.1.1). The annual log export production for each province is outlined in Table 4-5 below, noting the forest coverage for each province previously presented in Table 4-2. Small-scale logging (for the local market) may be higher around major population centres, especially Honiara. However, given the scale and locations of logging for the export market, there is not necessarily an overall spatial link at the national scale between population densities and rates of deforestation from logging. Rather, the extent of logging in each province is more driven by the interaction between factors such as existing resource availability (i.e. forest cover) and resource access (i.e. landowner permissions).

Table 4-5 Annual summary of log export production by province (Source: Pauku 2009)

Year	Central	Choiseul	Guadal canal	Isabel	Makira	Malaita	Western	Total
1995	19,900	88,400	55,100	102,700	40,300	38,400	392,200	737,000
1996	34,000	87,500	76,500	81,200	31,000	37,900	457,800	805,900
1997	16,700	83,000	75,200	126,100	11,500	12,300	284,800	609,600
1998	17,000	89,100	99,900	130,200	11,600	4,500	234,500	586,800
1999	41,900	35,700	21,800	82,600	23,100	13,100	397,700	615,900
2000	5,100	44,100	14,100	101,300	16,100	17,700	322,900	521,300
2001	15,900	8,200	0	167,400	1,500	34,100	282,300	509,400
2002	9,500	21,000	0	171,800	7,200	17,400	357,300	584,200
2003	14,100	46,000	0	188,500	19,300	0	471,000	738,900
2004	30,600	113,200	0	144,300	35,200	20,000	625,500	986,800
2005	34,300	76,400	9,800	93,600	77,500	50,200	725,500	1,067,300
Total	**239,000**	**692,600**	**352,400**	**1,389,700**	**274,300**	**245,600**	**4,551,500**	**7,745,100**
Average *04/05*	*32,450*	*94,800*	*9,800*	*118,950*	*56,350*	*35,100*	*675,500*	*1,018,100*

4.2.7 Fishing and marine exports

Most marine ecosystems such as mangroves, lagoons and reefs are also being over-exploited in many areas. While population growth is responsible for additional pressure on these ecosystems throughout the country, commercial extraction is worsening these effects in many cases. In Oceania, an estimated 70–80% of the catch from inshore fisheries is used for subsistence purposes, while around 20% is going to markets (SPREP 2016). In 2008, an Asian Development Bank (ADB) project examined several studies on coastal fishing in Solomon Islands and estimated the annual catch for commercial production during the mid-2000s to be 3,250 tonnes, worth USD 3,307,190 and the subsistence fisheries at 15,000 tonnes, worth USD 10,980,393.

Continued over-harvesting is further undermining the resilience of ocean systems, while fisheries management is failing to halt the decline of key species and damage to marine ecosystems (*ibid*). SPREP (2016) reports that there was a significant deterioration of the quality of governance in the fisheries sector by the government and donors to strengthen fisheries institutions during the period of ethnic tension.

4.2.8 Pollution

Many households in the country do not have access to water supply systems and still rely on streams and rivers to obtain water for drinking and domestic purposes (e.g. washing and bathing). Pollution from both solid waste and sanitation and sewerage discharges is the major existing threat to waterways throughout Solomon Islands. Poor community awareness or attitudes, a high reliance on plastic as opposed to biodegradable or reusable products, and the lack of adequate waste collection and disposal services throughout most of the country, result in excessive disposal and accumulation of solid wastes to rivers and streams. Additional pollution inputs directly to rivers and streams include contaminants from sanitation uses, industrial discharges, agricultural run-off, and watershed run-off (e.g. sediment inputs). These pose human health risks through the community's use of this ecosystem type, both directly (e.g. drinking, swimming) and indirectly (e.g. consumption of contaminated food). They also undermine the integrity and resilience of ecosystem components in the rivers and streams (i.e. flora, fauna and their habitats), as well as of downstream marine ecosystems.

Pollution to the coastal and marine environment stems from two main sources: (a) land-based sources and through rivers and streams; and (b) marine-based sources. For example, in Honiara alone, at least 75% of sewage flows through a piped collection system directly into the sea without treatment. Discharges from ships in the form of garbage, bilge water and other pollutants are also a major source of sea-based pollution. An increase in these forms of pollution is already a concern as more ships are coming into and using the country’s harbours and waters. Local ships are also contributing to these forms of pollution.

4.2.9 Energy production and use

The majority of energy use in Solomon Islands is biomass for cooking and for drying copra and cocoa for export. However, the accessible fuelwood is increasingly scarce in some areas. For some parts of the country, the major fuelwoods for copra drying is mangrove, and its overuse is now a major contributing factor to coastal erosion.

4.3 Environmental consequences

The drivers of change and root causes outlined above have a significant effect on ecosystems and ecosystem services. In line with the drivers of change and root causes outlined in the SOE 2008 report, the consequences of these changes are explored and summarised below. Threats to specific ecosystems types are then explored further as part of this ESRAM study (see Section 5).

4.3.1 Freshwater stress

Freshwater resources are under stress, as indicated below.

- Erosion and sedimentation of stream and river systems from logging operations, subsistence cultivation on sloping lands and land clearing for plantations affect water quality and thus degrade reefs, mangrove areas and coastal fisheries. There is poor understanding amongst loggers and communities of the effects of land-clearing, logging, erosion and run-off on downstream and receiving environments including reefs and fisheries.
- Flow alteration, barriers, habitat and water quality degradation, introduction of invasive species and over-harvesting are resulting in a decline in freshwater species richness (SPREP 2016).
- Indiscriminate land-clearing for subsistence food production and for plantation and commercial logging is resulting in catchment drying. In 2008, the Honiara water supply source saw a 50% drop in water availability in the catchment.
- Pollution problems in river catchments are also increasing with rapid population growth, reflecting inadequate planning to control development in catchments and conflicting regulatory decisions, such as the granting of development rights and logging licenses in catchment or conservation areas.
- The cumulative effects of these threats are intensifying the risk of extinctions, with several endemic fish species reported in the IUCN Red List as threatened, and are compromising the sustainable use of freshwater ecosystems by local communities (SPREP 2016).

4.3.2 Soil stress and degradation

Serious soil stress is experienced through low crop yield and high incidence of pests and diseases. As land is degraded, it becomes a haven for invasive species due to the diminished ability of the ecosystem to control them. Invasive species in turn affect the soil-nutrient moisture regimes of catchments, leading to poor soil structures and further fertility decline. Most of the accessible soils have fertility and/or micronutrient deficiencies and increased exposure results in soil leaching and erosion, with great impact on soil quality and subsequently low crop yield. Soil degradation reduces food security by reducing not only the quantity of food produced but also its nutritional quality, which is critical to human health (FAO 2011).

4.3.3 Forest depletion

Due to the depletion of forests, communities are finding it increasingly difficult to access good quality water and forest products and materials for housing and food, which are important for village well-being and livelihoods. Much of the deforestation over large tracts of land occurs on very steep land.

Serious erosion, siltation, soil structure decline and loss of soil fertility threaten terrestrial and marine biodiversity, provisioning services such as renewable water supplies, and regulating services such as and pollution and water quality regulation. The production potential of the land is also heavily diminished. Highly invasive weeds further threaten disturbed forest areas and increase soil degradation.

Existing threats to forest cover are dominated by logging and agriculture, while mining and infrastructure development pose less of a threat. Based on the forest cover estimates presented in Table 4-3 for 1990, 2000, 2005 and 2010, a forest clearing scenario is presented in Figure 4-2. The scenario is based on a five-year clearing rate estimated at 1.2%.

Forest management and governance practices have been poor, due to corruption and the lack of technical and human resources to conduct and monitor logging operations (TEEBcase 2012). The significant dependence of the national economy on timber exports was also a driver of continued deforestation. Poor forestry practices not only cause the loss of biodiversity and other ecosystem services, but also excessive soil erosion, silting of rivers and degradation of adjacent coral reefs due to sedimentation.

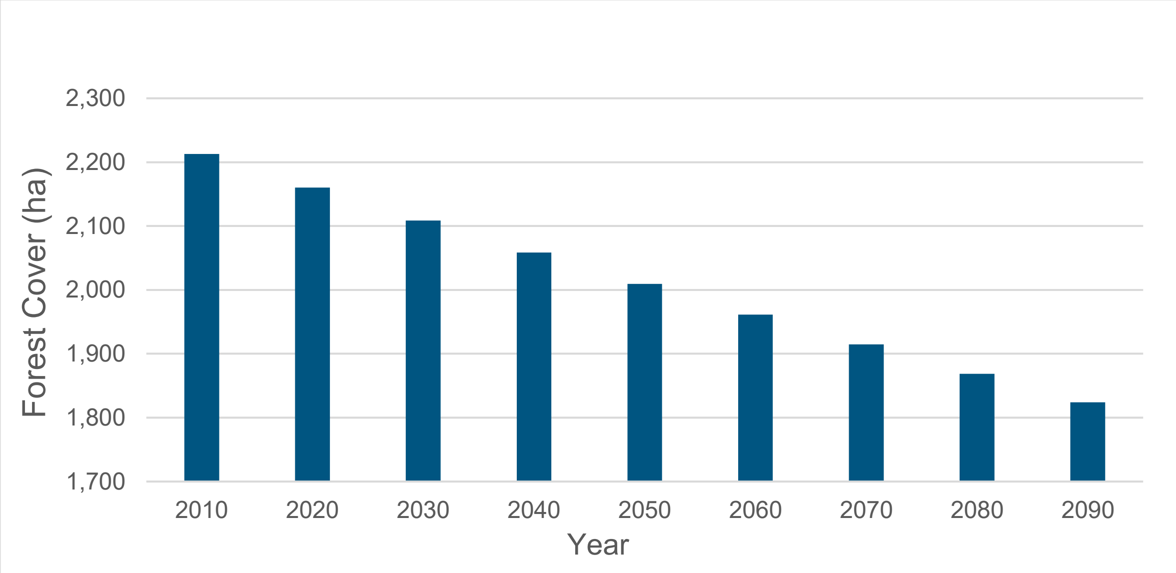


Figure 4-2 Projected forest clearing rates for Solomon Islands

4.3.4 Loss of biodiversity

Land and marine-based activities, including agriculture, forestry and mining, exert pressure on the terrestrial environment and are leading to a loss of biodiversity, an increase in invasive species, land degradation and contamination of marine and freshwater environments. Inappropriate land use, deforestation activities, pollution and over-harvesting of marine resources is resulting in a continued loss of biodiversity. The loss of biodiversity affects potential income generation from tourism and related activities, while Fisher *et al.* (2014) reports that regulating services are at risk, as the oceans' capacity to regulate climate is dependent on their biodiversity. The loss of biodiversity is generally considered irreversible.

4.3.5 Fish stock depletion and coral reef degradation

While population growth is responsible for additional pressure on these ecosystems almost everywhere, in many cases commercial extraction is worsening these effects. Over-exploitation for both subsistence and commercial use has resulted in severe depletion of several important food and commercial species. These include green snails, blacklip and goldlip shells, coconut crabs, giant clam and sandfish (sea cucumber). Other species such as trochus, crayfish/lobster and turtles are also threatened, despite being under some form of protection (regulation).

This pattern of overuse and non-existent or inadequate regulation limits the productivity of inshore fisheries to provide much needed protein in the population's diet, as well as preventing ongoing, reliable income-generation from marine product exports. Natural disasters such as cyclones, earthquakes, volcanic eruptions and tidal waves, greatly affect coastal environments and cause physical destruction and the alteration of the ecosystem, which has the capacity to destroy endangered species and the coral reefs itself.

The 2015 coastal fisheries report card (SPC 2015) reports that significant losses of coral reefs, mangroves, seagrasses and intertidal habitats, all of which provide shelter and food for coastal marine fauna, are expected to cause reductions in the productivity of coastal fisheries due to climate change, threatening food security and livelihoods.

5 National ecosystems and ecosystem services

This chapter presents the results of the ecosystems and ecosystem services identification component of the national ESRAM study. Subsequent ESRAM components (ecosystem valuations and climate change vulnerability assessment) are presented in Chapter 6 and Chapter 7.

This chapter provides a national overview to set the scene (Section 5.1), a summary of the key ecosystems and ecosystem services (Section 5.2), followed by more detailed descriptions of the services and threats associated with each key ecosystem (Section 0 to Section 5.14).

5.1 National overview

The ecosystem services across Solomon Islands are diverse and extensive. They continue to play an important role in defining and maintaining the livelihoods, subsistence and cultural identities of Solomon Islanders, particularly the rural communities, who are largely dependent on subsistence gardening and fishing, and rely on their surrounding environment for resources such as shelter (Filardi *et al.* 2007; Pauku and Lapo 2009). The high proportion of rural residents means that most of the population interacts with and relies on several ecosystem services every day. Additionally, this means that much of the population is potentially vulnerable to changes in the condition of ecosystems and ecosystem services.

The abovementioned livelihood and subsistence of rural communities (i.e. through fishing and gardening) are wholly dependent on the combination of: i) the ecosystem processes that sustain gardens and fisheries; and ii) sustainable use of these natural resources. Likewise, with the exception of mining, the country's major industries (timber, copra, palm oil, commercial fisheries) are directly dependent on ecosystem services, requiring sufficiently fertile, intact and watered land, and intact freshwater and marine habitats, if the industries are to persist sustainably.

Table 5-1 Examples of typical community reliance on local ecosystem resources

Ecosystem	Ecosystem Service (in terms of examples of direct community uses)
Marine	• Marine products harvested for community consumption or trade/sale: reef and pelagic fish (e.g. coral trout, silverfish, snapper, sweetlips, surgeon fish, trevally, parrotfish, kingfish, dolphinfish, bonito, tuna, shark, barracuda, wahoo, sailfish and marlin), trochus, shark fin, turtles, eels, crayfish, clams, beche-de-mer, octopus and limpets
Forest	• Construction materials: timber (*Gymnostoma papuana*, *Xanthostemon melanoxylon*), ropes for house building (*Flagelaria indica*) • Decoration and *kastom* clothing (*Gleichenia linearis, Antiaris toxicara*), dying handicrafts (*Melastoma affine*) • Pesticides (*Selaginella rechingeri*) • Food such as fruits, pigs and other hunted fauna • Medicinal products (*Gnetum gnemon, Pandanus spp, Cocos spp.*) • Firewood (*Timonius timon and various mangrove species*) • Calophyllum timber for building canoes
Gardens and plantations (i.e. modified terrestrial habitat in the form of domestic crops and	• Products harvested for community consumption or trade/sale: coconut, *Colocasia* and *Cyrtosperma* taros, manioc, banana, breadfruit, papaya, tobacco, sweet potato, yam, sago, pumpkin, watermelon, sugar cane, fruit trees (e.g. *Burckella obovata*, Malay apple), Tahitian chestnut, canarium almond, turmeric, cocoa, cordyline, areca nut, other fruits and *Piper betle*.

Ecosystem	Ecosystem Service (in terms of examples of direct community uses)
commercial agriculture)	• Plantations such as coconut, palm oil, cocoa, coffee
Other terrestrial	• Pandanus, mangroves and coconuts (leaves for sleeping mats, edible fruit, handicrafts and medicinal) • Coconut crab
Springs, streams and groundwater	• Water provision for drinking water in particular, but also for washing, bathing, cooking, etc.

5.2 Key ecosystems and ecosystem services

This assessment identified the following 12 categories as the key ecosystems in Solomon Islands in terms of the provision of ecosystem services to the population on a national scale.

(1) Rivers and streams

(2) Terrestrial forests, vegetation

(3) Cultivated land (plantations and gardens).

(4) Mountains and highlands

(5) Other terrestrial land

(6) Coral reefs

(7) Coastline / Beach

(8) Mangroves

(9) Sea / Ocean

(10) Wetlands / Lakes / Swamps

(11) Seagrass and marine macroalgae (seaweed)

(12) Groundwater

Note that some ecosystem categories are broad (e.g. terrestrial forest), whereas others are quite specific (e.g. seagrass). This distinction is associated with the need in some cases to highlight the specific ecosystem services provided by a particular component of what might otherwise often be classified as part of a broader ecosystem (e.g. a seagrass bed might also be considered to be a part of a broader nearshore or seabed marine ecosystem).

The key ecosystem services associated with each of these ecosystems are listed in Table 5-2. Most of them are derived, in general terms, from multiple ecosystem types (Table 5-2). For example, terrestrial forests, cultivated land and marine ecosystems (i.e. coral reefs, mangroves, seagrass, ocean) all contribute to primary productivity and nutrient cycling. Similarly, coastal protection services can be associated with beach, reef and mangrove ecosystems.

Ecosystems were also typically recognised as contributing to numerous ecosystem services. The main exception to this was groundwater, which was only recognised for providing water (i.e. drinking water etc.). Groundwater provides other ecosystem services, such as maintaining groundwater-dependent ecosystems/habitats (i.e. groundwater fed wetlands, caves, etc.). However, this assessment focuses only on key ecosystem services in the context of direct benefits to the human population.

Despite their high value, contributions of essential ecosystem services to the people of Solomon Islands, the ecosystems are subject to significant anthropogenic stressors and threats (i.e. human-derived pressures and degradation). In fact, most of the main existing threats of concern to ecosystems are directly brought about by human activities (see Section 4.2). This contrasts with future climate-related threats, which are typically indirect effects transpiring as legacy issues from past human activities affecting the global climate.

Understanding and addressing existing threats is a core feature of EbA. This is because a crucial adaptation option in EbA is to ameliorate existing threats (i.e. improve ecosystem health or functioning) in order to build the resilience of an ecosystem to future climate change. In terms of existing threats to ecosystems or ecosystem services at the national scale, major threats include commercial logging, commercial inshore fishing, industrial agriculture such as oil palm plantations, land-use change and habitat loss through urbanisation and the expansion of agricultural land, construction of urban infrastructure, and mining (Roughan and Wara 2010; Peterson *et al.* 2012; Furusawa *et al.* 2014). These threats are exacerbated by the nation's rapid rate of population growth and ongoing climate change (Walter and Hamilton 2014).

Further descriptions of the main services and threats associated with each ecosystem category are provided in the following sections.

Table 5-2 Key ecosystems and ecosystem services identified for Solomon Islands

Ecosystems	Key Ecosystem Services Identified during the National Workshop
Rivers, streams	Source of food directly and indirectly (irrigation)
	Water source (drinking and domestic use)
	Recreation (swimming, canoe)
	Transportation, anchorage
	Provision of building and cooking material (gravel, sand, stones)
	Energy generation (hydropower)
	Cultural significance (e.g. mark boundaries)
	Sanitation uses
	Waste/rubbish disposal
	Fisheries / aquaculture
	Irrigation source and agricultural activities
	Habitat provision, biodiversity
Terrestrial Forests, Vegetation	Provision of housing material (timber, leaves)
	Fauna habitat
	Gardening and farming (commercial and subsistence)
	Kastom medicine
	Source of income/revenue (SIG and private commodities – logging)
	Fuel (firewood)
	Carbon sequestration
	Nutrient cycling and primary productivity
	Maintain intact watershed (soil retention and fertility)
	Air regulator, oxygen supply
	Protection from hazards/risks (?)
	Recreation and tourism (cycling, hiking, bird watching)
	Cultural significance – ornaments, practices, costumes
	Shade / cool atmosphere)
	Handicrafts
	Tools
	Food source (hunting and plant-based foods)
	Regulate water cycle
Other Terrestrial Land	Agriculture, food production
	Support forests
	Minerals source (mining industry)
	Land provision (habitats, human settlements and developments)
	Regulator for temperature, nutrient, water
	Commercial value (security and collateral)
	Provides means of identity and heritage
Coral reefs	Habitat / biodiversity
	Food source
	Coastal protection / wave break
	Income source and revenue (fish, corals, lime, etc.)
	Fishing grounds (subsistence, commercial)
	Lime extraction
	Building and construction materials (coral rock)
	Traditional values (shell money, decorations, ornaments, turtles)
	Recreation and leisure
	Kastom medicine
	Tourism industry
	Support marine food chain
Coastline / Beach	Recreation/leisure
	Sanitation
	Domestic use (bathing)
	Jewellery (e.g. shells, stones, corals for income and cultural use)
	Building materials (sand)
	Transport (boat landing area, storage for canoes and vessels)
	Fauna habitat (e.g. nesting ground for turtles)

Ecosystems	Key Ecosystem Services Identified during the National Workshop
	Protection from coastal inundation
Mangroves	Source of food
	Building materials
	Breeding grounds
	Fuel source (firewood)
	Coastal protection, shoreline stabilisation, buffer
	Kastom medicine
	Recreation
	Sanitation
	Habitat, biodiversity, nursery grounds
	Carbon sequestration
	Craft materials and dye
	Tools (gardening) and weapons
	Shell money source
	Income / revenue source
Sea / Ocean	Transportation
	Habitat
	Food source
	Regulator of temperature/air
	Income source (both commercial, SIG and small scale)
Mountains	Building materials
	Habitat (particularly for endemic species – high biodiversity value)
	Support rivers (source of headwaters)
	Regulate climate and weather
	Safety from disasters (e.g. high ground)
	Navigation land marks
Wetlands / Lakes / Swamps	Food source
	Water source (drinking, domestic)
	Habitat (incl. fauna breeding sites)
	Transport
	Building materials
	Aquaculture
	Heritage
	Environmental filtration and water purification
	Reduce flood flow rates
	Tourism (birdwatching)
Seagrass and macroalgae (seaweeds)	Habitat (e.g. turtles, dugong)
	Food source (e.g. *Caulerpa* spp.)
	Income generation (commercial seaweed farming)
	Kastom medicine
	Stabilises coastal environments
Groundwater	Water source (drinking and domestic use)
	Source commercial bottled water (spring water)
Plantations and Gardens	Source of income and employment/livelihoods
	Food source

Table 5-3 Summary of ecosystem sources for key ecosystem services

Ecosystems	Food (land)	Food (sea, river)	Water (drinking)	Water (other)	Building and household materials	Fuel and energy	Other materials, land, minerals	Cultural and traditional	Transport, navigation	Waste disposal and sanitation	Habitat and biodiversity	Industry and commerce (income and revenue)	Medicine	Recreation and tourism	Carbon sequestration	Coastal protection	Nutrient cycling and primary productivity	Safety (shade, tsunami, hazards)	Regulate climate, air, water cycle, temp.	Regulate water quality	Regulate water flow rates
Rivers, streams		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓						✓	✓
Terrestrial Forests, Vegetation	✓				✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Other Terrestrial Land							✓	✓				✓									
Coral Reefs		✓			✓		✓	✓			✓	✓	✓	✓		✓	✓				
Coastline / Beach					✓		✓	✓		✓	✓			✓		✓					
Mangroves		✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓				
Sea / Ocean		✓		✓					✓	✓	✓	✓		✓			✓		✓	✓	
Mountains					✓		✓	✓	✓		✓	✓	✓				✓	✓	✓		
Wetlands / Lakes / Swamps		✓		✓				✓		✓	✓			✓						✓	✓
Seagrass and macroalgae (seaweeds)											✓	✓					✓				
Groundwater			✓	✓																	
Plantations and Gardens	✓											✓					✓				

5.3 Rivers and streams

Rivers and streams, including both freshwater and tidal systems, occur throughout Solomon Islands, particularly on the large islands, which have major rivers and watershed areas. The main exception is many of the very small and/or atoll type islands, where the topography does not support river or stream systems. Such waterways, and the ecosystems services they provide, are highly valued by the people of Solomon Islands, such that the majority of settlements are located adjacent, or in close proximity, to these ecosystems.

The ecosystem services provided by rivers and streams are many and varied, with the main services from a community perspective including:

- provision of water for drinking, domestic uses (i.e. bathing, laundry, cooking), industrial and irrigation needs;
- provision of food for both subsistence and commercial purposes (e.g. fish, eels, molluscs/shells, crustaceans, kangkung);
- support for both local and commercial fisheries, including aquaculture (e.g. tilapia aquaculture);
- provision of opportunities for recreation and leisure (e.g. swimming, canoeing);
- support for biodiversity, food sources and local flora and fauna through the provision of a range of aquatic habitats;
- provision of a means of transportation and travel, as well as storage (anchorage) for supporting vessels;
- provision of raw materials for building and cooking material (e.g. gravel, sand, motu stones);
- provision of a means of energy generation through hydro-power (e.g. Tina River Hydro Project);
- provision of various cultural values, depending on the location and local *kastom* (e.g. designate boundaries, baptisms, source of ornamental and handicraft materials); and
- provision of a conduit for waste disposal and dispersal, particularly for sanitation and household waste.

Together, the provision of river/stream derived food, water and sanitation disposal services are extremely high value services at a national scale. Adaptation to maintain these services in the face of climate change would be considered a high priority at a national scale, especially at locations where settlements are large or vulnerable, and highly dependent on local waterways.

Despite providing high value ecosystem services, rivers and streams are subject to major disturbances and degradation from development and pollution. Most of these threats persist throughout the nation.

The primary existing threats can generally be classified as developments, pollution, extraction and other threats, as follows:

- development – including instream, bank side and watershed developments, such as settlement development, mining, infrastructure, urbanisation;

- pollution – from household sanitation and solid waste disposal, commercial and industrial inputs, run-off from farming and catchment development (i.e. pesticide, fertiliser and sediment loads), mining discharges, logging-related run-off (especially sediment loads from cleared land), vessel inputs (e.g. fuel and oil spills);
- extraction activities, such as gravel extraction, fishing and aquaculture, particularly where these activities are undertaken on a commercial scale; and
- other threats such as habitat modification and disturbance (e.g. bank revetment works), flooding and extreme high rainfall events, slash and burn practices in close vicinity to waterways, invasive species (e.g. tilapia *Oreochromis* spp., water hyacinth *Eichhornia crassipes*), and growing human populations placing increasing pressure on waterway resources.

5.4 Wetlands, lakes and swamps

Enclosed fresh or brackish water bodies and swamps are common throughout Solomon Islands. Swamp areas may support various vegetation types, such as freshwater swamp forest, herbaceous swamps, sago swamp forest, and swamp with cultivated crops. At the community level and on a day-to-day basis, wetlands and lakes are most highly valued for their role in providing food and food security. Overall key ecosystem services associated with this ecosystem include:

- provision of food – commonly used for cultivation of swamp taro (*Cyrtosperma merkusii*), taro (*Colocasia esculenta*), sago palm *Metroxylon sagu,* fishing and aquaculture activities (e.g. fishing for freshwater eels, aquaculture of tilapia *Oreochromis* spp. and milkfish *Chanos chanos*) at both local subsistence and commercial scales;
- environmental and natural hazard regulation, such as filtration and purification of run-off from watersheds, and reducing flood flow rates;
- provision of aquatic fauna habitat and support of biodiversity, including value as critical habitat for migratory bird species;
- provision of raw materials (i.e. traditional building materials, reeds for weaving);
- support of tourism activities (e.g. bird watching) and
- provision of opportunities for transport and research, and provides links with cultural heritage.

Pollution, development, habitat modification and increased population growth are the main existing threats to the capacity of wetlands and lakes to continue to provide the above ecosystem services to communities. In some respects, wetlands and lakes are more prone to the effects of existing threats than are rivers and streams. This is because wetlands and lakes are often comparatively small in size (and therefore smaller relative to a given development or other threat), and have longer water retention times (i.e. lower capacity to flush pollutants). Key existing threats to this ecosystem type can be summarised as:

- pollution from household and commercial waste disposal (including sanitation), run-off from agriculture and watershed development, and mining discharges;

- developments such as wetland reclamation, as well as logging and developments in the watershed (i.e. causing direct disturbance through habitat loss and/or indirect disturbance via pollutant inputs);
- existing climatic effects through droughts and floods (i.e. loss of habitat and fauna) and
- other threats such as human population growth (i.e. increasing both pollutant inputs and extraction pressures) and invasive species (e.g. cane toad *Rhinella marina*, tilapia *Oreochromis* spp., water hyacinth *Eichhornia crassipes*).

5.5 Terrestrial forests / vegetation

This broad ecosystem captures the majority of the land area in Solomon Islands, specifically any vegetated land, excluding cultivated or otherwise developed land (i.e. plantations, built areas etc.). In 2010, forest covered approximately 77% of the land area of Solomon Islands (SPREP 2016). Most terrestrial vegetation is classified as varying types of forest, dominated by rainforest vegetation types (e.g. rainforest, lowland rainforest, degraded rainforest, etc.). Other vegetation types, such as grasslands also occur.

Important ecosystem services are provided not only from the vegetation directly but also from the fauna – and products thereof – that inhabit terrestrial ecosystems. Communities rely on vegetated land for raw materials (e.g. building materials, firewood) and food on a daily basis, and also acknowledge their dependence on many other ecosystem services associated with the vegetated terrestrial environment around them. Examples of forest uses by communities include: construction timber (*Gymnostoma papuana, Xanthostemon melanoxylon*), ropes for house building (*Flagelaria indica*), decoration and *kastom* clothing (*Gleichenia linearis*), dyeing handicrafts (*Melastoma affine*), pesticides (*Selaginella rechingeri*), food (*Finschia* spp.), medicinal (*Gnetum gnemon*) and firewood (*Timonius timon*) (Morrison *et al.* 2007).

Overall, key ecosystem services include:

- provision of raw materials for building, fuel and commercial purposes, particularly timber and thatching/weaving materials (i.e. materials for housing and household items, firewood, round log export, canoe trees, such as the kerosene tree);
- provision of food (i.e. hunting grounds, nuts such as the nglai nut from *canarium indicum*, traditional fruits and vegetables);
- provision of *kastom* medicine, and support of cultural items, practices and heritage (e.g. traditional tools, ornaments, costumes, weaving, handicrafts and traditional currency); examples of important resources in this regard include pandanus, reeds, feathers, shells, bark, coconut shells and seeds;
- environmental regulation of local environment and atmosphere by way of providing shade, cooler areas and oxygen;
- provision and regulation of environmental processes and functions such as primary productivity, nutrient cycling, soil fertility and carbon sequestration;

- provision of opportunities for recreation, sport, leisure and tourism (e.g. hiking, bird watching), as well as scientific research pursuits;
- means of generating income and revenue (e.g. logging);
- provision of fauna habitat (e.g. birds, insects, wildlife) and support of biodiversity;
- provision of landmarks (e.g. for navigation) and trees that can mark other important areas such as land ownership boundaries; and
- provision of soil stability and hazard protection for communities (e.g. landslides, erosion, wind or weather breaks).

Logging is arguably one of the most destructive existing threats to terrestrial forests and their inhabitant flora and fauna communities in Solomon Islands. As stated by Filardi *et al.* (2007):

> *There is increasing pressure on forest systems to provide cash for landholding communities with little access to alternatives for school fees, medical care and other basic services. The civil unrest of the early 2000's and accompanying economic hardship escalated large-scale unregulated logging, with devastating ecological effects*.

Extensive logging of lowland and hill forests, and subsequent land-clearing for copra and oil palm plantations, have devastated much of the easily accessible forest (Filardi *et al.* 2007). Isabel, in particular, has been subject to widespread and unregulated logging, with the only remaining tracts of intact forest on its most eastern and western ends (Filardi *et al.* 2007). Despite extensive degradation, there remain fragments of pristine forest, especially further inland and at higher altitudes (Filardi *et al.* 2007; Pollard *et al.* 2014).

In addition to the direct loss of forest vegetation, logging also has indirect consequences, such as the loss of important trees integral to the livelihoods of forest-dependent human communities, threats to clean running water, loss of biodiversity, and threats to marine life via sediment run-off (Morrison *et al.* 2007).

Other existing threats to this ecosystem and its services are numerous and may vary significantly between locations. In a general sense, the most significant threats are described below.

- Logging and deforestation, particularly at locations where logging activity is intensive and/or widespread. Upland logging has been extensive and ongoing in the region for last 30 years, with most of the upland area from the coast to 400 m elevation licensed to logging companies at one time or another during this period (Halpern *et al.* 2013). Other industries such as mining and agriculture may cause deforestation, noting that there are currently numerous proposals for new mines (especially for tenements throughout Isabel and Choiseul Provinces). Deforestation is also undertaken to improve land for the expansion of settlements (i.e. urban encroachment), plantations and other agriculture (e.g. slash and burn agricultural) practices, which occurs at both subsistence and commercial scales.
- Unsustainable harvesting – harvesting of plant species and local wildlife such as giant rats and possums as bush meat (Morrison *et al.* 2007), together with human population growth and increased cash-based needs (i.e. rising food and education costs), result in over-harvesting and further exploitation and/or destruction of terrestrial forests.

- Pollution, particularly from the use of pesticides and other agricultural chemicals on the land, sanitation uses (which also create a human health risk), and illegal waste disposal.
- Existing climate related threats such as bush fires, droughts, cyclones, alternating climate cycles (i.e. El Niño and La Niña cycles) and other natural disasters. Frequent deforestation occurs as result of cyclones, earthquakes, landslides and volcanism (Mayr and Diamond 2001).
- Invasive species – The Pacific Island Ecosystem at Risk (PIER) project lists over 150 invasive and potentially invasive species threatening terrestrial ecosystems in Solomon Islands. Key invasive species of concern include: feral pigs, rats, cats and dogs; insects such as fire ants (*Wasmannia auropunctata*), black twig borer, and fruit flies; cane toads (*Rhinella marina*); and invasive plants such as *Merremia peltata*, *Browsonaetia papyrifera*, and mimosa weed *Mimosa* sp. (Filardi *et al.* 2007). Note also that reforestation efforts on cleared lands often use introduced species of *Eucalyptus* (Morrison *et al.* 2007).
- Illegal wildlife trade – native wildlife (e.g. birds, snakes and possums), including species of high conservation value, are commonly captured and sold in the illegal wildlife trade (Morrison *et al.* 2007; Pikacha *et al.* 2012).
- Other threats such as poor governance or poor coordination between jurisdictions for management, lack of awareness among the community about forest values, recovery and sustainable management.

5.6 Mountains (highlands / cloud forests)

Mountains and their montane cloud forests are a high-altitude sub-category of terrestrial forest. In this sense, they provide many of the same ecosystem services (and are subject to many of the same threats) as those described above for terrestrial forests (Section 5.5). However, they are commonly perceived as a separate ecosystem type with discrete values worth highlighting, in part due to both altitude related factors and their often unique biodiversity values. These are briefly addressed below.

Montane cloud forests descend to approximately 1200 m above sea level on Guadalcanal and Kolombangara, 650 m on Vangunu and Makira, and to 600 m on Gatakae (Filardi *et al.* 2007). Note that these elevations are somewhat unique (i.e. they only descend to 2000 m above sea level in neighbouring Papua New Guinea) due to small island effects on climate (Filardi *et al.* 2007). At high elevations, the forests are situated within a zone shrouded by cloud on most days; trees are stunted, decreasing forest height; trunks and branches are gnarled and draped with moss and ferns; the canopy is more open; and palm and pandana are plentiful (Hadden 1981; Filardi *et al.* 2007).

Montane cloud forests in Solomon Islands are recognised for their high biodiversity value because they: i) support high altitude species that do not occur in other ecosystems; and ii) often contain endemic species. These montane ecosystems often give rise to endemic species because they essentially comprise isolated high altitude ‘islands’ within the terrestrial landscape.

These high altitude ecosystems tend to be most valued for the following ecosystem services:

- provision of raw materials (trees) for building materials;
- support for biodiversity, particularly by providing habitat for endemic species;

- provision of the headwaters (i.e. water source) for downstream waters;
- regulating local climate and weather;
- provision of hazard protection and safety from disasters (e.g. high ground, physical barrier against weather); and
- supporting navigation (i.e. natural landmarks).

While the threats identified in Section 5.5 are broadly applicable here also, the most relevant existing threats (in terms of the above-mentioned ecosystem services) include logging and deforestation, mining proposals, and invasive species. Even where logging does not occur directly within a montane area, logging of adjacent hills and lowlands can continue to cause environmental effects on lands at higher elevations. Firstly, with the loss of lowland and hill forests, communities are forced to rely more heavily on montane forests for ecosystem services (e.g. provision of building materials) that would normally be provided by forests at lower elevations. Secondly, land clearing appears to cause shifts in local microclimates along altitudinal gradients (i.e. along the lowland to montane forest gradient), such that some otherwise intact montane environments are being degraded due to microclimate shifts (Filardi *et al.* 2007). Other edge effects associated with the deforestation of adjacent (lowland/hill) ecosystems may also be an issue, such as exposed montane forests potentially being more vulnerable to infiltration by weed species.

Tourism is an additional threat that has been identified since the mountains are targeted for ecotourism pursuits, such as trekking and bird watching. The mountains generally cover a comparatively small spatial area and have fewer residents compared to lowland and hilly terrains, so tourism and its effects may be more prominent.

5.7 Other terrestrial land

This ecosystem category has been included to capture any terrestrial lands that would not typically be considered to be vegetated or cultivated land (i.e. forests, plantations, etc.). It includes built-up areas, such as settlements, urban areas, industrial and commercial precincts, and the locations of infrastructure. While inherently highly modified or disturbed by definition, this category is important from a human perspective, as it is where the majority of the population of Solomon Islands reside and spend most of their time.

Non-forested or otherwise vegetated lands provide areas for housing, development, businesses, administrative buildings, and services, such as schools, police stations, hospitals, landfill and transport services (e.g. airports). Land has commercial value (e.g. security and collateral). It also provides a means of identity and heritage for people.

As a source of minerals, land in general (regardless of whether it is vegetated or not) also has value to the mining industry.

Despite the above values, this category is not considered to provide much in the way of ecosystem services, given its highly modified nature and particularly when compared to ecosystems in a more natural state. That being said, it is acknowledged that the greener areas of this landscape (e.g. urban greenspace, urban gardens and landscaped areas) provide ecosystem services at highly localised scales. These include, for example:

- provision of shade (and associated human health and leisure values);
- provision of aesthetic values (in an often heavily built-up environment);
- support for biodiversity through the provision of urban habitat and fauna corridors; and
- provision of opportunities for recreation and leisure.

Threats arise through pollution (e.g. solid waste disposal), physical damage by people and vehicles, poor management and inadequate maintenance.

5.8 Coral reefs

Coral reefs border most of the islands and/or form barrier reefs around and between the larger islands, especially throughout Choiseul and Isabel Provinces (Figure 5-1). These reefs and the marine lagoons they form are a vital natural resource, sustaining the livelihoods and sustenance of nearby coastal communities, and are also directly essential for maintaining the nation's inshore fisheries. Specifically, inshore fisheries and marine resources play a critical and unique role in the rural economy and livelihoods of Solomon Islands communities, supplying daily protein and micronutrients, and serving as one of the few sources of cash income (Abernathy *et al.* 2014). Examples of the types of resources harvested include fish (e.g. coral trout, silverfish, snapper, sweetlips, surgeon fish, trevally, parrotfish, kingfish, sharks, eels), crayfish, turtles, octopus, clams, beche-de-mer, trochus and coral (Feinberg 2010; Moseby *et al.* 2012).

Other ecosystem services are also recognised and together the key services for coral reefs at a national scale are summarised below.

- Provision of food – Inshore marine resources are the most common source of animal-based food in diets (Aswani 2002; Bell *et al.* 2009 in Abernathy *et al.* 2014), essential for subsistence and food security.
- Support biodiversity and marine fauna of the Solomon Islands' EEZ – marine species' richness is mainly concentrated in waters from Guadalcanal north-westward to Isabel, Western and Choiseul Provinces (
- Figure 5-2). These are largely coastal waters, of which coral reefs are a prominent feature. Coral reefs are a very important habitat for marine fauna, often being required as essential feeding, breeding, spawning, cleaning and aggregation habitats (e.g. for sea turtles, grouper, coral and migratory species).
- Support income and revenue generation, as well as community livelihoods – This is primarily through commercial extractive enterprises (e.g. fishing, aquarium trade, coral, lime extraction), and also tourism operations such as scuba diving.
- Provision of raw materials – This includes coral rock (i.e. building and construction material) and lime production (associated with both the construction industry for concrete production, and also for betel nut use).
- Hazard protection, particularly coastal protection from natural hazards – Reefs act as a wave against wave energy (important during major events such as tsunami, cyclones and storm surges).

- Regulation of marine primary productivity, nutrient and carbon cycling – Reefs are critical to coastal food chains, which are in turn essential for maintaining the food, biodiversity and income-related services above.
- Support of traditional cultural values and practices – this includes *kastom* medicine, shell money, ornaments and decorations.
- Provision of opportunities for recreation and leisure, as well as scientific research pursuits.

With respect to commercial harvesting of sharks (i.e. reef sharks for both the meat and fin trades) it is worth mentioning that shark fins are highly valued as both a reliable and extremely cost-effective export. Fins are dried, do not require refrigeration and, if treated with care, can be stored for months without losing their value (Feinberg 2010). Demand is high and Solomon Islanders eat shark meat so the carcasses do not go to waste (Feinberg 2010).

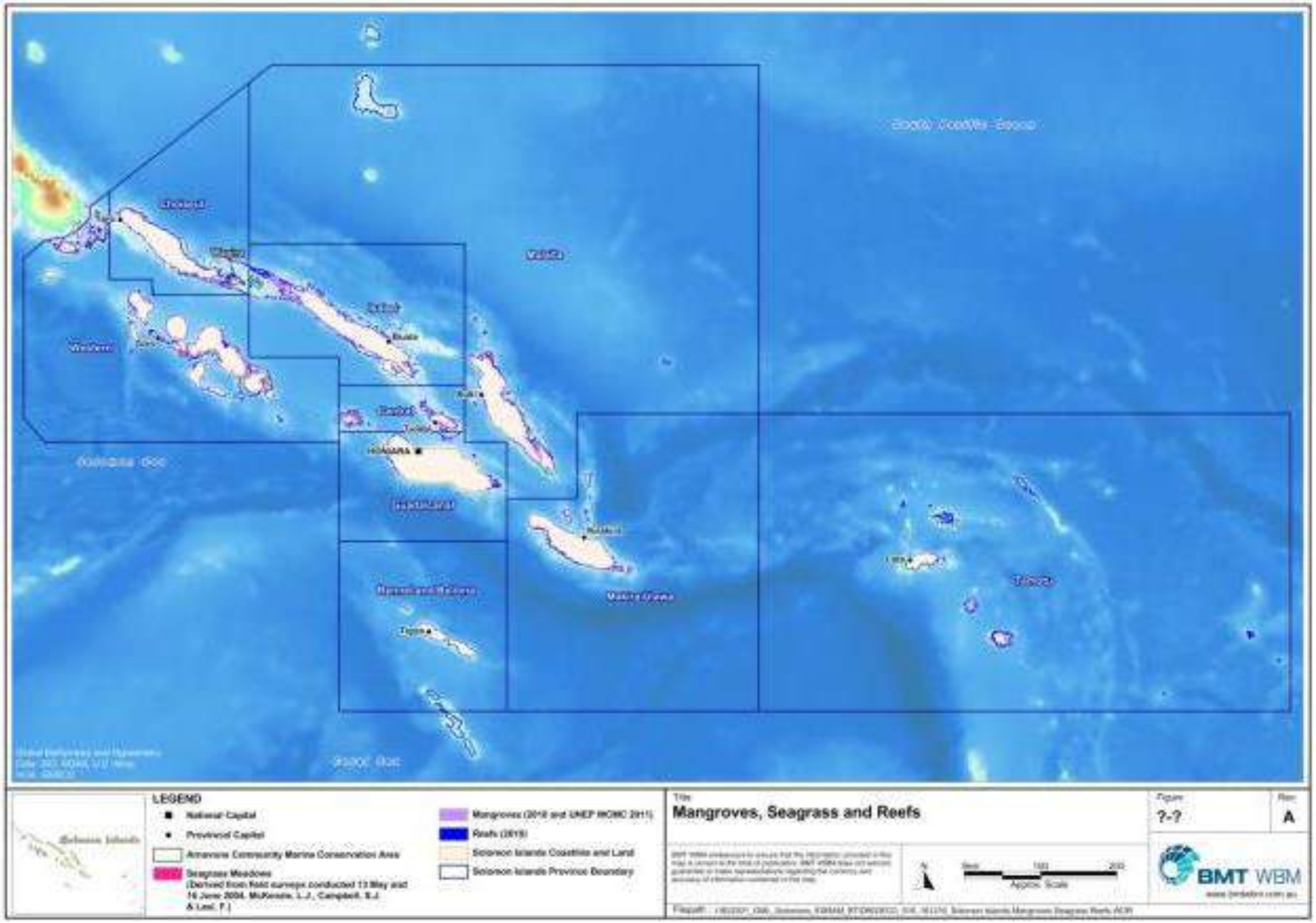


Figure 5-1 Mangroves, seagrass and reefs

ent state of freshwater fair.

er species richness from rcial plantation activities ality degradation (due to nd overharvesting (*ibid*). ures that threaten these rs (*ibid*).

includes a diverse range reefs and atolls (Sabetian ndition of most reefs and moderate at most sites. s were unique, had high were generally in good ever, an earthquake and

threats (*ibid*). Converting mangroves to other land uses and the over harvesting of mangroves increases coastal erosion, reduces mangrove species richness and threatens fish and invertebrate spawning grounds. This results in ecosystem changes and affects the provisioning and regulating ecosystem services that many communities rely on (e.g. habitat for food sources, coastal protection, water regulation, shelter).

Table 4-4 presents the trend in the decline in mangrove forest cover over time from 1990 to 2010. Trends relating to both the state of mangroves and the pressures that threaten mangroves are

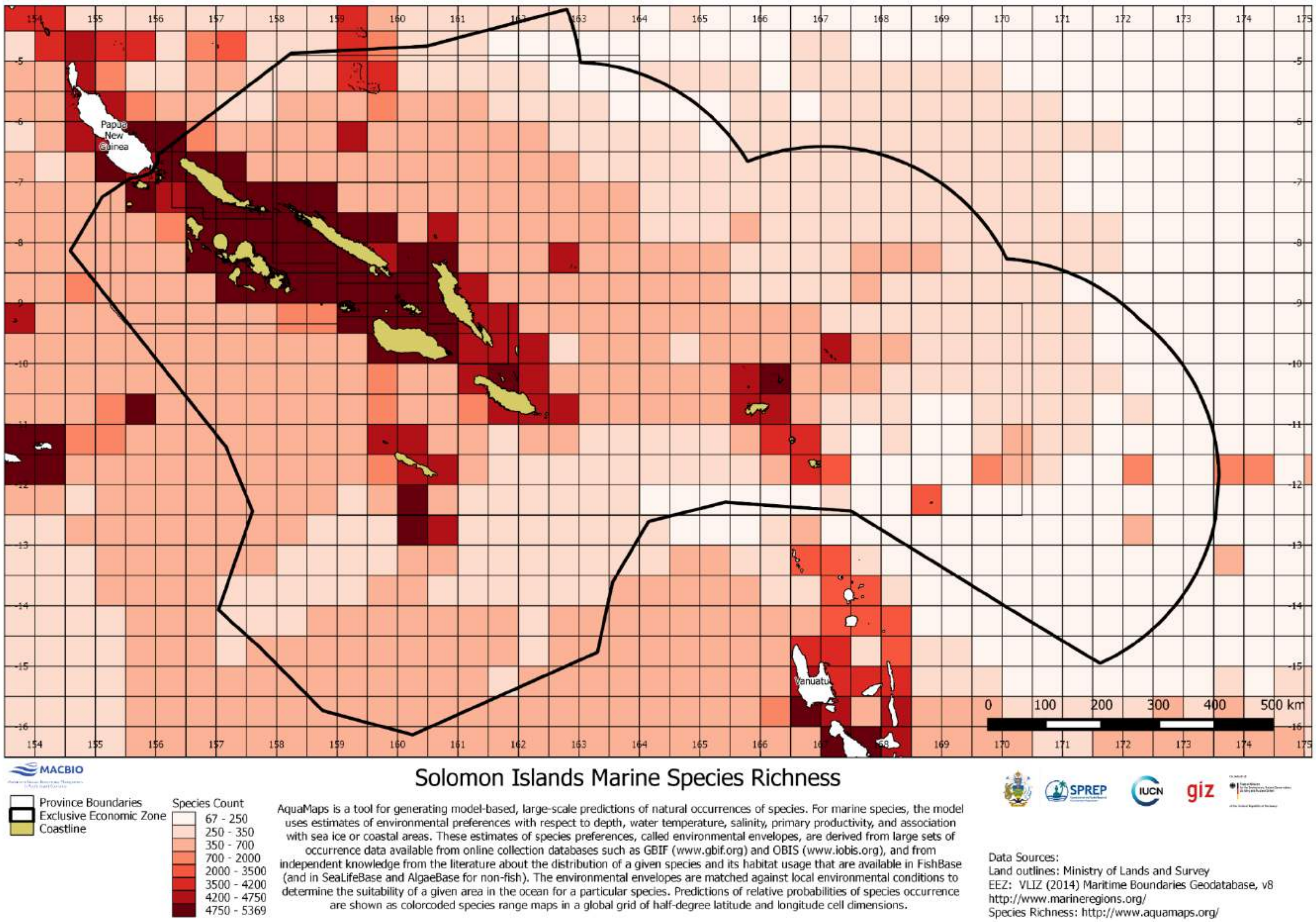


Figure 5-2 Solomon Islands marine species richness (courtesy MACBIO)

Coral reefs and the services they provide are subject to existing threats from both land and sea-based sources, most of which are associated with anthropogenic activities. Key threats are described below.

- Logging and deforestation result in increased sediment loads to coastal waters and sedimentation of reefs and seagrass meadows. Halpern *et al.* (2013) observed many lagoon reefs in the Solomon Islands smothered with sediment up to 10 cm deep through sedimentation from upland logging. It is thought that lagoons and reefs have some resilience to sedimentation where they are located in close proximity to major rivers, because they naturally experience sediment run-off (Halpern *et al.* 2013).
- Overharvesting – overfishing and unsustainable harvesting/extraction of marine resources occur to varying degrees throughout Solomon Islands. This threat is likely to be exacerbated by increasing population growth and the associated increase in demand for reef resources. With respect to fisheries, there are limits to the capacity of the domestic fisheries sector to support the nutritional requirements of people in Solomon Islands (Bell *et al.* 2009; Weeratunge *et al.* 2011 in Abernathy *et al.* 2014). In this regard, the SI National Strategy for the Management of Inshore Fisheries and Marine Resources (2010) identifies community-based marine resource management as critical for sustainable and secure inshore fisheries. This strategy is essential to the Solomon Island government's strategy for sustaining inshore marine resources and ensuring food security in the face of population growth, climate change and resource degradation (Abernathy *et al.* 2014) and additionally, the government is considered an existing EbA strategy.
- Habitat destruction and deterioration through destructive harvesting practices such as dynamite fishing, and other activities damaging reef habitat (e.g. anchorage, coral harvesting, tourism pollution – see below).
- Coastal pollution – which primarily originates from untreated discharges, solid waste disposal and chemical inputs (e.g. sewage and industrial, shipping and hospital waste disposal), and run-off (e.g. sediment, nutrients, pesticides). In addition to direct pollution threats (e.g. digestion of plastic, food contamination, water quality decline, bioaccumulation), secondary threats may also occur and may include increasing populations of crown-of-thorns starfish (which feed on corals).
- Coastal development through developments, such as reclamation and settlement expansion, and construction of coastal infrastructure, such as jetties and seawalls.
- Other threats such as coral bleaching, ghost fishing (i.e. fishing by discarded nets and traps), and the potential threat of invasive species (i.e. marine pests) via shipping activities or other means.

5.9 Seagrass / marine flora

Seagrass meadows in the Solomon Islands occur in shallow nearshore areas, primarily in marine lagoons, in the vicinity of river mouths and other semi-enclosed coastal waters (Figure 5-1).

This ecosystem category also includes other marine flora (marine macroalgae), primarily to capture the commercial farming of seaweed. Seaweed farming tends to occur in marine lagoons and therefore tends to occupy a similar niche to seagrass (see map of production sites in

Figure **5-3**), and therefore are also subject to some of the same threats as seagrass.

From a community perspective, the following key ecosystem services are recognised:

- provision of food for subsistence and commercial purposes directly (i.e. net fishing in marine lagoons), and indirectly as a primary producer contributing to the productivity and food chains of nearshore marine environments;
- source of income generation (i.e. in the case of commercial farming of seaweed);
- support for marine fauna habitats and biodiversity, including essential habitats for marine megafauna of cultural and conservation significance (e.g. turtles, dugong);
- provision of *kastom* medicine (e.g. there are traditional medicinal uses for *holophila* spp.); and
- regulation of coastal sedimentary habitats and sediment transport (i.e. stabilises coastal environments by trapping and retaining sediment).

Figure 5-3 Seaweed production sites (from Kronen 2010)

Existing threats to this ecosystem category are derived from both land and sea-based sources, with key threats to seagrass meadows including:

- sedimentation, which smothers seagrass and is exacerbated by run-off from deforested areas;

- physical habitat loss and disturbance from destructive harvesting practices (e.g. trawling) in seagrass areas, anchoring, reclamation and coastal development;
- pollution from sources such as sewage inputs, run-off and inappropriate disposal of solid wastes, which can affect seagrasses (e.g. nutrient, sediment and herbicide loads) and their inhabitant fauna (e.g. plastic digestion, contamination, bioaccumulation of potential contaminants); and
- overharvesting of target fauna species associated with seagrass meadows.

Seaweed farms are affected by threats such as cyclones and other climatic events that can devastate farms, herbivory of seaweed by fish and other animals, extreme low tides and market effects.

5.10 Coastline / beaches

Beaches and other foreshores throughout Solomon Islands' extensive coastline(s) – or side sea – provide the boundary between terrestrial and marine environments. As most communities are situated in or near coastal areas, environments along the coastline are often heavily utilised by communities for a variety of uses. Key ecosystem services in this regard include:

- supporting waste disposal for sanitation purposes (i.e. toileting).;
- provision of water for domestic uses (e.g bathing);
- provision of raw materials for building and construction (e.g. sand, gravel, stones).
- support for transport activities (e.g. act as a boat landing area, provide accessible land for storage for canoes and other vessels);
- support for cultural values and practices through the provision of materials for jewellery, ornaments and decorations (e.g. shells, stones).
- support of biodiversity and fauna, with special recognition as an essential breeding habitat for sea turtles (both of which are of high cultural and conservation value);
- regulation of coastal protection from natural hazards (i.e. buffer coastal communities against inundation from tsunami and storm surge etc.); and
- provision of opportunities for recreation and leisure activities.

Existing threats tend to be concentrated at locations where this ecosystem occurs in close proximity to human settlements and/or other human activities. At these locations, the main existing threats include:

- habitat loss and modification through activities such as coastal development and reclamation, seawall construction and other physical disturbances (including extraction of sand, gravel and other materials);
- habitat loss and modification via natural events and processes, such as cyclones, tsunami, natural sediment transport processes (i.e. coastal erosion and accretion);
- pollution caused by sanitation and disposal of household solid wastes. These have multiple effects on the environment, such as habitat modification, habitat and fauna contamination and

loss of aesthetic values. They also pose a significant human health risk to communities that utilise the same area for bathing, recreation and/or fishing.

- unsustainable or excessive extraction of raw materials, especially sand and gravel, which can alter both the ecosystem characteristics and functions; and
- increasing human population sizes, which adds pressure to the above ecosystem services.

5.11 Mangroves

Solomon Islands possesses nearly 65,000 ha of mangrove forests containing approximately 25 mangrove species (Warren-Rhodes *et al.* 2011). The indicative location of mangrove areas is shown in Figure 5-1, noting that this intertidal vegetation type is patchily distributed and not prominent around the coastline of all islands. Again, being a coastal ecosystem, mangroves are often located in close proximity to coastal settlements. In such cases, they are usually highly valued and heavily utilised by local communities.

The primary mangrove ecosystem services for communities and the natural resources they rely upon are:

- provision of food, primarily to meet subsistence and food security needs through sources such as fish, mud crabs, molluscs, mangrove fruit (e.g. mangrove clams in the genus *Polymesoda* and ark clams *Andara* spp.);
- provision of raw materials (mainly mangrove timber) for construction and building, as well as for firewood;
- support of biodiversity and fauna habitat, noted for value as breeding, nursery and feeding grounds for fisheries species;
- contribution to coastal protection from natural hazards by acting as a physical barrier between the land and sea, and stabilising foreshores to protect against coastal erosion;
- support of traditional cultural values and practices through the provision of materials used for *kastom* medicine, crafts, tools (gardening), weapons, shell money and dye, etc.
- support of waste disposal and dispersal services, particularly with respect to sanitation uses (i.e. common toilet area);
- regulating of the carbon cycle and climate, particularly through carbon sequestration; and
- support for community-level income-generation and livelihoods where the above services are commercialised or traded (e.g. food, timber).

In the context of the above ecosystem services, the most relevant existing threats to mangroves are unsustainable harvesting of mangrove timber, as well as clearing/loss of mangroves for reclamation and coastal constructions. Overall, key existing threats include:

- unsustainable harvesting of timber and food resources, which is being exacerbated in coastal communities that have high population growth rates (and rely on mangroves);

- mangrove clearing/loss for land reclamation, construction and coastal development, as well as clearing for transport/passage;
- sediment transport processes (erosion and accretion), particularly large scale and sudden sediment movements such as sedimentation resulting from flooding; such processes can undermine (erosion) or smother (sedimentation) mangrove root systems;
- pollution from household sanitation uses and solid waste disposal, which can contaminate local food resources, cause water quality degradation, reduce aesthetic values and introduce persistent materials such plastics into the environment; and
- the fact that mangrove environments are often poorly perceived by people (i.e. often considered a waste disposal area) and do not usually have the conservation prestige afforded to coral reefs, for example). This can further contribute to the above anthropogenic effects.

5.12 Sea / Ocean

Beyond the nearshore marine ecosystems already mentioned (i.e. reefs, seagrasses, mangroves, beaches), the marine area of Solomon Islands remains vast, encompassing much of the nation's approximately 1.6 million km^2 exclusive economic zone (EEZ). This sea contains pelagic waters to the deep sea, and a complex topography of seafloor features such as seamounts, ridges and canyons. While oceans provide extensive ecosystem services on a global scale, for the people of Solomon Islands, the most directly relevant services at a local to national scale include:

- provision of food in the form of pelagic fish (e.g. dolphinfish, bonito, tuna, sharks, barracuda, wahoo, sailfish and marlin); together with fish from other marine environments (e.g. reefs and lagoons), this food contributes to providing the primary animal protein in local diets;
- a means of income and revenue-generation through supporting the fisheries industries, from artisanal to major international fishing operations (detailed further below);
- provision of a means of transport, noting that marine-based transport is an important means of inter-island travel, freight and logistics, as well as the primary means of importing and exporting international goods;
- provision of mineral resources – while deep-sea mining is not being undertaken, the ocean is recognised as containing a wealth of mineral resources in Solomon Islands' EEZ; these minerals are particularly concentrated around deep-sea hydrothermal vents and sea mounts, and have been the subject of considerable exploration activities in recent years; and
- regulation of atmosphere and climate.

Seas are highly connected globally, such that Solomon Island marine ecosystems are prone to effects from outside the nation's EEZ. Indeed, global phenomena such as global warming are among the greatest threats. Existing threats originating locally remain relevant and are also important to concentrate on, particularly since they are within the nation's jurisdiction and can be managed autonomously by the Solomon Island's government. In this regard, and in the context of the above ecosystem services, the key existing threats are pollution and unsustainable extractive industries.

Pollution is both land-derived (i.e. run-off, sewage inputs, solid waste disposal) and marine-derived from shipping and vessel operations (e.g. vessel fuel and oil spills, antifoulant, ballast, rubbish disposal). Solid wastes (i.e. rubbish) do not necessary originate locally, but may be mobilised from external waters by currents (e.g. floating plastics, ghost nets, floating rafts of accumulated marine debris). Unsustainable harvesting is also a significant threat to most of the fisheries resources, especially some tuna species that are a major revenue stream to the nation through fishing licences to international fishing fleets.

By way of further fisheries background, marine waters in Solomon Islands are separated into distinct fishing access areas as summarised in Table 5-4 and illustrated in Figure 5-4.

Note that waters from the mean high water mark (MHWM) to the archipelagic waters, inclusive, are the most productive of the EEZ (Figure 5-5).

In part due to these fishing access boundaries, as well as other factors (such as proximity and access to land and markets, varying population sizes across the nation, and the distribution of marine habitats and productivity), the intensity of fishing is not uniform across the nation.

Higher intensity artisanal fishing tends to occur around northern Guadalcanal, Western Province and Malaita (Figure 5.6).

Tuna catches (combining catches from purse seine, pole-and-line, and longline tuna fishing methods from 2001 to 2010) are strongly concentrated in the north-western quarter of the EEZ (Figure 5-7).

Table 5-4 Fishing access arrangements (as per Solomon Islands Tuna Management and Development Plan)

Area	Permitted methods and licence types
MHWM–3 NM	Artisanal fishers and small scale fishing operations supplying local markets
3 NM–12 NM	Permitted methods and licence types as above, plus: - small scale industrial fishing, pole-and-line, troll and handline
Archipelagic waters (12 NM to UNCLOS recognised archipelago)	Permitted methods and licence types as above, plus: - locally registered fishing vessels landing their catch for onshore processing and using either purse seine, pole-and-line, troll or handline methods
12-30 NM	Permitted methods and licence types as above, plus: - foreign vessels chartered by local companies landing their catch for onshore processing and using the fishing methods listed above
30–60 NM	Permitted methods and licence types as above, plus: - foreign longline, including chartered by locally based vessel, not landing catch to onshore processing - foreign purse seine vessels operating under the FSM arrangement and foreign vessels operating under bilateral agreements using the fishing methods above
60–200 NM	Permitted methods and licence types as above, plus: - purse seine vessels operating under the US Treaty

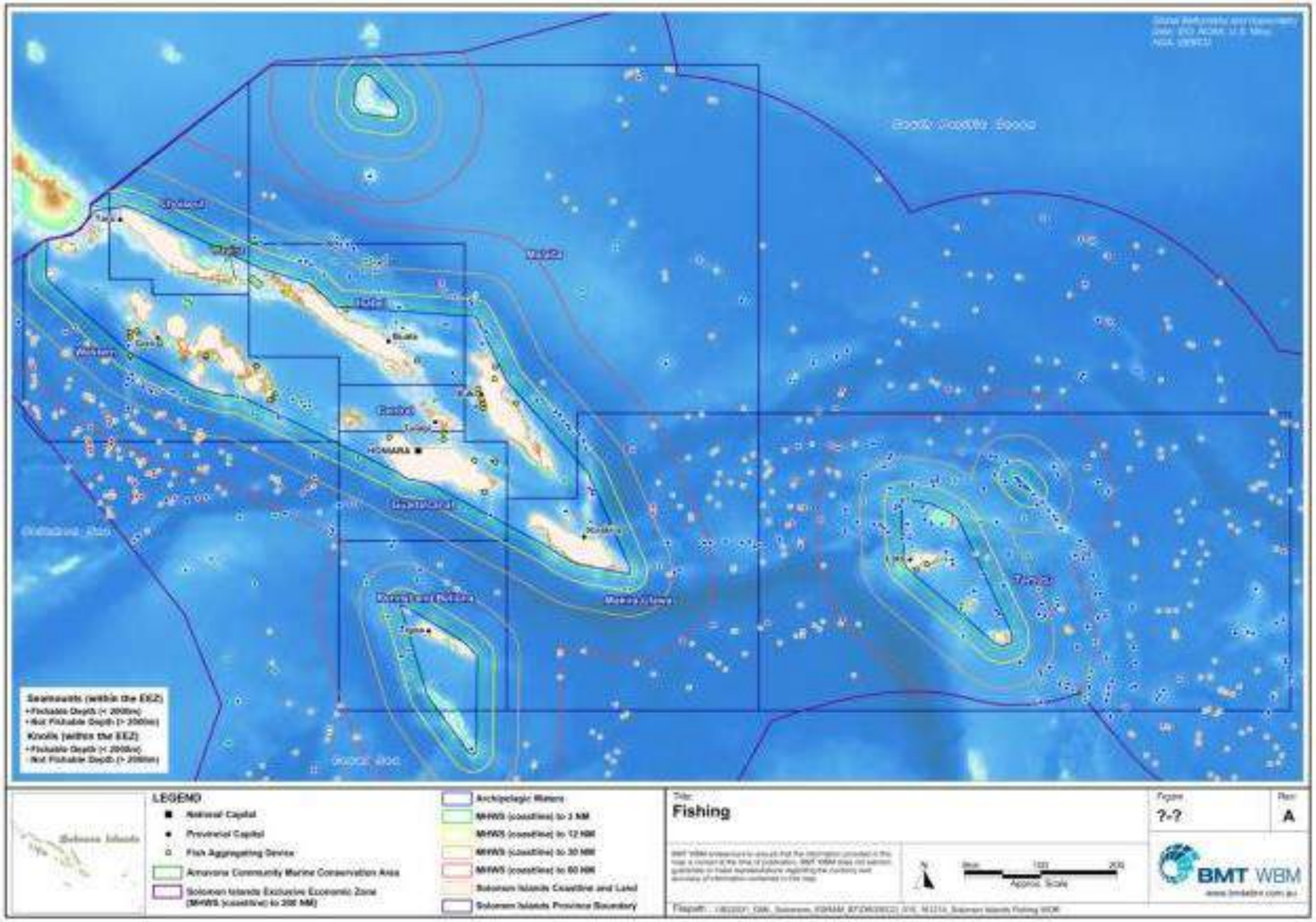


Figure 5-4 Fishing access area boundaries

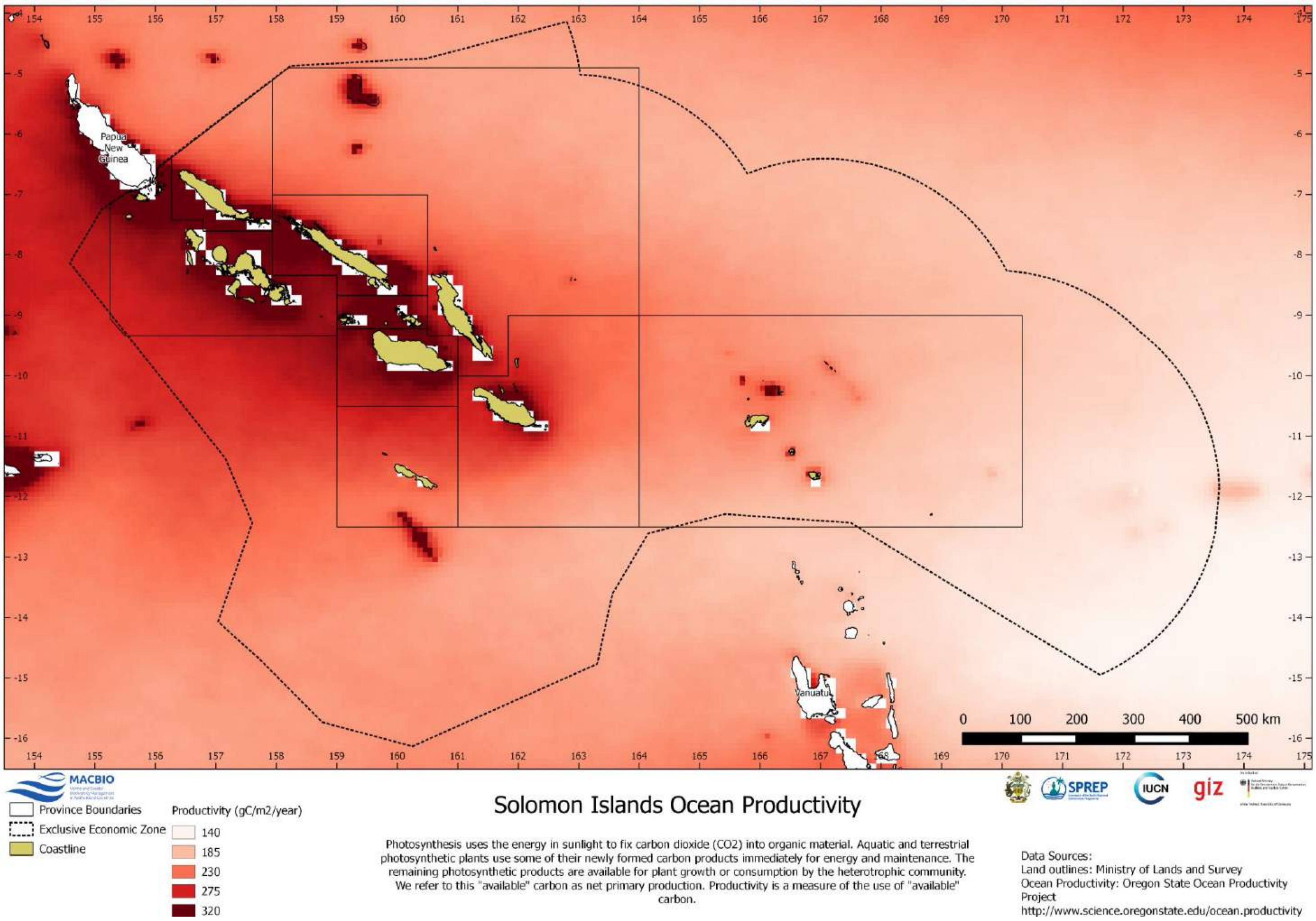


Figure 5-5 Ocean productivity (courtesy MACBIO)

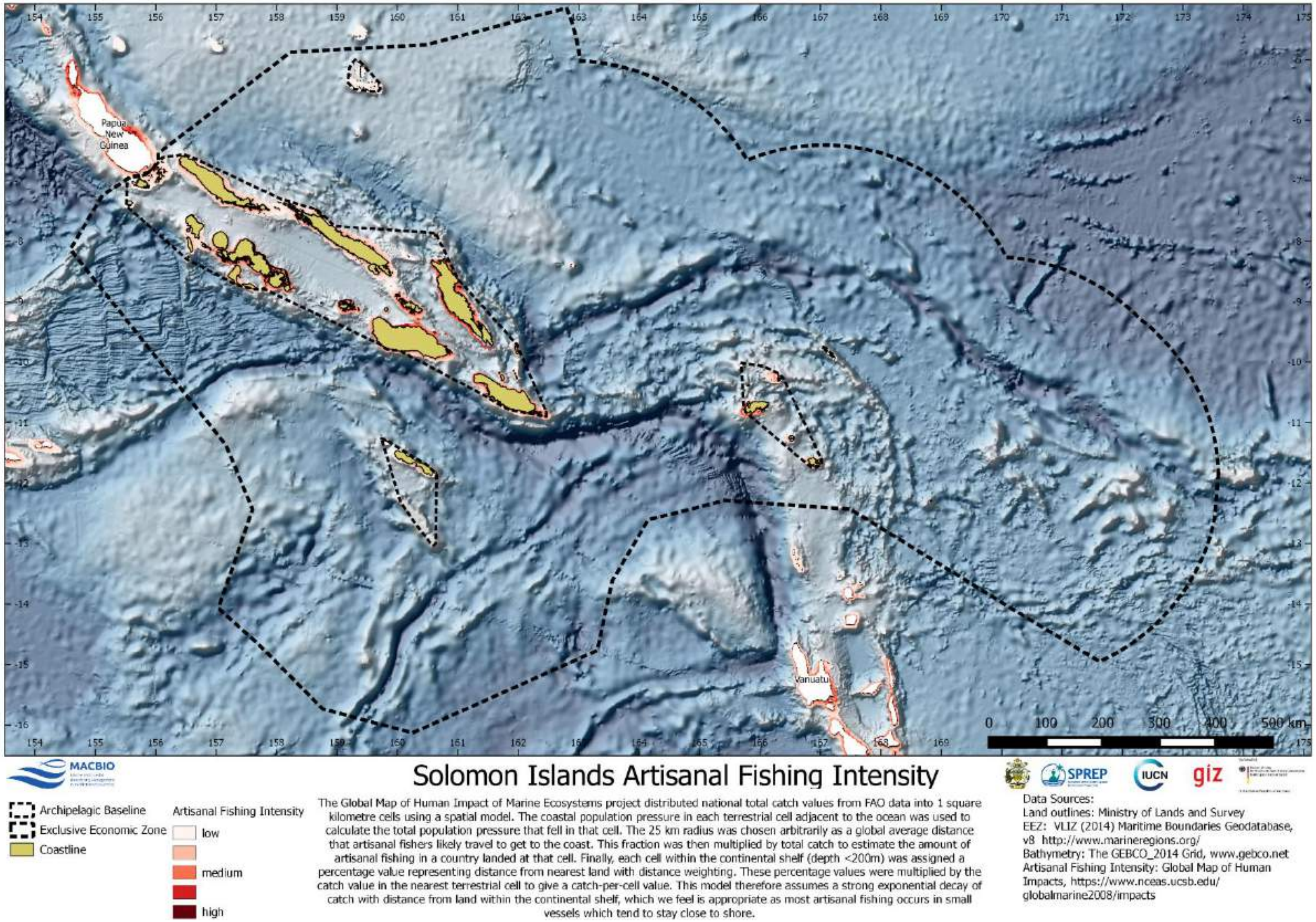


Figure 5-6 Artisanal fishing intensity (courtesy MACBIO)

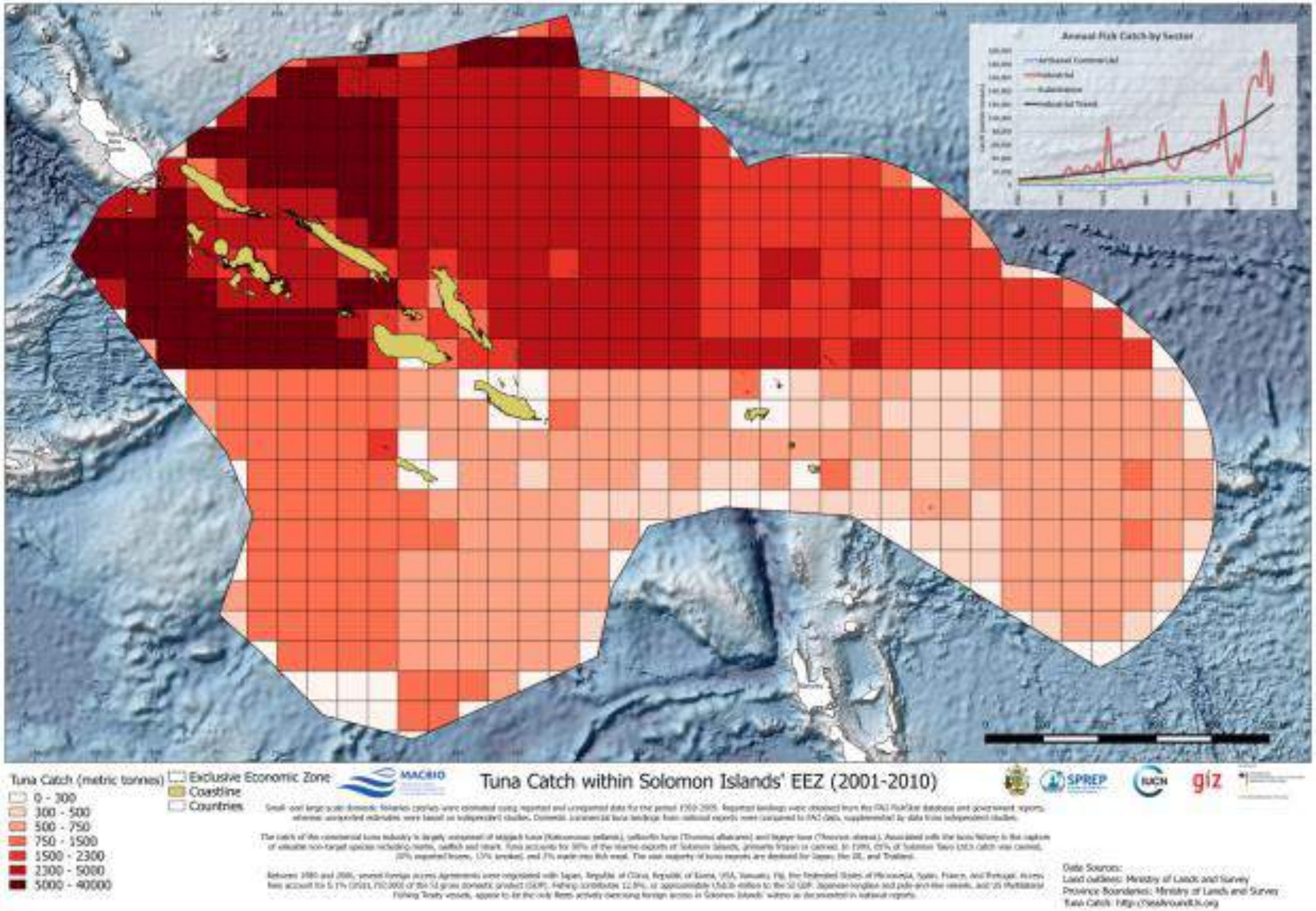


Figure 5-7 Tuna catch in Solomon Islands, 2001–2010 (courtesy MACBIO)

5.13 Groundwater

Fresh to brackish ground water is thought to occur throughout most of the Solomon Islands. At a national scale, ground water is an essential ecosystem providing a water source for communities, including water for drinking and/or domestic uses. This is particularly important for communities on smaller islands, atolls and cays with little in the way of alternative freshwater sources. In such cases, groundwater is a critical survival resource for communities. These locations include, for example, many communities in Rennell and Bellona, and Temote Provinces, as well as Ontong Java atoll.

Groundwater is also used as a commercial resource for income generation through the bottled water industry.

Given the primary ecosystem service to communities is the provision of water for human consumption and domestic uses, the main threat of concern in this respect is contamination and declining water quality. This can occur as a result of natural disturbances (e.g. drought, tsunami or earthquakes causing saltwater infiltration) or human-derived pollution sources such as sewage, domestic wastes (e.g. grey water, domestic animals such as keeping pig pens near wells), and industrial discharges (e.g. mining). Growing human populations also increase the reliance on (and/or extraction of) groundwater.

5.14 Cultivated land (gardens and plantations)

Land is cultivated throughout Solomon Islands, primarily as a means of subsistence, but also commercially for income-generation through both the local and export markets. Land may be cultivated in the form of community gardens or larger plantations. Communities rely heavily on root crops as staples for subsistence (e.g. cassava, sweet potato, taro, yam). Other important cultivated crops and food sources include banana, pineapple, breadfruit, papaya, tobacco, sago, coconuts, oil palm, pumpkin, watermelon, sugar cane, fruit trees (e.g. *Burckella* spp., Malay apple), Tahitian chestnut, canarium almond, turmeric, and areca nut (Feinburg 2010).

In addition to food and income, commercial use of cultivated land provides wealth, employment and livelihoods. Coconuts, palm oil and, to a lesser extent, sweet potato, yams and taro have the highest production value. For example, coconuts had an estimated production value of approximately 25,000,000 in 2009 (Table 5-5). Coconuts, oil palm and cocoa were the crops with the greatest export value.

Table 5-5 Production value of key crops, 2009 (adapted from Rodil and Mias-Crea 2014)

Crop	Banana	Cassava	Cocoa	Coconut	Oil Palm	Rice	Sweet Potato	Taro	Yam
Production (tons)	330	2,500	4,259	276,000	39,000	2,800	86,000	44,000	32,000
Production value (million)			3.3	25.0	11.8	0.6	8.6	4.5	6.5
Quantity exported (tons)			3,575	21,352	19,745				
Export value (million)			5.6	6.5	14.0				

Key existing threats to the ongoing functioning and value of cultivated land for food and income production include:

- invasive species, pests and diseases affecting crops;
- reduced soil fertility and land productivity from factors such as over farming and monoculture cropping;
- accumulation and/or inappropriate use of chemicals (i.e. pesticides, fertilisers);
- climatic effects and natural hazards, especially drought and extremely hot days, as well as physical damage from cyclone and storm events; and
- competing land uses and indirect impacts from other industries (e.g. logging, mining, industrial activities).

5.15 Summary of human induced threats to ecosystem services

Table 5-6 provides a summary of the key threats to ecosystems at the national scale. The concept of social-ecological resilience recognises the interdependence between people and nature and is clearly reflected by the ecosystem services identified above, on which Solomon Island communities and economies rely heavily for their livelihoods and well-being.

Despite the critical contribution ecosystem services provide to the human resilience, the ecosystems of Solomon Islands are subject to significant anthropogenic threats such as land-use change, habitat loss and pollution through logging, urbanisation, expansion of agricultural land, infrastructure development, mining, overfishing and exploitation. Furthermore, these threats are exacerbated by the nation's rapid rate of population growth and the current and future effects of climate change (to be explored further in Section 7).

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

Table 5-6 Summary of key threats to each ecosystem service

Key Ecosystems	Key Ecosystem Services identified by community	Climate Related Threats												Non-Climate Related Threats									
		Tides, storm surge, saline intrusion	Drought / decreased rainfall	Flooding / increased rainfall	Coastal erosion / current changes	River, gully, stream bank erosion	Hot days	Landslide	Ocean acidification	Cyclones (intens. freq.)	Invasives	Disease	Changing species distribution	Pollution (water-based)	Solid waste Mngt.	Development (e.g. resource devel.)	Land clearing / habitat loss and modification	Pop. Increase, loss of knowledge transfer	Change in land use / urbanisation	Inadequate resource management	Economic pressures	Policy changes	Negative human behaviour/ attitude
Rivers, streams	Food provision	✓	✓	✓							✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Water supply (drinking and domestic)	✓	✓			✓								✓	✓	✓	✓	✓	✓	✓		✓	✓
	Water supply (irrigation)	✓	✓															✓		✓	✓	✓	
	Recreation		✓	✓										✓	✓	✓			✓	✓			
	Transportation, anchorage		✓	✓				✓		✓												✓	
	Raw materials provision					✓												✓		✓	✓	✓	✓
	Energy generation (hydropower)		✓																	✓	✓		
	Cultural values													✓	✓	✓	✓		✓	✓		✓	✓
	Waste disposal and dispersal		✓															✓		✓			✓
	Support fisheries	✓	✓								✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Habitat provision, biodiversity	✓	✓			✓		✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Terrestrial Forests, Vegetation	Raw materials and fuel provision		✓					✓		✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓
	Fauna habitat		✓					✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
	Kastom medicine provision		✓					✓		✓	✓	✓	✓			✓	✓	✓	✓	✓		✓	✓
	Source of income/revenue		✓					✓		✓	✓	✓	✓			✓	✓		✓	✓	✓	✓	✓
	Carbon sequestration															✓	✓		✓	✓		✓	✓
	Nutrient cycling and primary productivity		✓					✓		✓						✓	✓		✓	✓		✓	✓
	Soil retention and fertility		✓	✓		✓		✓		✓						✓	✓		✓	✓		✓	✓
	Air regulation and shade provision		✓					✓		✓	✓	✓	✓			✓	✓		✓	✓		✓	✓

	Support recreation and tourism							✓		✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓
	Cultural values and handicrafts		✓					✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Food provision							✓		✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓
Other Terrestrial Lands	Commercial value	✓	✓	✓	✓			✓							✓	✓		✓			✓	✓	✓
	Provides identity and heritage															✓							
	Support forests	✓	✓	✓	✓			✓								✓	✓		✓	✓	✓	✓	✓
	Minerals source (mining industry)															✓							
	Land provision	✓		✓	✓			✓								✓							
Coral Reefs	Habitat provision / biodiversity					✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
	Food provision					✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
	Coastal protection																						
	Income and revenue source								✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Fishing grounds					✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Lime extraction								✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓		
	Raw materials provision (coral rock)								✓	✓											✓		
	Cultural values (shells, ornaments)								✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓
	Recreation and leisure								✓	✓	✓	✓		✓	✓	✓	✓	✓				✓	✓
	Kastom medicine								✓	✓	✓	✓	✓	✓		✓	✓	✓					✓
	Supports tourism industry								✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Supports marine food chain					✓			✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
Coastline / Beach	Support recreation/leisure	✓			✓					✓				✓	✓	✓	✓		✓	✓	✓		✓
	Waste disposal and dispersal									✓								✓			✓		✓
	Domestic use (bathing)	✓								✓				✓	✓	✓		✓	✓	✓			✓
	Cultural values and handicrafts	✓			✓				✓	✓						✓	✓		✓	✓	✓	✓	✓
	Raw materials provision	✓			✓											✓	✓	✓	✓	✓	✓		✓

	Supports transport (boat landing)	✓								✓						✓			✓				
	Fauna habitat (e.g. turtle nesting)	✓			✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Coastal protection	✓			✓					✓						✓			✓	✓		✓	✓
Mangroves	Food provision	✓		✓	✓	✓			✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓
	Raw materials and fuel provision	✓		✓	✓	✓				✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓
	Fauna habitat	✓		✓	✓	✓				✓	✓	✓		✓	✓	✓	✓		✓	✓		✓	✓
	Coastal protection, shoreline stabilisation	✓		✓	✓	✓				✓	✓	✓				✓	✓		✓	✓		✓	
	Kastom medicine	✓		✓	✓	✓				✓	✓	✓	✓			✓	✓	✓	✓	✓			✓
	Recreation	✓		✓	✓	✓				✓	✓	✓		✓	✓	✓	✓		✓	✓			✓
	Waste disposal and dispersal	✓				✓												✓					✓
	Cultural values (crafts, dye)	✓		✓	✓	✓				✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓
	Carbon sequestration				✓						✓	✓				✓	✓		✓	✓		✓	
Sea / Ocean	Support transport									✓													
	Habitat provision								✓					✓	✓	✓	✓				✓		✓
	Food provision								✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
	Climate and atmospheric regulation								✓														✓
	Income and revenue generation								✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
Mountains, Highlands	Raw materials provision		✓					✓								✓	✓	✓	✓	✓	✓	✓	✓
	Habitat provision and biodiversity		✓				✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Water source		✓					✓						✓									
	Climatic regulation																						
	Provide protection from disasters																						
	Support navigation																						
Wetlands / Lakes / Swamps	Food provision	✓	✓	✓	✓		✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Water provision (drinking, domestic)	✓	✓	✓	✓									✓	✓	✓		✓	✓	✓		✓	✓
	Habitat provision	✓	✓		✓						✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
	Support aquaculture	✓	✓	✓	✓						✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓

	Cultural values (heritage)													✓	✓	✓	✓		✓	✓		✓	✓
	Water quality and flood flow regulation		✓	✓	✓	✓		✓		✓				✓	✓	✓	✓		✓	✓	✓	✓	✓
Seagrass and marine macroalgae (seaweeds)	Habitat provision								✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓
	Primary productivity									✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓
	Income generation (seaweed)									✓	✓	✓	✓	✓	✓		✓			✓	✓		
	Kastom medicine and food									✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓
	Seabed stabilisation													✓		✓	✓			✓			✓
Groundwater	Water provision	✓	✓											✓		✓		✓	✓	✓		✓	✓
	Income generation (spring water)	✓	✓											✓		✓			✓	✓	✓		✓
Plantations and Gardens	Income generation	✓	✓	✓		✓	✓	✓		✓				✓	✓	✓	✓		✓	✓	✓		✓
	Food provision	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓

6 National ecosystem valuations

6.1 Economic values for ecosystem services

The values used for national scale ecosystem services have been adapted from MACBIO (2015) and de Groot *et al* (2012). The values from MACBIO (2015) are based on local analysis and were used in the first instance, while the values from de Groot *et al*. 2015 were used where MACBIO values are not applicable.

MACBIO (2015) values are shown in Table 6-1. It should be noted that these values are shown as national totals, and while they provide insights into the total value of services they may be less applicable in economic assessment. Additionally, some values may not completely capture benefits or costs.

Table 6-1 Summary of national ecosystem service values (adapted from MACBIO 2015)

Ecosystem	USD 2015, hectare/p.a.	SBD 2015, hectare/p.a.
Subsistence fisheries	61,000,000	476,900,000
Inshore commercial	9,700,000	75,800,000
Beche-der-mer	500,000	3,600,000
Aquarium trade	200,000	1,300,000
Trochus	300,000	2,300,000
Offshore tuna	228,900,000	1,789,900,000
Deep sea minerals	100,000	1,100,000
Tourism	16,400,000	128,000,000
Coastal protection	5,000,000	39,400,000
Carbon sequestration	22,300,000	174,600,000
Research, education and management	1,300,000	9,900,000

The de Groot *et al.* (2012) values presented in Table 6-2 have been aggregated at the ecosystem level. Disaggregated values for specific services within specific ecosystems can also be utilised for the development of future adaptation options.

Table 6-2 Summary of national ecosystem service values (adapted from de Groot *et al.* 2012)

Ecosystem	USD 2015, hectare/p.a.	SBD 2015, hectare/p.a.
Coral reefs	256,469	2,005,230
Coastal systems (estuaries, continental shelf area and seagrass)	29,670	231,975
Coastal wetlands (tidal marsh, mangroves and saltwater wetlands)	8,913	69,683
Fresh water lakes, rivers	7,071	55,289
Inland wetlands	8,441	65,993
Tropical forests	3,202	25,037
Grasslands	1,473	11,516

Solomon Islanders rely heavily on ecosystem services for their livelihood, income generation, health and well-being. The economic value of these services is clearly substantial and likely to exceed revenue generated from services involved in extractive industries (e.g. forest ecosystems).

Where data were available on ecosystem coverage at a national scale, the estimated overall annual economic value is presented below.

- Mangroves are reported to cover an estimated 65,000 ha in Solomon Islands (Sulu *et al.* 2012). Utilising the per hectare estimate for coastal wetlands in Table 6-2, mangroves have an annual economic value of USD 579,345,000 (2015) or SBD 4,529,395,000 (2015).
- Seagrass is estimated to cover an area of 10,000 ha (*ibid*) and represents an economic value of USD 296,700,000 (2015) and SBD 2,319,750,000 (2015) based on the annual ecosystem value for coastal systems.
- Based on the trend of forest clearing presented in Section 5, Figure 4-2, forests were estimated to cover an area of 2,150,000 ha in 2015. Utilising the economic value presented in Table 6-2 for tropical forest, Solomon Island forests represent an annual economic value of approximately USD 6,884,300,000 (2015) and SBD 53,829,550,000 (2015).

Ecosystem valuations provide the support and justification for public policies to protect ecosystems and prioritise the allocation of programme spending to maximise the environmental benefits per dollar spent (King and Mazzotta 2000). There is a strong economic case for investing in ecosystem services, as many studies find that the costs of ecosystem restoration and protection are far outweighed by the benefits (Carabine 2015). Additionally, if land and resource owners had an increased understanding of the value of ecosystems and the ecosystem services they provide, more informed decisions could be made for the long term.

7 Climate change vulnerability assessment

As discussed in Section 2.4, the vulnerability of an ecosystem to climate change is the degree to which a system is susceptible to the adverse effects of climate change. This is a function of its exposure to climatic variations, its sensitivity to climate variation, and its adaptive capacity, or ability to adjust or cope, with climate change.

The following section presents a snapshot of Solomon Islands' current climate, climate projections for 2030 and 2090, the potential effects of climate change threats on the broad marine, aquatic and terrestrial ecosystems, and, lastly, it identifies the ecosystem services that are predicted to have high or very high vulnerability to various climate change variables for 2030 and 2090.

7.1 Current climate

Climate is usually defined as the average weather over 30 years or more. Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC 2007).

The climate of Solomon Islands varies considerably from year to year due to the El Niño-Southern Oscillation (ENSO). ENSO includes two extreme phases and a neutral phase. The El Niño phase brings warmer, drier wet season conditions and La Niña brings cooler, wetter, wet seasons. The ENSO effect is stronger in Santa Cruz than in Honiara.

The following section presents a snapshot of the current climate for Solomon Islands based on the assessments by PACCSAP (CSIRO 2011; 2014).

7.1.1.1 Air temperature

Temperatures in Solomon Islands are relatively constant throughout the year with only very small changes from season to season and are strongly tied to changes in ocean temperature. Annual maximum and minimum temperatures have increased in Honiara since 1951, with maximum temperatures increasing at a rate of 0.15°C per decade. Consistent with global warming, there have been significant increases in warm nights and decreases in cool nights for both Honiara and Munda. Cool days have also decreased at Munda.

7.1.1.2 Rainfall

Rainfall in Solomon Islands is affected by the South Pacific Convergence Zone and the Intertropical Convergence Zone, which bring bands of heavy rainfall and thunderstorm activity. The West Pacific Monsoon also influences rainfall in Solomon Islands. It is driven by large differences in temperature between the land and the ocean.

Solomon Islands has two distinct seasons, with a wet season from November to April and a dry season from May to October. In the dry season at Honiara, on average about 100 mm of rain falls per month compared to upwards of 300 mm in the wet season. Further east, Santa Cruz receives more constant rainfall during the year, averaging between 280 mm and 420 mm per month.

There is notable interannual variability in rainfall associated with ENSO but there has been little change in rainfall trends at Honiara since 1950 and at Munda since 1962. However, since 1955 there has been a decreasing trend in the number of rainy days at Honiara. Since 1962, there has been an increasing trend in annual maximum one-day rainfall at Munda.

7.1.1.3 Wind-driven waves

The wind-wave climate for Solomon Islands shows strong interannual variability associated with ENSO and there is strong spatial variation across the region. Small waves (mean height around 0.15 m) occur at Honiara, which is sheltered from easterly trade winds, and display strong seasonal variability of direction characterised by trade winds, monsoons and cyclones. Larger waves occur on the outlying easterly islands (e.g. to the north of Santa Cruz), and are characterised by variability of the Southern Hemisphere trade winds and westerly monsoon winds. Waves larger than 2.5 m occur mostly during December–March from the north-west through to north-east associated with tropical cyclones and extra-tropical storms. The height of a 1-in-50 year wave event on the north coast of Santa Cruz is 8.0 m.

7.1.1.4 Tropical cyclones

Based on the 1969 to 2011 seasons, tropical cyclones occur mainly between November and April with an average of 29 cyclones per decade. Cyclones were most frequent in El Niño years (39 cyclones per decade) and least frequent in La Niña years and neutral years (21 cyclones per decade). Twenty-seven per cent of the cyclones between 1981 and 2011 were severe events (Category 3 or stronger) and most intense events occur during an El Niño.

7.1.1.5 Sea level

Sea level has risen near Solomon Islands by about 8 mm per year since 1993, which is more than the global average of 2.8–3.6 mm per year. The higher rate of rise may be related to natural fluctuations caused by ENSO.

7.1.1.6 Ocean acidification

Aragonite, a metastable form of calcium carbonate, is used by hard reef-building corals to build skeletons. As the oceans acidify in response to increasing carbon uptake, the carbonate ion concentration of seawater decreases, making it harder for corals to grow. For coral growth, saturation states above 4 are optimal, Between 3.5 and 4 are adequate, and between 3 and 3.5, marginal, with no corals historically found below 3 (Guinotte *et al.* 2003). Aragonite saturation state has declined In Solomon Islands from about 4.5 in the late 18th century to an observed value of about 3.9 ± 0.1 by 2000.

7.2 Future climate projections

The following section summarises the climate projections for Solomon Islands (Australian Bureau of Meteorology and CSIRO [2014]) based on the very high IPCC emissions scenario Representative Concentration Pathways (RCP) 8.5, the highest scenario of the 5th Assessment Report, for the short term (2030) and longer term (2090). All projected changes represent the overall change relative to 1995 levels of each climate variable.

7.2.1.1 *Average temperature*

There is very high confidence there will be further warming over Solomon Islands. Relative to 1995, warming increases up to 1.0°C by 2030 and up to 2.0–4.0°C by 2090 are projected for RCP 8.5. Temperature rises may be 0.2°C greater over land than over the ocean. While relatively warm and cool years and decades will still occur due to natural variability, there is projected to be more warm years and decades on average in a warmer climate.

7.2.1.2 *Extreme temperature*

There is very high confidence that the temperature of extremely hot days and extremely cool days will increase, but there is low confidence in the magnitude of projected change. The temperature on extremely hot days is projected to increase by about the same amount as the average temperature, and the frequency of extremely hot days is expected to increase. The temperature of the 1-in-20-year hot day is projected to increase by approximately 0.6°C to 0.8°C by 2030 and 0.8°C to 2.9°C by 2090.

7.2.1.3 *Average rainfall*

The effect of climate change on average rainfall may not be obvious in the short or medium term due to natural variability, and there is low confidence that annual rainfall will increase slightly. The CMIP5 model average is for a slight increase in projected annual rainfall change, with the range greater in the highest emissions scenarios. Dynamical downscaling suggests that there may be some difference in the rainfall change over land compared to over the ocean, and on the western side of islands compared to the east.

7.2.1.4 *Extreme rainfall*

There is high confidence that the frequency and intensity of extreme rainfall events will increase but there is there is low confidence in the magnitude of projected change. The current 1-in-20-year daily rainfall amount is projected to increase by approximately 9 mm by 2030. By 2090, it is projected to increase by 43 mm under RCP 8.5. The current 1-in-20-year daily rainfall event may become, on average, a 1-in-4-year event for RCP 8.5 by 2090.

7.2.1.5 *Drought*

There is low confidence in the projections of drought duration and frequency because of the low confidence in the magnitude of rainfall projections and uncertainty around projected changes in ENSO. However, the overall proportion of time spent in drought is expected to decrease under all scenarios. Under RCP 8.5 the frequency of mild, moderate and severe drought events is expected to decrease, while the frequency of extreme drought events is expected to remain stable.

7.2.1.6 *Cyclones*

There is a medium level of confidence that globally, the frequency of tropical cyclones is likely to decrease by the end of the 21st century. However, there is likely to be an increase in the mean maximum wind speed between 2% and 11% and an increase in rainfall intensity of about 20% within 100 km of the cyclone centre. For Solomon Islands, there is a medium level of confidence that there will be a decrease in cyclone genesis frequency for the south-west basin in the order of 5 to 30%.

However, by the late 21st century there is an expected increase in the proportion of more intense storms.

7.2.1.7 Wind-driven waves

Overall, there is low confidence in projected changes in Solomon Islands' windwave climate. There is 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 (which is variable in the wet season). There is also low confidence there will be a decrease in the strength of prevailing winds, with no change in the height of larger storm waves predicted. In June–September, there are no statistically significant projected changes in wave properties. Possible changes may include an increase in wave height and a decrease in period.

7.2.1.8 Sea level

There is very high confidence that mean sea level in Solomon Islands will continue to rise over the 21st century. There is moderate confidence that there will be a rise of between approximately 5–15 cm by 2030, with increases of 20–60 cm indicated by 2090 under the higher emissions scenarios. A rise larger than that projected cannot be excluded and, since the early 1990s, sea level has been rising globally near the upper end of the projections. Similar levels of interannual variability of sea level, leading to periods of lower and higher regional sea levels, will occur in the order of 31 cm. Winds and waves associated with weather phenomena will continue to lead to extreme sea-level events.

7.2.1.9 Ocean acidification

The aragonite saturation state in Solomon Islands has declined from about 4.5 in the late 18th century to about 3.9 by 2000. There is very high confidence that levels will continue to decrease with increases in atmospheric CO_2. Under RCP 8.5, the median aragonite will transition to marginal conditions (3.5) around 2030. There is moderate confidence that the annual maximum aragonite saturation state will reach values below 3.5 by about 2045 and continue to decline thereafter. Under RCP 8.5 the aragonite saturation state continues to strongly decline thereafter to values where coral reefs have not historically been found (<3.0).

7.2.1.10 Coral bleaching risk

The risk of 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, there is medium confidence in the projected rate of change for Solomon Islands based on the medium confidence in the rate of change of sea-surface temperature, and the complexity of changes at the reef-scale, including other potential stressors.

Based on current projections for sea-surface temperature, there is an overall decrease in the time between two periods of elevated risk for bleaching and an increase in the duration of the elevated risk. Under a long-term mean increase of 1°C, the average period of severe bleaching risk will last 8.2 weeks (with a minimum of 1.8 weeks and maximum of 4.5 months), and the average time between risk events will be 2.6 years (minimum recurrence of 4.3 months and maximum recurrence of 7.4 years). If severe bleaching events occur more often than once every five years, the long-term viability of coral reef ecosystems becomes threatened.

7.3 Climate change threats

The following section discusses the potential effects of these climate change threats on the broad marine, aquatic and terrestrial ecosystems of Solomon Islands and their ecosystem services. Climate change threats have focused on the use of projections that have high to very high confidence of occurring and represent the highest risks to Solomon Islands. Whilst drought may be an issue, there is limited capacity to predict future scenarios for 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.

7.3.1 Temperature increase

Sea and air temperatures will continue to rise, with projections of up to 1.0°C by 2030 and up to 2.0–4.0°C by 2090

Temperature is important in regulating chemical and physiological processes in terrestrial, aquatic, estuarine and marine communities. However, predicting ecosystem responses to increasing temperatures is complicated by the feedback and interactions among temperature change and the interactions of other climate change stressors, such as rainfall and ocean acidification.

Increases in temperature could result in some changes to the composition and structure of terrestrial vegetation communities of Solomon Islands, which may include the spread of insects, pathogens, herbivores and pests. These ecological changes could affect native vegetation and community responses to stressors such as fire, drought, storms and erosion, and also affect fauna habitat values, including aquatic receiving environments. The potential increase in pests and disease could affect agricultural lands, potentially resulting in reduced crop yields, and an increase in the number of hot days will potentially have negative effects on human health.

Water temperature regulates oxygen, pH, conductivity, photosynthesis and respiration rates. Increases in temperatures could directly alter aquatic ecological processes, affect the distribution of aquatic species and could also affect the quality of water resources for human and agricultural use. Increased water temperature could affect algal production and the availability of light, oxygen and carbon for estuarine species. It could also affect important microbial processes such as nitrogen fixation and denitrification in estuaries (Short and Neckles 1999; Lomas *et al.* 2002).

It is well established that the risk of coral bleaching increases with elevated sea temperatures. When ocean temperatures exceed summertime maximums by 1.0–2.0°C for a prolonged period (1–3 weeks), corals become stressed, increasing the risk of coral bleaching (Berkelmans *et al.* 2004; Hoegh-Guldberg 1999). The longer the temperature is elevated above this limit, the greater the coral bleaching risk. Long-term ocean warming will reduce the time between risk events and if these occur more often than once every five years, the long-term viability of coral reef ecosystems becomes threatened (Donner 2009).

7.3.2 Sea-level rise

The sea level will continue to rise, with projected increases of 5–15 cm by 2030 and 20–60 cm by 2090.

Ongoing sea-level rise may exacerbate shoreline erosion, inundate low-lying coastal habitats and infrastructure, cause saline intrusion of surface waters and coastal aquifers, lead to higher levels of sea flooding and increase the landward reach of sea waves and storm surges. Provided coastal ecosystems can accrete vertically and maintain their elevation relative to sea level, they may be able to adapt and migrate with sea level rise. However, local ecosystem responses to sea-level rise will depend on coastal dynamic processes, including the total sediment budget, and the effect of saltwater intrusion will depend on local conditions, such as aquifer dimensions, geology, groundwater and surface water factors, run-off and rainfall patterns.

The combined effects of beach erosion from sea-level rise and an increase in cyclone intensity as a result of climate change may exacerbate erosion, sedimentation or saline inundation of coastal ecosystems, and may alter coastal hydrological regimes. Other variables, such as altered biogeochemistry, altered amounts and patterns of suspended sediments loading, oxidation of organic sediments, and the physical effects of wave energy, may all play important roles in determining regional and local effects of-sea level rise and more intense storms (IPCC 2007).

When not subjected to environmental or anthropogenic stresses, coral reefs have been shown to keep pace with rapid postglacial sea-level rise, suggesting sea-level rise may be unlikely to threaten reefs in the next few decades (Hallock 2005). However, degradation of reefs following bleaching or from ocean acidification may result in increased wave energy across reef flats, with the potential for exacerbating shoreline erosion with sea-level rise (Sheppard *et al.* 2005).

Erosion of sandy barrier islands as a result of increased sea level could also alter local wave conditions, which may enhance erosion rates of the shoreline, tidal creeks and adjacent wetlands. Whilst the effects of accelerated sea-level rise on rocky shores is poorly understood, their persistence will be influenced by storms and other coastal processes.

7.3.3 Ocean acidification

Ocean acidification is projected to increase with an associated decline in aragonite concentrations, potentially to 3.5 around 2030, below 3.5 by 2045, and could potentially continue to decline to 2090, and after, to < 3.0.

Decreased sea-water pH and carbonate saturation has the potential for reducing the ability of carbonate flora and fauna to calcify, and could potentially increase dissolution of nutrients and carbonate minerals in sediments (IPCC 2007).

Increases in the amount of dissolved CO_2 in ocean ecosystems may lead to higher rates of photosynthesis in submerged aquatic vegetation, such as seagrass and seaweed. However, algae growth in lagoons and estuaries may also respond positively to elevated dissolved inorganic nutrients and an increase in epiphytic or suspended algae may decrease light availability to submerged aquatic vegetation.

As the oceans acidify in response to increasing carbon uptake, the aragonite concentration of seawater decreases. Guinotte *et al.* (2003) suggest that seawater aragonite saturation states above 4 are optimal for coral growth and for the development of healthy reef ecosystems, with values from 3.5 to 4 adequate for coral growth, and values between 3 and 3.5, marginal. Coral reef ecosystems have not been recorded at aragonite saturation states below 3, and these conditions have been classified as extremely marginal for supporting coral growth (Guinotte *et al.* 2003). Ocean acidification may also affect the growth of crustaceans and molluscs, and fisheries production. The effect 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 fishing pressure, and will be an important adaptive challenge.

7.3.4 More extreme rain events

More extreme rain events are projected to occur with the current 1-in-20-year daily rainfall amount, increasing by 9 mm by 2030 and 43 mm by 2090, and becoming a 1-in-4-year event by 2090.

More extreme rain events could lead to more frequent episodes of soil saturation, increased soil instability and soil erosion, and landslide frequency. Receiving aquatic ecosystems are sensitive to changes in the frequency, duration and timing of extreme rainfall events and long-term changes in run-off may alter hydrologic characteristics of aquatic ecosystems and affect species' composition and productivity.

Extreme rainfall events also determine the patterns and quality of freshwater flow to coastal and estuarine habitats. Run-off into estuaries influences water residence time, nutrient delivery, vertical stratification and salinity. Altering 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. Rainfall patterns and sea-level rise, in combination with human land use, will be important determinants of water quality in coastal and marine ecosystems of Solomon Islands.

7.3.5 Summary of climate change threats

Figure 2-3 provides a summary of the ecosystems and their services for Solomon Islands, a summary of their critical biophysical, ecological and land management dependencies, and the major climate change threats to these. The way these ecosystems and their services will respond to the effects 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 the services. The following section provides a vulnerability assessment to calculate exposure, sensitivity and adaptive capacity of the key ecosystem services to the main climate changes identified for Solomon Islands: temperature rise, sea-level rise, ocean acidification and more extreme rain events.

7.4 Vulnerability of ecosystem services to climate change variables

Based on the critical climate variables or threats assessed for this project, by 2030 sea-level rise and temperature increases, including extremes, could potentially affect a broad range of national ecosystem services. Whilst sea-level rise will continue to affect coastal ecosystem services to 2090 and beyond, the projected magnitude of temperature increase may become the dominant climate change threat to the broadest range of national ecosystem services (refer to Appendix C for the output scores of the national scale vulnerability assessment). All projected changes presented in each text box are changes relative to 1995 levels for each climate variable (e.g. for sea-level rise, an increase of 13 cm to that of 1995 levels is projected).

7.4.1 Sea-level rise

2030 Sea-level Rise Projection Summary

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

By 2030, sea-level rise poses potential climate change threats across a range of national ecosystem services. A large proportion of national ecosystem services identified during stakeholder engagement are found to be potentially highly vulnerable to sea-level rise, including income generation and food provision, demonstrating the social attachment and reliance on coastal ecosystems. At an overall ecosystem level, those potentially most vulnerable to 2030 and 2090 (and beyond) sea-level rise are freshwater-dependent wetlands, lakes, swamps, and groundwater, which have low adaptive capacity to saline intrusion. Beach-dependent species such as marine turtles (and the services which rely on these) have a high vulnerability to sea-level rise, given their limitations to adapt to other ecosystems (nesting is restricted to sand dunes). These projections are dependent on the specific ecosystems' adaptive capacity to retreat landward, and factors such as topography and development boundaries.

2090 Sea-level Rise Projection Summary

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

As expected, 2090 sea level rise by 40 to 89 cm will potentially affect a broader range of coastal ecosystems and their services. Despite their potentially high adaptability, mangroves and their associated services, such as *kastom* medicine, raw material and fuel, are expected to be more vulnerable to 2090 sea levels, depending on mangrove location and their ability to migrate. Ecosystem services associated with coastal rivers, streams and terrestrial forests, including food, biodiversity, fisheries and water supply for both drinking and irrigation purposes, may also be vulnerable, due to their low adaptive capacity to saline intrusion, but effects will depend on their location and local hydrologic and geographic features.

7.4.2 Air and sea temperature

Surface air temperatures in the Pacific are closely related to sea-surface temperatures. Projected changes to air temperature can therefore be used as a guide to changes in sea-surface temperatures (Australian Bureau of Meteorology and CSIRO 2014).

> **2030 Air and Sea Temperature Projection Summary**
>
> - Temp increase up to 1.0ºC relative to 1995
> - Mean change: 0.7ºC
> - Confidence level is very high
>
> **2030 Extreme Air Temperature Projection Summary**
>
> - Temperature on extremely hot days is projected to increase the same amount as average temp
> - Frequency of extremely hot days is also expected to increase.
> - Temp of the 1-in-20-year hot day is projected to increase by approx. 0.8°C
> - Confidence level is very high

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

Ecosystems most vulnerable to the projected 2030 increase in air and sea temperature include coral reefs, ocean/sea, seagrass and marine algae (seaweed), due to their moderate adaptive capacity to increasing temperature. Based on the magnitude of temperature change, all other ecosystem services are expected to demonstrate high adaptive capacity to a 1.0°C temperature increase.

> **2090 Air and Sea Temperature Projection Summary**
>
> - Temp increase up to 2–4°C
> - Mean change: 2.8'C
> - Confidence level is very high
>
> **2090 Extreme Air Temperature Projection Summary**
>
> - Temperature on extremely hot days is projected to increase the same amount as average temp
> - Temp of the 1-in-20-year hot day is projected to increase by approx. 2.9°C
> - Confidence level is very high

On a national scale, the projected 2090 increase in air temperature by 2–4°C presents a potential climate change risk to a broad range of services across marine, coastal and terrestrial ecosystems. Marine ecosystems are anticipated to be highly vulnerable to the projected temperature increase due to coral reef, lagoon and macroalgae having high sensitivity and low capacity to adapt to temperature changes. Aquatic and terrestrial ecosystems will be moderately vulnerable to the projected temperature change, which may be expressed by changes in local biodiversity and sensitivity to other threats such as pests and disease, but many of these effects may be manageable, e.g. improved land management.

7.4.3 Ocean acidification

Coral reefs and their dependent services are vulnerable to ocean acidification. Aragonite, a metastable form of calcium carbonate, is used by reef building corals to build skeletons. As oceans acidify, the carbonate ion concentration in seawater decreases, making it harder for corals to grow. For corals, saturation states above 4 are optimal, 3.5–4 adequate, and between 3 and 3.5 marginal, with no corals historically found below 3 (Guinotte *et al.* 2003).

2030 Ocean Acidification Projection Summary

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

Based on the projections, aragonite concentrations by 2030 may be adequate for corals but by 2090, and beyond, the median aragonite saturation state may continue to strongly decline to values where coral reefs have not historically been found (< 3.0).

2090 Ocean Acidification Projection Summary

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

Due to the projected strong decline of the aragonite saturation state by 2090, threats to other marine ecosystems are expected. For example, mangrove food provisioning services, such as crustaceans and molluscs, may also be vulnerable to ocean acidification. Communities relying on corals for essential services such as income, food and raw materials, would need to adapt to other sources.

7.4.4 Extreme rainfall events

Compared with the other climate change variables described above, extreme rainfall events for 2030 and 2090 are predicted to be a lower climate change threat to national ecosystem services. Despite this, the quality of drinking water may be vulnerable due to the effect of extreme rainfall on soil erosion and sedimentation.

2030 Extreme Rainfall Events Projection Summary

- Current 1-in-20-year daily rainfall amount to increase by approx. 9 mm
- 3% increase in annual rainfall
- Confidence level is high

2090 Extreme Rainfall Events Projection Summary

- Rainfall to increase by approx. 43 mm
- Current 1-in-20-year daily rainfall event will become a 1-in-4 year event
- 6% increase in annual rainfall
- Confidence level is high

Extreme rainfall also presents a potential threat to terrestrial forests and their services through soil erosion and landslip, which could have indirect effects on water quality in receiving ecosystems, such as rivers and coastal lagoons. Land management practices such as reforestation of receiving catchments could help reduce these threats.

7.4.5 Summary of ecosystem service vulnerability to climate change

Under future climate change scenarios, Solomon Islands is likely to face rising sea levels, increasing air and sea temperatures and an increase in extreme rainfall events. It is anticipated that these changes will put further stress on marine resources by increasing bleaching events and the death of corals, molluscs and crustaceans from ocean acidification. Based on the vulnerability assessment to climate threats, Table 7-1 summarises the national ecosystem services that are predicted to have high (ticked) to very high (ticked and shaded) vulnerability to various climate change variables for 2030 and 2090.

The key findings from the results of this assessment are outlined below.

- As climate change threats intensify over time, ecosystems may become more vulnerable, which correlates to the increased number of climate variables listed for 2090 in Table 7-1.
- The key climate change threat to national ecosystems and their services for 2030 is sea-level rise. Many of the ecosystem services vulnerable to this threat are critical provisioning services related to water supply (groundwater, lakes, rivers and streams) and food source (seaweed, aquaculture)
- By 2090, a high proportion of national ecosystem services could be highly vulnerable to sea-level rise, increased temperatures and ocean acidification.
- A 2-4°C temperature increase by 2090 is a potential threat to a broad range of national services across marine, coastal and terrestrial ecosystems, where:
    - marine ecosystems are anticipated to be vulnerable to the projected temperature increase due to coral reef, lagoon and macroalgae having high sensitivity and low capacity to adapt to temperature changes. Local communities that rely upon these ecosystems for essential services (such as food, income and raw materials) are likely to be required to adapt to alternative ecosystems for these provisional services; and
    - aquatic and terrestrial ecosystems will be moderately vulnerable to the projected temperature change, which may be expressed by changes in local biodiversity and sensitivity to other threats such as pest and disease. Adaptive land management practices may address these threats,
- Based on current projections, coral reefs and their services will be particularly vulnerable to 2090 ocean acidification levels, where aragonite concentrations may decline to values where coral reefs have not historically been found. Intertidal ecosystems providing food, such as crustaceans and molluscs, may also be vulnerable. Local communities that rely on these ecosystems for essential services (such as food, income and raw materials) will be required to adapt to alternative ecosystems for provisional services by 2090.
- The effects of extreme rainfall events by 2090 may affect soil stability and the water quality of receiving environments. Improving land management practices and reforestation within catchments may help reduce these threats.

Table 7-1 Climate variables and the high to very highly vulnerable ecosystem services at the national scale

Ecosystem	Ecosystem Services	2030*		2090					
		Sea Level Rise	Extreme Rainfall Events	Sea Level Rise	Increased Sea Temp	Extreme Rainfall	Extreme Air Temp	Annual Air Temp	Ocean Acidific-ation
Seagrass and marine macroalgae (seaweeds)	Habitat provision				✓		✓	✓	✓
	Income generation (seaweed)				✓		✓	✓	✓
	Kastom medicine and food				✓		✓	✓	✓
	Primary productivity				✓		✓	✓	✓
	Seabed stabilisation				✓		✓	✓	✓
Wetlands, lakes and swamps	Cultural values (heritage)	✓		✓					
	Food provision	✓		✓					
	Habitat provision	✓		✓					
	Support aquaculture	✓		✓					
	Water provision (drinking, domestic)	✓		✓					
	Water quality and flood flow regulation	✓		✓					
Coral reefs	Coastal protection				✓		✓	✓	✓
	Cultural values (shells, ornaments)				✓		✓	✓	✓
	Fishing grounds				✓		✓	✓	✓
	Food provision				✓		✓	✓	✓
	Habitat provision / biodiversity				✓		✓	✓	✓
	Income and revenue source				✓		✓	✓	✓
	Kastom medicine				✓		✓	✓	✓
	Lime extraction				✓		✓	✓	✓
	Raw materials provision (coral rock)				✓		✓	✓	✓
	Recreation and leisure				✓		✓	✓	✓
	Supports marine food chain				✓		✓	✓	✓

		2030*		2090					
	Supports tourism industry				✓		✓	✓	✓
Groundwater	Income generation (spring water)	✓		✓					
	Water provision	✓		✓					
Coastline and beaches	Fauna habitat (e.g. turtle nesting)	✓		✓					
Rivers and streams	Water supply (drinking and domestic)	✓	✓	✓		✓			
	Water supply (irrigation)	✓	✓	✓		✓			
	Food provision			✓					
	Habitat provision, biodiversity			✓					
	Support fisheries			✓					
Ocean/sea	Climate and atmospheric regulation				✓		✓	✓	✓
	Food provision				✓		✓	✓	✓
	Habitat provision				✓		✓	✓	✓
	Income and revenue generation				✓		✓	✓	✓
Mangroves	Carbon sequestration			✓					
	Coastal protection, shoreline stabilisation			✓					
	Food provision						✓	✓	
	Kastom medicine			✓					
	Raw materials and fuel provision			✓					

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

8 ESRAM outcomes

The vulnerability of social and ecological systems to human activities such as logging, agriculture, pollution and the over-exploitation of marine resources is increasing. As one of the fastest growing populations in the world, these activities will only intensify and have an increased detrimental effect on the communities and economies of Solomon Islands. The direct and indirect effects of climate change and their interactions with human-induced threats increases the vulnerability of critical ecosystems and ecosystem services. 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 and effective governance structures and ultimately increase the resilience of both people and ecosystems.

The following section provides a summary of the vulnerabilities of Honiara's ecosystem services to climate and non-climate related threats and their effect on the resilience of the communities and economies of Solomon Islands. Due to the linked, interconnectedness of the social ecological systems and climate and non-climate threats, and the high-level nature of the national scale study, ESRAM outcomes are presented in three broad ecosystem types: freshwater (groundwater, wetlands, swamps, lakes, rivers, and streams), coastal and marine (beaches, mangroves, coral reefs, estuaries, seagrass and marine macroalgae, and ocean) and terrestrial (forests and cultivated land).

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

8.1.1 Freshwater ecosystems and services

Increasing erosion and sedimentation of stream and river systems from logging operations, subsistence cultivation on sloping lands, and land clearing for commercial and residential purposes is affecting the water quality of freshwater systems. In addition to sediment run-off, pollution in water catchments from inappropriate solid waste and sanitation practices, and chemical, pesticide and fertiliser inputs is increasing with rapid population growth, urbanisation and extractive industries. The projected increase in extreme rainfall events is likely to increase pollution inputs in the upper catchment areas, which then have detrimental flow-on effects to lower catchments.

The effects of extreme rainfall events by 2030 and beyond is likely to worsen soil stability and the water quality of receiving environments. Ecosystem services most likely to be vulnerable to these threats are critical provisioning services provided by freshwater ecosystems (i.e. rivers and streams) such as water supply (for drinking, domestic and irrigation purposes), food provision for both subsistence and commercial purposes (eels and other fish, molluscs, crustaceans, etc.), habitat provision (supporting biodiversity and food sources) and recreational activities (e.g. swimming). Communities and economies that rely on these ecosystems for essential services (such as food, income and raw materials) may be required to adapt to alternative ecosystems for provisional services.

The effect on freshwater systems such as groundwater, wetlands, swamps, lakes, rivers and streams will be further intensified by the threat of saltwater intrusion from rising sea levels due to ecosystems having high sensitivity and low capacity to adapt to increased salinity levels. Many of the ecosystem services vulnerable to sea-level rise are critical provisioning services related to water supply (groundwater and lakes) and food source (aquaculture), income generation (bottled spring water), habitat provision and biodiversity, and regulating services such as water purification. The high vulnerability of water supply and food provisioning services to both human-induced and climate change effects severely reduces the resilience of communities, particularly in times following natural or climate-related disasters.

The potential economic loss of freshwater ecosystems (e.g. freshwater lakes, rivers, wetlands) is estimated to cost USD 15,512 (2015) or SBD 121,282 (2015) per hectare per annum.

8.1.2 Coastal and marine ecosystems and services

Increasing habitat destruction, pollution and over-exploitation of marine resources for both subsistence and commercial use has resulted in severe decline of marine biodiversity and ocean health, and the depletion of important food and commercial species. An increasing population and inadequate environmental regulations are intensifying the rate of degradation.

The projected 2-4°C sea temperature increase by 2090 will further intensify these threats and increase the risk of coral bleaching. Marine ecosystems are likely to be highly vulnerable to the projected temperature increase due to coral reefs and lagoons having high sensitivity and low capacity to adapt to changes in sea temperature. An increase in sea temperature of this magnitude, coupled with coral bleaching and the over-exploitation and pollution, is likely to result in all regulating and many provisioning ecosystem services provided by marine ecosystems becoming highly vulnerable to these changes. Marine regulating ecosystem services assessed in this study that are likely to be most vulnerable include: marine primary productivity (reefs are critical to coastal food chain), climate and atmosphere regulation, and carbon sequestration. All ecosystems play a vital role in cycling and storing carbon for climate regulation, but the carbon dioxide exchange of oceans is larger than that of terrestrial ecosystems (Carabine *et al.* 2015).

The provisioning services identified as vulnerable to the projected sea temperature rise are extensive and many of these services are critical to the well-being and livelihoods of a large proportion of Solomon Island communities and economies. Provisioning ecosystem services identified as highly vulnerable include: food provision (supplying daily protein and micronutrients through fish, including pelagic fish, turtles, octopus, clams, beche-de-mer and trochus); habitat (essential feeding, breeding, spawning, cleaning and aggregation habitat); biodiversity; income and revenue generation (commercial extractive enterprises, i.e. fishing, aquarium trade, coral, lime extraction); tourism; provision of raw materials (coral rock and lime production), and hazard protection (wave attenuation by coral reefs, and seabed stabilisation by marine macroalgae). Cultural ecosystem services are also threatened by temperature changes, particularly those services provided by corals, and include: cultural practices and values (shell money, ornaments and decorations), cultural identity and status, and *kastom* medicine.

Furthermore, the projected levels of ocean acidification and the associated decline in aragonite concentrations (a metastable form of calcium carbonate used by reef building corals and crustaceans and molluscs to build skeletons) will further reduce the resilience of coral reefs and all ecosystem services, particularly by 2090 and beyond, when the median aragonite saturation state may continue to strongly decline to values where coral reefs have not historically been found (< 3.0). The effect of acidification on the health of reef and marine ecosystems is likely to be compounded by other stressors, including coral bleaching, storm damage, water quality and fishing pressure. Intertidal ecosystems that provide food, such as crustaceans and molluscs, may also be vulnerable, further reducing the resilience of local communities that rely on these ecosystems for essential services such as food, income and raw materials. Communities and economies that rely on these ecosystems for essential services (such as food, income and raw materials) will be required to adapt to alternative ecosystems for provisional services by 2090.

The projected sea-level rise of 40 to 89 cm by 2090, together with the effects of coastal development, urbanisation and pollution, are likely to increase the vulnerability of ecosystem services provided by mangroves and sand beaches from inundation and erosion of coastal habitats. The level of vulnerability for both ecosystems and their services will, however, largely depend on their location, adequate expansion space, and local hydrologic and geographic features. Mangrove ecosystem services likely to be vulnerable to 2090 sea levels include: carbon sequestration, coastal protection and shoreline stabilisation, food provision, raw material and fuelwood provision, and *kastom* medicine. It is estimated between 50% and 71% of the carbon sequestered in oceans (which totals up to 55% of total sequestration) is captured by coastal vegetation (Nellemann *et al.* 2009) while the rates of sequestration and storage by coastal vegetation can be equal or more than the sequestration rates of tropical rainforests or peatlands (*ibid*). Beach-dependent species such as marine turtles, are likely to have a high vulnerability to sea-level rise, given their inability to adapt to nesting outside of sand dunes. The over-exploitation of marine turtles, their sensitivity to temperature changes and the increasing pollution of oceans will further increase their vulnerability to rising sea levels.

An increase in extreme rainfall events will also result in an increase of run-off into estuaries, which influences water residence time, nutrient delivery, vertical stratification and salinity. Changes to 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. The increased levels of rainfall events and sea levels, together with threatening land-based activities, will be critical determining factors of water quality in coastal and marine ecosystems of Solomon Islands.

Marine and coastal ecosystem services are essential to the livelihoods and well-being of many Solomon Islanders for both subsistence and income generation purposes. The depletion of marine resources, and the corresponding reduced generation of income, will affect food security by forcing people to be more dependent on the market, which can have severe implications due to increasing prices. The high reliance on resources for subsistence, combined with the depletion of marine resources, is reducing the resilience of communities and ecosystems, both to future climate change effects and the high population growth. The degradation of marine resources from both climate and human-induced impacts is also likely to increase the rural-urban migration, as the provision of food and income becomes insufficient to meet the basic needs of rural households.

The potential economic loss of marine and coastal ecosystems (e.g. coral reefs, coastal systems, and coastal wetlands, including mangroves) and all ecosystem services is estimated to cost USD 295,052 (2015) or SBD 2,306,888 (2015) per hectare per annum. Utilising the estimated total coverage of mangroves in Solomon Islands of 65,000 ha (Sulu *et al.* 2012), the loss of mangroves and their ecosystem services is equivalent to an economic loss of USD 579,345,000 (2015) or SBD 4,529,395,000 (2015). Based on the estimated seagrass cover of 10,000 ha (Sulu *et al*. 2012) throughout Solomon Islands, the loss of ecosystem services provided by seagrass would equate to a loss of approximately USD 296,700,000 (2015) and SBD 2,319,750,000 (2015).

8.1.3 Terrestrial ecosystems and services

The greatest threat to terrestrial forests and inhabitant flora and fauna communities in Solomon Islands is dominated by logging and agriculture activities, while threats from mining and infrastructure development activities are likely to increase in the future. Rapid population growth and urbanisation will further increase land-clearing activities. The projected air temperature increase of 2–4°C by 2090 and beyond is likely to further increase the existing vulnerability of forests and cultivated land to these threatening activities. The increased vulnerability of terrestrial ecosystems may be expressed by a reduction in local biodiversity and species structure, and sensitivity to other threats, such as pests and disease and prolonged dry periods.

Climate, water and soil regulation provide suitable conditions for cultivated lands for food production and quality. Land-use change affects the levels of these regulating services, while the interaction of land-clearing and climate change is predicted to affect the provision of stable climatic conditions (Carabine *et al.* 2015) and threaten food security and livelihoods at a national scale.

The clearing of forests will continue to reduce the resilience of social and ecological systems by reducing the provision of essential ecosystem services. Ecosystem services identified in this study likely to be highly vulnerable include: provisioning services, such as food (hunting grounds, nuts, traditional fruits and vegetables); water supply (produced by forests and mountains and supported by vegetation, soils and microorganisms); habitat and biodiversity; raw materials and income generation (building, fuel and commercial purposes); and cultural services, such as cultural items, values, practices, identity and heritage (traditional tools, ornaments, costumes, weaving, handicrafts and traditional currency). Irreplaceable regulating services of forests are also vulnerable to climate and non-climate threats. Deforestation has the potential to reduce the capacity of terrestrial ecosystems to regulate and provide freshwater. The clearing of large forested areas can affect microclimates and vapour formation and rainfall patterns (Gordon 2003). Regulating services likely to be highly vulnerable to human-induced and climate change effects include: primary productivity, nutrient cycling, soil fertility and stability, and carbon sequestration.

A critical ecosystem service provided by terrestrial forests is the mitigation of natural hazards and extreme weather events. Terrestrial forests act as a barrier or buffer to extreme events and natural hazards by protecting people in downstream areas from landslides and flash floods, and reduce the level of sediment run-off into rivers and streams. Forest degradation, clearing and change in land use reduces the resilience of both humans and ecosystems to natural hazards. As the frequency and intensity of climate-related disasters increase with global climate change (Munang *et al.* 2013), the resilience of ecosystems and human societies against the effects of climate change will continue to decrease with further environmental degradation.

The potential economic loss of terrestrial ecosystems (e.g. tropical forests and grasslands) and their ecosystems is estimated to cost USD 4,675 (2015) or SBD 36,553 (2015) per hectare per annum.

Based on the estimated forest cover of 2,150,000 ha in 2015, this would equate to a loss of approximately USD 6,884,300,000 (2015) and SBD 53,829,550,000 (2015).

8.2 National ecosystem based adaptation options

Well managed and healthy ecosystems provide essential services for the health, well-being and livelihoods of the people of Solomon Islands. The ESRAM process has identified the vulnerabilities of social ecological systems to climate and non-climate change threats and impacts. By strengthening and assisting ecosystems to adapt to future threats, the resilience of local communities and national and sub-national economies is increased.

There is a strong economic case for investing in ecosystem services for human benefits, and most studies discover that the costs of ecosystem restoration and protection are far outweighed by the benefits (Carabine *et al.* 2015). Political support at the national level is critical for mainstreaming ecosystem-based adaptation to respond and act to future climate change impacts and climate-related disasters. Strong governance and well-coordinated regulations between jurisdictions of management is needed at all levels of government, together with awareness among communities about the values, restoration, protection and sustainable management of ecosystem services.

Based on the vulnerable ecosystem services outlined above, Table 8-1 presents high level EbA options to be considered in the protection, restoration and strengthening of ecosystems to increase the resilience of Solomon Island social and ecological systems.

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

High Level Ecosystem Type	Most Vulnerable Ecosystem Services to Climate and Non-climate Effects	Anthropogenic and Non-Climate Stressors	Potential Climate Change Related Impact	Adaptation and Ecosystem Resilience Options	Key Stakeholders to Support EbA Option Implementation
Fresh water	• Water supply (drinking, domestic, irrigation) • Habitat and biodiversity • Food provision (aquaculture) • Income generation • Recreational activities (swimming)	• Population growth • Vegetation clearing and land disturbance • Sediment run-off from inappropriate land management activities such as logging and agriculture • Pollution from poor solid waste management and sanitation, chemical, pesticides and fertiliser inputs, urbanisation and extractive industries	• Soil erosion, sedimentation and landslip from extreme rainfall events. Exacerbated by more intense tropical cyclones. • Salt water intrusion from sea-level rise	• Relocate communities and businesses from vulnerable riparian areas to drier, higher ground • Rezone areas within 50 m of a waterway to exclude development • Environmental compliance training for government staff • Vegetation protection and catchment and riparian revegetation programme • Land-use planning restrictions on steep and unstable soils • Nationwide environmental awareness and education programmes on: - Sustainable land management practices, including importance of riparian vegetation - Stormwater management systems - Good waste management and sanitation practices	• Ministry of Environment, Climate Change, Disaster Management and Meteorology • Ministry of Forests and Research • Ministry of Education and Human Resources Development • Ministry of Women, Children and Youth • Solomon Islands Water Authority • Town and Country Planning Board • Ministry of Infrastructure and Development • Botanical Garden and National Herbarium • Solo Enviro Beautification • The Nature Conservancy • World Wildlife Fund • SPREP
Coastal and marine	• Food provision (fish, including pelagic fish, turtles, octopus, clams, beche-de-mer and trochus) • Habitat (essential feeding, breeding, spawning, cleaning and aggregation habitat) and biodiversity	• Population growth • Depletion of marine resources and loss of biodiversity from over-exploitation (over-fishing) • Sediment run-off from inappropriate land management activities	• Decline in reef ecosystem condition and coral dieback due to coral bleaching (rising temperature), ocean acidification, poor water quality (sedimentation due to extreme rainfall events) Exacerbated by more intense tropical cyclones.	• Designate national marine and reef protection areas • Relocate communities and businesses from vulnerable coastal areas further inland or to higher ground • Sustainable fisheries management • Environmental compliance training for government staff	• Ministry of Environment, Climate Change, Disaster Management and Meteorology • Ministry of Fisheries and Marine Resources • Ministry of Education and Human Resources Development

High Level Ecosystem Type	Most Vulnerable Ecosystem Services to Climate and Non-climate Effects	Anthropogenic and Non-Climate Stressors	Potential Climate Change Related Impact	Adaptation and Ecosystem Resilience Options	Key Stakeholders to Support EbA Option Implementation
	• Income generation (commercial extractive enterprises and tourism) • Provision of raw materials (coral rock and lime production) • Hazard protection (wave attenuation by coral reefs, shoreline stabilisation by mangroves, and sea-bed stabilisation by marine macroalgae). • Cultural practices and values (shell money, ornaments and decorations) • Cultural identity and status • *Kastom* medicine • Marine primary productivity • Climate and atmosphere regulation • Carbon sequestration	such as logging and agriculture • Pollution from poor solid waste management and sanitation, chemical, pesticide and fertiliser inputs, urbanisation and extractive industries • Coastal development and vegetation clearing	• Shift in marine ecosystem structure due to rise in sea temperature • Altered capacity for oceans to regulate climate from increased sea temperatures • Sediment run-off from extreme rainfall events • Coastal erosion of mangroves forests and sand beaches from sea-level rise, storm surge and tropical cyclones • Permanent saltwater inundation of mangrove areas	• Coastal vegetation protection and revegetation • Land-use planning restrictions on coastal fringe • Nationwide environmental awareness and education programmes on the value of coral reefs for ecosystem services and sustainable fishing	• Ministry of Education and Human Resources Development • Ministry of Women, Children and Youth • Solomon Islands Water Authority • Town and Country Planning Board • Ministry of Infrastructure and Development • Botanical Garden and National Herbarium • Solo Enviro Beautification • The Nature Conservancy • World Wildlife Fund • SPREP
Terrestrial	• Provision of food (hunting grounds, nuts, fruits and vegetables) • Water supply (produced by forests and mountains) • Habitat and biodiversity • Raw materials and income generation (building, fuel and commercial purposes) • Cultural items (traditional tools, ornaments, costumes, weaving, handicrafts and traditional currency) • Cultural values and practices	• Population growth • Depletion of forests and loss of biodiversity from clearing and development • Change of land use • Sediment run-off from inappropriate land management activities such as logging and agriculture • Soil degradation from chemical, pesticide and	• Soil erosion, sedimentation and landslip from extreme rainfall events. Exacerbated by more intense tropical cyclones. • Increase in invasive species due to increase in temperature and extreme rainfall events	• Designate national protected areas • National food security programme • Environmental compliance training for government staff • Vegetation protection and catchment and riparian revegetation programme • Nationwide education programme on the value of terrestrial watersheds and sustainable land management practices • Land-use planning restrictions on steep and unstable soils	• Ministry of Environment, Climate Change, Disaster Management and Meteorology • Ministry of Forests and Research • Ministry of Education and Human Resources Development • Ministry of Women, Children and Youth • Solomon Islands Water Authority • Town and Country Planning Board

High Level Ecosystem Type	Most Vulnerable Ecosystem Services to Climate and Non-climate Effects	Anthropogenic and Non-Climate Stressors	Potential Climate Change Related Impact	Adaptation and Ecosystem Resilience Options	Key Stakeholders to Support EbA Option Implementation
	• Cultural identity and heritage • Water purification • Primary productivity • Nutrient cycling • Soil fertility • Carbon sequestration • Natural hazard protection	fertiliser inputs, and extractive industries			• Ministry of Infrastructure and Development • Botanical Garden and National Herbarium • Solo Enviro Beautification • The Nature Conservancy • World Wildlife Fund • SPREP

Glossary

Adaptation	Changes made in order to reduce the vulnerability of a community, society or system to the negative effects of climate change
Adaptive capacity	The ability of an ecosystem service to adjust to climate change, to moderate potential damage, to take advantage of opportunities, or to cope with the consequences
Biodiversity	The variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (CBD)
Climate change	Changes in the Earth's climate, due to human activities (anthropogenic climate change) or natural processes, which are already occurring or predicted to occur. Anthropogenic climate change is expected to happen much more rapidly than natural changes in the climate, posing an enormous challenge to both natural and human systems.
Ecosystem	A complex set of relationships of living organisms functioning as a unit and interacting with their physical environment
Ecosystem-based adaptation	Ecosystem-based adaptation (EbA) is an ecosystems focussed approach to building the resilience of human communities to the negative effects of climate change.
Ecosystem services	The benefits that an ecosystem provides to humans
Exposure	The degree to which an ecosystem service is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g. coral bleaching in response to temperature rise) or indirect (e.g. seagrass dieback due to sedimentation from extreme rainfall events).
Resilience	The capacity of a community, society or natural system to maintain its structure and functioning through stress or change. The combination of resistance and recovery time influence the degree to which a system experiences long-term consequences of a stressor's impact (Folke 2006).
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain. (Probability of physical event occurring x Consequences).
Sensitivity	The degree to which an ecosystem service is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g. coral bleaching in response to temperature rise) or indirect (e.g. seagrass dieback due to sedimentation from extreme rainfall events).
Vulnerability	The degree to which exposed elements, such as human beings, their livelihoods and their assets, are susceptible and unable to cope with the adverse impacts of natural and climate change hazard events.

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Appendix A National workshop attendees

National ESRAM Workshop Attendees (9 August 2016, Honiara)

Name	Affiliation
Rosemary Apa	Ministry of Environment, Climate and Disaster Management
Steve Likaveke	UN-Habitat
Gloria Suluia	SI Water Sector Adaptation Project (UNDP)
Reginald Reuban	PRRP / Ministry of Environment, Climate and Disaster Management
Mary Tahu	SI National University
Joyce Aburii	Youth@Work
May	SI Community Resilience to Climate and Disaster Risk Project (CRISP)
Debra Potakana	ECD / Ministry of Environment, Climate and Disaster Management
Junior Pikacha	Ecological Solutions SI
Ikuo Tigulu	Ecological Solutions SI
Tammy Tabe	University of South Pacific
Hudson K	Ministry of Environment, Climate and Disaster Management
Gideon Solo	Ministry of Forestry and Research
Nelly K	Ministry of Environment, Climate and Disaster Management
Myknee Sirikolo	Ministry of Forestry and Research
Simba Paza	Prime Minister's Office
Winston Lapo	Ministry of Infrastructure and Development
Shannon Seeto	WWF-Pacific
Matsuko Pelomo	Ministry of Development, Planning and Aid Coordination
Nancy Raeka	Ministry of Environment, Climate and Disaster Management
John Leqata	Ministry of Fisheries and Marine Resources
Tia Masolo	Ministry of Environment, Climate and Disaster Management
Donald Kudu	DREGAR Consulting
Fred Patison	SPREP
Simon Albert	University of Queensland
Beth Toki	BMT WBM

Appendix B Climate projections

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (AR5 2013) provides projections of future changes in the climate system. These projections use a hierarchy of global climate models based on a set of four greenhouse gas concentration trajectories, called representative concentration pathways (RCPs). In combination, the RCPs represent a range of 21st century climate policies.

The RCPs are labelled according to the range of radiative forcing values in the year 2100 relative to pre-industrial values:

- RCP 2.6 applies a radiative forcing value of +2.6 W/m^2 and represents a low forcing level.
- RCP 4.5 and RCP 6 apply radiative forcing values of +4.5 and +6.0 W/m^2 and represent stabilisation scenarios.
- RCP 8.5 applies a radiative forcing value +8.5 W/m^2 and represents a high forcing level.

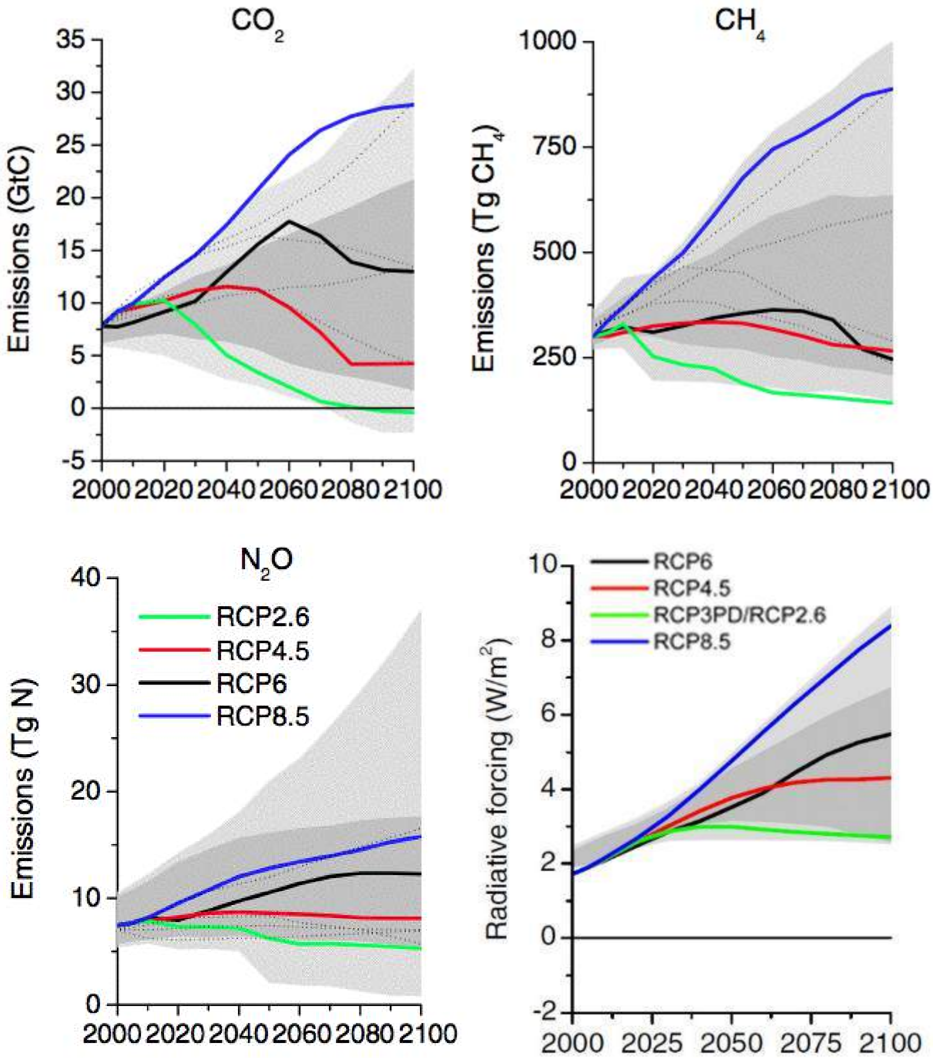

Figure B-1 Projected emissions of greenhouse gases for the range of RCP trajectories. Radiative forcings for each trajectory shown (bottom right). (van Vuuren *et.al.* 2011).

The Solomon Islands *National Climate Change Policy 2012–2017* (MECDM, 2012) was prepared prior to the release of the AR5 (IPCC 2013). This policy is based on the projections produced by the Pacific Climate Change Science Program (PCCSP) using data from the IPCC Fourth Assessment Report (AR4 2007).

B.1.1 Pacific and country-based projections

The climates of countries within the Pacific region (partners in the PCCSP) are strongly influenced by one or more of the following features of the climate: the South Pacific Convergence Zone (SPCZ), the West Pacific Monsoon (WPM), the Inter-Tropical Convergence Zone (ITCZ) and El Niño-Southern Oscillation (ENSO) (refer to Figure B-2). There are still major deficiencies in understanding the properties and impacts of these climate features, despite the fact that they can strongly influence rainfall, winds, tropical cyclone tracks, ocean currents, nutrients and other aspects of the environment (BOM and CSIRO 2012).

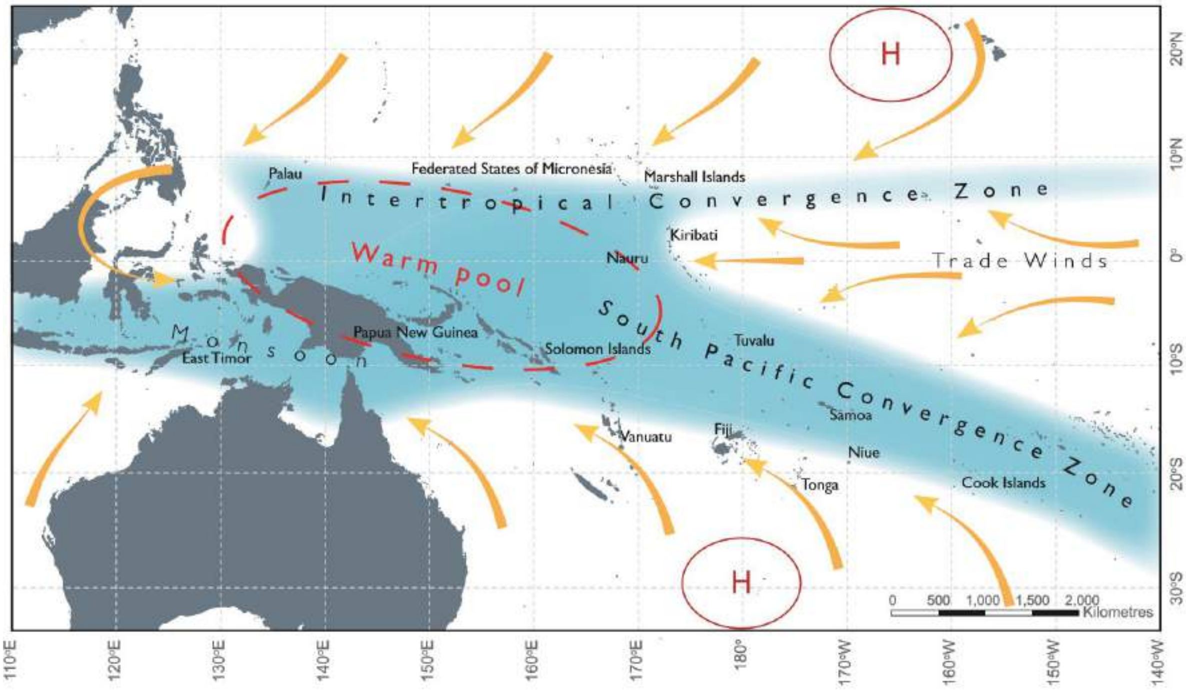

Figure B-2 The main climate features in the western tropical Pacific region (source: BOM and CSIRO 2012)

Prior to PCCSP, limited information was available regarding projections for the Pacific region. PCCSP aimed to provide more detailed atmospheric and ocean projections for each Pacific country. Twenty-four global climate models were evaluated. AR4 climate simulations were compared against historical observations from participating PCCSP countries, and 18 models were considered suitable for projections in the Pacific region. Projections were developed for three 20-year periods (centred on 2030, 2055 and 2090) and three emissions scenarios (low-B1, medium-A1B and high-A2. Further information on these scenarios is provided in the AR4).

Appendix C National vulnerability assessment results

	Climate Variable	SLR										Increasing sea temperature										Extreme rainfall event										Ocean acidification										Increasing Air Temperature										Extreme Air Temperature									
	Current Climate	- sea level has risen by about 8 mm per year since 1993 (larger than the global average of 2.8–3.6 mm per year possibly due to El Nino-Southern Oscillation) -										Sea surface temperatures average 27 to 30 deg C.										No clear trends in rainfall since mid-1950s with substantial variation in rainfall from year to year. Little change in extreme daily rainfall over the same period. 70% of Honiara's annual rainfall occurs in wet season with average monthly rainfall of more than 300 mm. Dry season monthly average is 100 mm. Santa Cruz receives more constant rainfall during the year, averaging 280 mm and 420 mm per month.										Since 18th century level of ocean acidification has been slowly increasing										Temperatures are relatively constant throughout the year. Average temperature ranges from 26-27 deg C.										Max temperatures range from 29-31 deg C.									
	Time Slice and Scenario	2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5				
	Projection	- SLR of between approx. 7–18cm (very similar values for different RCPs) - Mean change: 13cm - Confidence level is medium					- SLR of between approx. 40–89 cm - Mean change: 63cm - Confidence level is medium					- Under all RCPs, the warming is up to 1.0°C relative to 1995 - Mean change: 0.7'C - Confidence level is very high					- Under all RCP8.5, the warming is up to 2 - 4°C - Mean change: 2.8'C - Confidence level is very high					- The current 1-in-20-year daily rainfall amount is projected to increase by approx. 9 mm - 3% increase in annual rainfall - Confidence level for frequency and intensity of extreme rainfall events is high					- Rainfall to increase by approx. 43 mm - current 1-in-20-year daily rainfall event will become, on average, a 1-in-4- year event - 6% increase in annual rainfall - Confidence level for frequency and intensity of					- Median aragonite saturation state will transition to marginal conditions (3.5) around 2030. - Mean change: -0.4 Ωar - Confidence level is medium					- Median aragonite saturation state will continue to strongly decline thereafter to values where coral reefs have not historically been found (< 3.0). - Mean change: -1.5 Ωar - Confidence level is medium					- Under all RCPs, the warming is up to 1.0°C, relative to 1995 - Mean change: 0.7'C - Confidence level is very high					- Under all RCP8.5, the warming is up to 2 - 4°C - Mean change: 2.8'C - Confidence level is very high					- Temp on extremely hot days is projected to increase by about the same amount as average temp - Frequency of extremely hot days is also expected to increase. - Temp of the 1-in-20-year hot day is projected to increase by approx. 0.8°C					- Projected hot day temp increase and frequency is expected to increase as per 2030. - Temp of the 1-in-20-year hot day is projected to increase by approximately 2.9°C - Confidence level is very high				
Ecosystem	Ecosystem Service	SLR 2030	SLR 2030	SLR 2030	SLR 2030	SLR 2030	SLR 2090	SLR 2090	SLR 2090	SLR 2090	SLR 2090	Sea temp 2030	Sea temp 2030	Sea temp 2030	Sea temp 2030	Sea temp 2030	Sea temp 2090	Sea temp 2090	Sea temp 2090	Sea temp 2090	Sea temp 2090	Extreme rainfall 2030	Extreme rainfall 2030	Extreme rainfall 2030	Extreme rainfall 2030	Extreme rainfall 2030	Extreme rainfall 2090	Extreme rainfall 2090	Extreme rainfall 2090	Extreme rainfall 2090	Extreme rainfall 2090	Ocean Acidification 2030	Ocean Acidification 2030	Ocean Acidification 2030	Ocean Acidification 2030	Ocean Acidification 2030	Ocean Acidification 2090	Ocean Acidification 2090	Ocean Acidification 2090	Ocean Acidification 2090	Ocean Acidification 2090	Increasing Air Temp 2030	Increasing Air Temp 2030	Increasing Air Temp 2030	Increasing Air Temp 2030	Increasing Air Temp 2030	Increasing Air Temp 2090	Increasing Air Temp 2090	Increasing Air Temp 2090	Increasing Air Temp 2090	Increasing Air Temp 2090	Extreme Air Temp 2030	Extreme Air Temp 2030	Extreme Air Temp 2030	Extreme Air Temp 2030	Extreme Air Temp 2030	Extreme Air Temp 2090	Extreme Air Temp 2090	Extreme Air Temp 2090	Extreme Air Temp 2090	Extreme Air Temp 2090
		E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V
Rivers, streams	Food provision	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams	Water supply (drinking and domestic)	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	3	18	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams	Water supply (irrigation)	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	3	18	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams	Recreation	1	1	1	3	3	2	1	2	3	6	0	0	0	1	0	0	0	0	1	0	3	2	6	1	6	3	2	6	1	6	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Rivers, streams	Transportation, anchorage	1	1	1	1	1	2	1	2	1	2	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Rivers, streams	Raw materials provision	1	3	3	3	9	2	2	4	3	12	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams	Energy generation (hydropower)	1	1	1	3	3	2	1	2	2	4	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	3	9	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Rivers, streams	Cultural values	1	1	1	2	2	2	2	4	2	8	0	0	0	1	0	0	0	0	1	0	3	2	6	1	6	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams	Waste disposal and dispersal	1	1	1	1	1	2	1	2	1	2	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Rivers, streams	Support fisheries	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Rivers, streams	Habitat provision, biodiversity	1	3	3	3	9	2	3	6	3	18	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial Forests, Vegetation	Raw materials and fuel provision	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial Forests, Vegetation	Fauna habitat	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial Forests, Vegetation	Kastom medicine provision	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial Forests, Vegetation	Source of income/revenue	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial Forests, Vegetation	Carbon sequestration	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial Forests, Vegetation	Nutrient cycling and primary productivity	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial Forests, Vegetation	Soil retention and fertility	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial Forests, Vegetation	Air regulation and shade provision	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial Forests, Vegetation	Support recreation and tourism	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial Forests, Vegetation	Cultural values and handicrafts	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Terrestrial Forests, Vegetation	Food provision	0	2	0	2	0	1	2	2	2	4	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Other terrrestrial land	Commercial value (incl. agriculture)	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	2	6	3	1	3	2	6	3	1	3	2	6
Other terrrestrial land	Provides identity and heritage	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	3	1	3	1	3	3	1	3	1	3
Other terrrestrial land	Support forests	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	2	6	3	1	3	2	6	3	1	3	2	6
Other terrrestrial land	Minerals source (mining industry)	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	3	1	3	1	3	3	1	3	1	3
Other terrrestrial land	Land provision	0	3	0	3	0	1	3	3	3	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	2	6	3	1	3	2	6	3	1	3	2	6
Coral Reefs	Habitat provision / biodiversity	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coral Reefs	Food provision	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coral Reefs	Coastal protection	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coral Reefs	Income and revenue source	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coral Reefs	Fishing grounds	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coral Reefs	Lime extraction	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coral Reefs	Raw materials provision (coral rock)	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coral Reefs	Cultural values (shells, ornaments)	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coral Reefs	Recreation and leisure	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coral Reefs	Kastom medicine	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coral Reefs	Supports tourism industry	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coral Reefs	Supports marine food chain	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coast line / Beach	Support recreation/leisure	2	1	2	1	2	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coast line / Beach	Waste disposal and dispersal	2	1	2	1	2	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coast line / Beach	Domestic use (bathing)	2	1	2	1	2	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coast line / Beach	Cultural values and handicrafts	2	1	2	2	4	3	1	3	2	6	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coast line / Beach	Raw materials provision	2	1	2	2	4	3	1	3	2	6	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coast line / Beach	Supports transport (boat landing)	2	1	2	1	2	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coast line / Beach	Fauna habitat (e.g. turtle nesting)	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	0	0	3	0	3	0	0	3	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Coast line / Beach	Coastal protection	2	2	4	2	8	3	2	6	2	12	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0

	Climate Variable	SLR										Increasing sea temperature										Extreme rainfall event										Ocean acidification										Increasing Air Temperature										Extreme Air Temperature									
	Current Climate	- sea level has risen by about 8 mm per year since 1993 (larger than the global average of 2.8–3.6 mm per year possibly due to El Nino-Southern Oscillation) -										Sea surface temperatures average 27 to 30 deg C.										No clear trends in rainfall since mid-1950s with substantial variation in rainfall from year to year. Little change in extreme daily rainfall over the same period. 70% of Honiara's annual rainfall occurs in wet season with average monthly rainfall of more than 300 mm. Dry season monthly average is 100 mm. Santa Cruz receives more constant rainfall during the year, averaging 280 mm and 420 mm per month.										Since 18th century level of ocean acidification has been slowly increasing										Temperatures are relatively constant throughout the year. Average temperature ranges from 26-27 deg C.										Max temperatures range from 29-31 deg C.									
	Time Slice and Scenario	2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5					2030 RCP8.5					2090 RCP8.5				
	Projection	- SLR of between approx. 7–18cm (very similar values for different RCPs) - Mean change: 13cm - Confidence level is medium					- SLR of between approx. 40–89 cm - Mean change: 63cm - Confidence level is medium					- Under all RCPs, the warming is up to 1.0°C relative to 1995 - Mean change: 0.7°C - Confidence level is very high					- Under all RCP8.5, the warming is up to 2 - 4°C - Mean change: 2.8°C - Confidence level is very high					- The current 1-in-20-year daily rainfall amount is projected to increase by approx. 9 mm - 3% increase in annual rainfall - Confidence level for frequency and intensity of extreme rainfall events is high					- Rainfall to increase by approx. 43 mm - current 1-in-20-year daily rainfall event will become, on average, a 1-in-4- year event - 6% increase in annual rainfall - Confidence level for frequency and intensity of					- Median aragonite saturation state will transition to marginal conditions (3.5) around 2030. - Mean change: -0.4 Ωar - Confidence level is medium					- Median aragonite saturation state will continue to strongly decline thereafter to values where coral reefs have not historically been found (< 3.0). - Mean change: -1.5 Ωar - Confidence level is medium					- Under all RCPs, the warming is up to 1.0°C, relative to 1995 - Mean change: 0.7°C - Confidence level is very high					- Under all RCP8.5, the warming is up to 2 - 4°C - Mean change: 2.8°C - Confidence level is very high					- Temp on extremely hot days is projected to increase by about the same amount as average temp - Frequency of extremely hot days is also expected to increase. - Temp of the 1-in-20-year hot day is projected to increase by approx. 0.8°C					- Projected hot day temp increase and frequency is expected to increase as per 2030. - Temp of the 1-in-20-year hot day is projected to increase by approximately 2.9°C - Confidence level is very high				
Ecosystem	Ecosystem Service	SLR 2030	SLR 2030	SLR 2030	SLR 2030	SLR 2030	SLR 2090	SLR 2090	SLR 2090	SLR 2090	SLR 2090	Sea temp 2030	Sea temp 2030	Sea temp 2030	Sea temp 2030	Sea temp 2030	Sea temp 2090	Sea temp 2090	Sea temp 2090	Sea temp 2090	Sea temp 2090	Extreme rainfall 2030	Extreme rainfall 2030	Extreme rainfall 2030	Extreme rainfall 2030	Extreme rainfall 2030	Extreme rainfall 2090	Extreme rainfall 2090	Extreme rainfall 2090	Extreme rainfall 2090	Extreme rainfall 2090	Ocean Acidification 2030	Ocean Acidification 2030	Ocean Acidification 2030	Ocean Acidification 2030	Ocean Acidification 2030	Ocean Acidification 2090	Ocean Acidification 2090	Ocean Acidification 2090	Ocean Acidification 2090	Ocean Acidification 2090	Increasing Air Temp 2030	Increasing Air Temp 2030	Increasing Air Temp 2030	Increasing Air Temp 2030	Increasing Air Temp 2030	Increasing Air Temp 2090	Increasing Air Temp 2090	Increasing Air Temp 2090	Increasing Air Temp 2090	Increasing Air Temp 2090	Extreme Air Temp 2030	Extreme Air Temp 2030	Extreme Air Temp 2030	Extreme Air Temp 2030	Extreme Air Temp 2030	Extreme Air Temp 2090	Extreme Air Temp 2090	Extreme Air Temp 2090	Extreme Air Temp 2090	Extreme Air Temp 2090
		E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V	E	S	PI	AC	V
Coral Reefs	Supports marine food chain	3	1	3	1	3	3	1	3	1	3	3	2	6	2	12	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Coast line / Beach	Support recreation/leisure	2	1	2	1	2	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coast line / Beach	Waste disposal and dispersal	2	1	2	1	2	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coast line / Beach	Domestic use (bathing)	2	1	2	1	2	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coast line / Beach	Cultural values and handicrafts	2	1	2	2	4	3	1	3	2	6	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coast line / Beach	Raw materials provision	2	1	2	2	4	3	1	3	2	6	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coast line / Beach	Supports transport (boat landing)	2	1	2	1	2	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Coast line / Beach	Fauna habitat (e.g. turtle nesting)	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	0	0	3	0	3	0	0	3	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Coast line / Beach	Coastal protection	2	2	4	2	8	3	2	6	2	12	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Mangroves	Food provision	2	2	4	2	8	3	2	6	2	12	2	2	4	2	8	2	2	4	3	12	3	1	3	1	3	3	1	3	1	3	2	2	4	2	8	2	2	4	3	12	3	2	6	2	12	2	3	6	3	18	3	2	6	2	12	2	3	6	3	18
Mangroves	Raw materials and fuel provision	2	3	6	2	12	3	3	9	2	18	2	1	2	2	4	2	1	2	3	6	3	1	3	1	3	3	1	3	1	3	2	1	2	2	4	2	1	2	3	6	2	1	2	2	4	2	2	4	3	12	2	1	2	2	4	2	2	4	3	12
Mangroves	Fauna habitat	2	2	4	2	8	3	2	6	2	12	2	1	2	2	4	2	1	2	3	6	3	1	3	1	3	3	1	3	1	3	2	1	2	2	4	2	1	2	3	6	2	1	2	2	4	2	2	4	3	12	2	1	2	2	4	2	2	4	3	12
Mangroves	Coastal protection, shoreline stabilisation	2	3	6	2	12	3	3	9	2	18	2	1	2	2	4	2	1	2	3	6	3	1	3	1	3	3	1	3	1	3	2	1	2	2	4	2	1	2	3	6	2	1	2	2	4	2	2	4	3	12	2	1	2	2	4	2	2	4	3	12
Mangroves	Kastom medicine	2	3	6	2	12	3	3	9	2	18	2	1	2	2	4	2	1	2	3	6	3	1	3	1	3	3	1	3	1	3	2	1	2	2	4	2	1	2	3	6	2	1	2	2	4	2	2	4	3	12	2	1	2	2	4	2	2	4	3	12
Mangroves	Recreation	2	1	2	2	4	3	1	3	2	6	2	0	0	2	0	2	0	0	3	0	3	1	3	1	3	3	1	3	1	3	2	0	0	2	0	2	0	0	3	0	2	0	0	2	0	2	0	0	3	0	2	0	0	2	0	2	0	0	3	0
Mangroves	Waste disposal and dispersal	2	1	2	1	2	3	1	3	1	3	2	0	0	2	0	2	0	0	3	0	3	1	3	1	3	3	1	3	1	3	2	0	0	2	0	2	0	0	3	0	2	0	0	2	0	2	0	0	3	0	2	0	0	2	0	2	0	0	3	0
Mangroves	Cultural values (crafts, dye)	2	2	4	2	8	3	2	6	2	12	2	1	2	2	4	2	1	2	3	6	3	1	3	1	3	3	1	3	1	3	2	1	2	2	4	2	1	2	3	6	2	1	2	2	4	2	2	4	3	12	2	1	2	2	4	2	2	4	3	12
Mangroves	Carbon sequestration	2	3	6	2	12	3	3	9	2	18	2	1	2	2	4	2	1	2	3	6	3	1	3	1	3	3	1	3	1	3	2	1	2	2	4	2	1	2	3	6	2	1	2	2	4	2	2	4	3	12	2	1	2	2	4	2	2	4	3	12
Sea / Ocean	Support transport	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	2	0	3	0	6	1	12	3	0	0	1	0
Sea / Ocean	Habitat provision	3	0	0	1	0	3	0	0	1	0	3	2	6	2	12	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Sea / Ocean	Food provision	3	0	0	1	0	3	0	0	1	0	3	2	6	2	12	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Sea / Ocean	Climate and atmospheric regulation	3	0	0	1	0	3	0	0	1	0	3	2	6	2	12	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Sea / Ocean	Income and revenue generation	3	0	0	1	0	3	0	0	1	0	3	2	6	2	12	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Mountains, Highlands	Raw materials provision	0	3	0	3	0	0	3	0	3	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Mountains, Highlands	Habitat provision and biodiversity	0	3	0	3	0	0	3	0	3	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Mountains, Highlands	Water source	0	3	0	3	0	0	3	0	3	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Mountains, Highlands	Climatic regulation	0	3	0	3	0	0	3	0	3	0	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Mountains, Highlands	Provide protection from disasters	0	3	0	3	0	0	3	0	3	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Mountains, Highlands	Support navigation	0	3	0	3	0	0	3	0	3	0	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	0	0	0	1	0	0	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0	3	0	0	1	0
Wetlands / Lakes / Swamps	Food provision	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	0	0	2	0	3	0	0	2	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Wetlands / Lakes / Swamps	Water provision (drinking, domestic)	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	2	6	2	12	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Wetlands / Lakes / Swamps	Habitat provision	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	0	0	2	0	3	0	0	2	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Wetlands / Lakes / Swamps	Support aquaculture	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	0	0	2	0	3	0	0	2	0	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Wetlands / Lakes / Swamps	Cultural values (heritage)	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	1	3	2	6	3	1	3	2	6	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Wetlands / Lakes / Swamps	Water quality and flood flow regulation	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	2	6	2	12	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Seagrass and marine macroalga	Habitat provision	3	2	6	1	6	3	2	6	1	6	3	2	6	2	12	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Seagrass and marine macroalga	Primary productivity	3	2	6	1	6	3	2	6	1	6	3	2	6	2	12	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Seagrass and marine macroalga	Income generation (seaweed)	3	2	6	2	12	3	2	6	2	12	3	2	6	2	12	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Seagrass and marine macroalga	Kastom medicine and food	3	2	6	2	12	3	2	6	2	12	3	2	6	2	12	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Seagrass and marine macroalga	Seabed stabilisation	3	2	6	2	12	3	2	6	2	12	3	2	6	2	12	3	2	6	3	18	0	0	0	1	0	0	0	0	1	0	3	2	6	2	12	3	2	6	3	18	3	2	6	2	12	3	3	9	3	27	3	2	6	2	12	3	3	9	3	27
Groundwater	Water provision	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Groundwater	Income generation (spring water)	2	3	6	3	18	3	3	9	3	27	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Plantations and Gardens	Income generation	2	3	6	1	6	3	3	9	1	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12
Plantations and Gardens	Food provision	2	3	6	1	6	3	3	9	1	9	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	1	3	1	3	0	0	0	1	0	0	0	0	1	0	3	1	3	1	3	3	2	6	2	12	3	1	3	1	3	3	2	6	2	12

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