ECOSYSTEM-BASED ADAPTATION

OPTIONS ASSESSMENT AND MASTERPLAN

WAGINA

BMT WBM

SPREP
Secretariat of the Pacific Regional Environment Programme

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Natural Solutions for Island Resilience

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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 the Ecosystem-based Adaptation (EbA) Options Assessment and Masterplan for Wagina prepared as part of the Solomon Islands Ecosystems and Socio-economic Resilience Analysis and Mapping (ESRAM) to assess and prioritise climate change-related ecosystem-based adaptation options for selected locations in Solomon Islands. The report outlines EbA options for Wagina Island.

Author: Sophie Hipkin

All photographs are credited to Beth Toki unless stated otherwise.

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1.1 Pacific Ecosystem-based Adaptation to Climate Change Project

1.1.1 Background

This project forms part of the Solomon Island component of the broader 'Pacific Ecosystems-based Adaptation to Climate Change' (PEBACC) project. PEBACC is a five-year project funded by the German Government and 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 adverse 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 Solomon Islands, which are heavily reliant on local land and sea resources for maintaining national, provincial and local economies, community livelihoods and socio-cultural values. In this respect, maintaining healthy and well-functioning ecosystems will be crucial to building community resilience and reducing the vulnerability to the effects of climate change.

1.1.2 Project stages

The key stages of the PEBACC project are listed below and presented in Figure 1-1.

(1) Ecosystem and socio-economic resilience analysis and mapping (ESRAM) study – a baseline study for adaptation planning at the national, provincial and community level.

(2) EbA options assessment – identification and prioritisation of EbA options for Honiara and Wagina Island.

(3) Implementation plans – development of implementation plans for demonstration sites in Honiara and Wagina Island.

(4) EbA implementation – implementation of EbA options in Honiara and Wagina Island.

The second stage of the PEBACC project is the subject of the present report: EbA options analysis and prioritisation. Prior to this stage, an ESRAM study was undertaken in order to: (i) identify and map ecosystem types, ecosystem services, threats and trends; (ii) define the economic value of key ecosystem services; and (iii) assess the resilience of ecosystem services and communities to future climate and non-climate threats and impacts. Overall, the ESRAM study has been used as the basis for identifying ecosystem-based adaptation options for strengthening the resilience of Solomon Islands to the potential 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 locations within Solomon Islands).

The EbA options analysis and prioritisation will be followed by the development of EbA implementation plans for selected demonstration sites (Stage 3); and on-ground EbA implementation works (Stage 4).

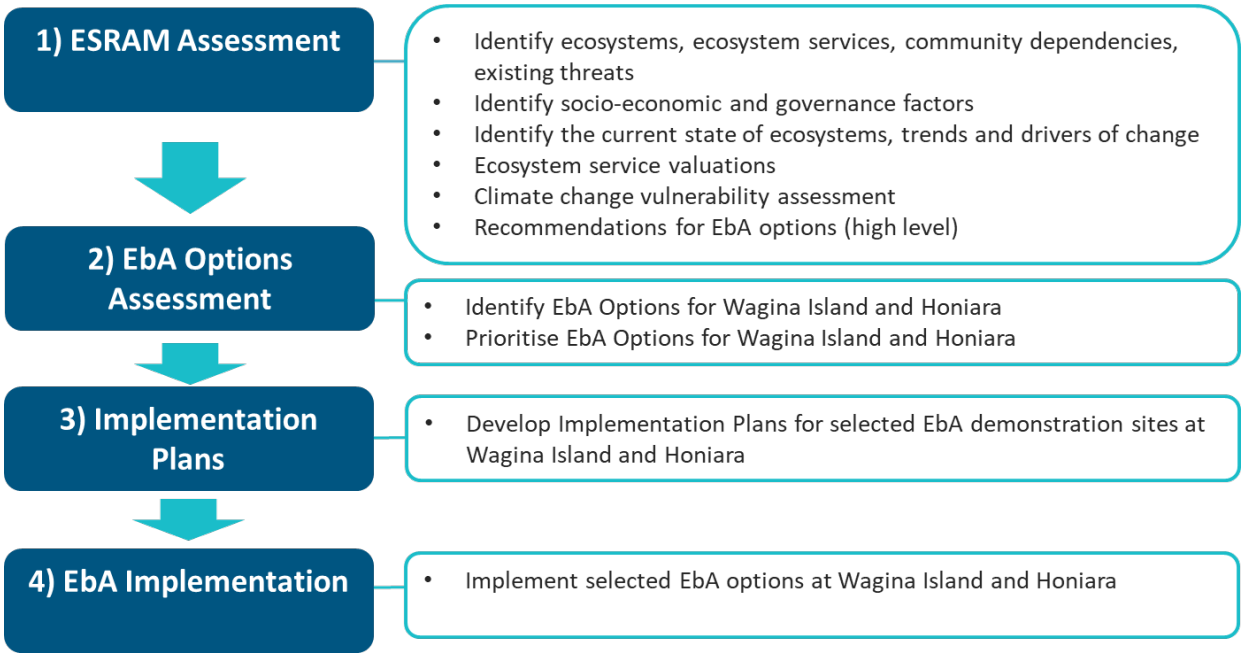

Figure 1-1 PEBACC Project process

1.2 Conclusions of the ESRAM study

The completion of the ESRAM study provides a baseline for developing and prioritising EbA options. Several community and stakeholder workshops and site visits were undertaken across Wagina Island to identify all ecosystem services utilised by residents, and to determine those services that have a low resilience to threats posed by future climate and non-climate events. Ecosystems and ecosystem services were mapped by workshop participants, and results were presented to community and stakeholder representatives for validation. Ecosystem services were assessed for their vulnerability to the effects of climate change and, where possible, economic valuations were undertaken to provide an insight into the relative extent and magnitude of ecosystems and ecosystem service values across different environments.

To provide context to the current EbA development phase, all ecosystem services identified during stakeholder engagement at each scale (national, Honiara and Wagina Island) are presented in the tables below. Ecosystem services most vulnerable to the threats posed by future climate and non-climate events are presented first and bolded (under their relevant provisioning ecosystem).

High-level EbA options were then established to respond to the need to build environmental resilience and provide ecosystems with the ability to adapt and, in turn, increase the likelihood of human adaptation to the adverse effects of climate change.

1.2.1 National ESRAM study findings

The climate change projections likely to have the greatest effect on ecosystem services on a national scale are an increase in sea and air temperature and ocean acidification, an increase in extreme rainfall events, and sea-level rise. Increasing habitat destruction from unsustainable logging and agriculture practices, freshwater and marine pollution, and the over-exploitation and degradation of marine resources, combined with a rapid population growth and inadequate environmental regulations and enforcement, are the key threats faced by ecosystem services on the national scale.

Table 1-1 presents the ecosystem services identified by community and stakeholder representatives on a national scale. Ecosystem services bolded and presented first have been identified as the key ecosystem services most vulnerable and in need of the provisioning ecosystems to be protected, restored and enhanced to build and strengthen resilience under future climate conditions.

Table 1-1 National ecosystem services (bolded ecosystem services are likely to be less resilient to future climate conditions)

Ecosystems	Ecosystem Services	Ecosystems	Ecosystem Services	Ecosystems	Ecosystem Services
Rivers, streams	**Food provision (e.g. fish, eels, molluscs, crustaceans, aquaculture)**	Other terrestrial land	Land provision	Mangroves	Cultural values (crafts, dye)
	Water supply (drinking and domestic)	Coral Reefs	**Habitat provision / biodiversity (essential feeding, breeding, spawning, cleaning and aggregation habitat)**		Recreation
	Water supply (irrigation and industrial)		**Food provision (fish, including pelagic fish, turtles, octopus, clams, beche-de-mer and trochus)**	Ocean	**Food provision**
	Recreation (swimming)		**Coastal protection (attenuation and buffering of wave and storm energy by reefs)**		**Habitat provision**
	Support fisheries (local and commercial)		**Income and revenue source (fish, including pelagic fish, turtles, octopus, clams, beche-de-mer, trochus, lime extraction, tourism, aquarium trade)**		**Climate and atmospheric regulation**
	Habitat and biodiversity				**Income and revenue generation**
	Energy generation (hydropower)				Support transport
	Cultural values (e.g. baptisms, source of ornamental and handicraft materials)		**Raw materials provision (coral rock and lime)**	Mountains, Highlands	Raw materials provision (building materials)
	Waste disposal and dispersal		**Cultural values (shells, ornaments and decorations)**		Habitat provision and biodiversity
	Transportation, anchorage		**Regulation of marine primary productivity, nutrient and carbon cycling**		Water source
	Raw materials provision (e.g. gravel, sand, *motu* stones)		***Kastom* medicine**		Climatic regulation
Terrestrial Forests	**Raw materials (building, fuel and commercial purposes)**		**Supports tourism industry**		Provide protection from disasters
	Fauna habitat (e.g. birds, insects, wildlife) and support of biodiversity		Recreation and leisure		Support navigation
	Food provision (hunting grounds, nuts, fruits and vegetables)	Coastline/ Beach	**Fauna habitat (e.g. turtle nesting)**	Wetlands/ Lakes/ Swamps	**Food provision (e.g. swamp taro taro, sago, fishing and aquaculture activities)**
	Source of income/revenue (e.g. logging)		Domestic use (bathing)		**Water supply (drinking and domestic)**

Ecosystems	Ecosystem Services	Ecosystems	Ecosystem Services	Ecosystems	Ecosystem Services
	Nutrient cycling and primary productivity		Raw materials provision (e.g. sand, gravel, stones)		**Habitat provision and support of biodiversity (incl. value as critical habitat for migratory bird species)**
	Land stability and hazard protection for communities (e.g. landslides, erosion, wind or weather break)		Coastal protection (e.g. buffer coastal communities against inundation from tsunami and storm surge)		**Support aquaculture**
					Water quality and flood flow regulation (filtration and purification of run-off from watersheds, and reducing flood flow rates)
	Soil retention and fertility		Supports transport (boat landing)		**Cultural values (heritage)**
	Air regulation and shade provision		Cultural values and handicrafts (e.g. for jewellery, ornaments, decorations, turtle nesting)		Provision of raw materials (e.g. traditional building materials, reeds for weaving)
	Carbon sequestration		Support recreation/leisure	Seagrass and marine macroalgae (seaweeds)	**Habitat provision (turtles, dugong)**
	Support provision of water		Waste disposal and dispersal		**Primary productivity**
	Kastom medicine provision	Mangroves	**Food provision (fish, mud crabs, molluscs, mangrove fruit)**		**Income generation (seaweed farming)**
	Cultural values and handicrafts (traditional tools, ornaments, costumes, weaving, handicrafts and traditional currency)		**Coastal protection, shoreline stabilisation**		***Kastom* medicine and food**
	Support recreation and tourism		**Fauna habitat and nursery grounds**		**Seabed stabilisation**
Other terrestrial land	Commercial value (incl. agriculture)		**Raw materials and fuel provision**	Groundwater	**Water supply (drinking and domestic)**
	Provides identity and heritage		***Kastom* medicine**		**Income generation (spring water)**
	Support forests		**Carbon sequestration**	Plantations and Gardens	**Income generation**
	Minerals source (mining industry)		Waste disposal and dispersal		**Food provision**

1.2.2 Wagina Island ESRAM study findings

Wagina's ecosystems are critical to the long-term resilience and prosperity of local communities, and even more so in building community resilience to climate change. Current anthropogenic pressures such as over-harvesting of marine resources, ignoring protected area policies, and poor sanitary and waste disposal practices, in addition to the existing and future effects of climate change, are threatening the services ecosystems provide to the local community. Climate change variables projected to have the greatest effect on ecosystem services are an increase in air and sea temperature, ocean acidification, an increase in extreme rainfall events, and sea-level rise.

Table 1-2 presents the Wagina Island ecosystem services identified by community and stakeholder representatives. Ecosystem services bolded and presented first have been identified as the key ecosystem services most vulnerable and in need of the provisioning ecosystems to be protected, restored and enhanced to build and strengthen resilience under future climate conditions.

Table 1-2 Wagina Island ecosystem services (bolded ecosystem services are likely to be less resilient to future climate conditions)

Ecosystems	Ecosystem Services	Ecosystems	Ecosystem Services	Ecosystems	Ecosystem Services
Terrestrial forest	**Food provision**	Beaches and sand islands	Canoe/boat landing	Marine lagoons	**Primary industry (seaweed farming)**
	Timber source - raw materials		Raw materials (sand)		**Biodiversity**
	Timber source - fuel/firewood	Rivers, streams and freshwater springs	Canoe landing	Groundwater	**Water supply (drinking)**
	Toilet place		Fresh water source	Reefs	**Food/trade source (fish, molluscs, crustaceans, turtles)**
	Fresh water filtration		Toilet place and waste disposal		**Biodiversity**
	Biodiversity		Washing area		**Coral source (coral rock, lime)**
	Fresh groundwater replenishment		Food source (stream side gardens)		**Coastal protection**
	Erosion control		Food source (aquatic fauna)		Sand source
Lowland swamps	**Raw materials (sago leaves)**		Timber source	Marine (open water)	**Food/trade (fish, shark, turtle)**
	Food security (giant swamp taro, sago)		Fresh water filtration	Cultivated land (gardens and plantations)	**Raw materials (sago leaves, coconut and pandanus leaves)**
	Habitat and biodiversity		Biodiversity		**Food source (vegetables and fruits e.g. sweet potato, cassava, taro, banana, paw paw, mango, coconut, sago, pandanus)**
	Fresh groundwater replenishment		Fresh groundwater replenishment		*Kastom* medicine/costumes (coconut and pandanus leaves)
	Flood control	Mangroves	**Biodiversity**		Betel nut (trade)
	Fresh water filtration		**Food source (fish, molluscs, crustaceans, mud crab)**	Terrestrial (other)	Land source (for housing, transport, services)
Beaches and sand islands	**Food source (turtles)**		Food source (mangrove fruit)	Rocky shores	Recreation
	Land source (for housing, transport, services)		Raw materials (timber for housing and seaweed farming, fuelwood)		Waste disposal
	Biodiversity		Income/trade source - timber		Toilet place
	Coastal protection		Coastal protection		Coastal protection
		Marine lagoons	**Food/trade source (fish, molluscs, crustaceans)**		Anchorage

1.2.3 EbA recommendations

The high reliance on ecosystem services by many Solomon Island households and economies, combined with the ecosystem degradation and a rapid population growth rate, are critical issues for building the nation's resilience to future climate change effects. Based on the ecosystem services and threats identified during the ESRAM study, high level EbA options were suggested to assist in restoring and maintaining healthy and well-functioning ecosystems that will be crucial to building environmental and social resilience to the effects of climate change.

The high-level EbA options were used as a basis for presenting EbA examples during the Wagina options development workshops and, in some cases, have been expanded on by workshop participants. The high level EbA options for Wagina Island are presented below in **Error! eference source not found.**.

Table 1-3 Suggested Wagina Island EbA options based on ESRAM findings

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

5 Cost-effectiveness analysis

Following the establishment of the shortlist of EbA options for Wagina Island, a cost-effective analysis (CEA) was undertaken for each option. The results of the CEA are presented below in **Error! Reference source not found.**.

Cost-effectiveness is reported in USD (2017) and provides an indication of the potential monetary benefit for each option per dollar invested.

High-level Ecosystem Type	Most Vulnerable Ecosystem Services to Climate and Non-climate Effects	Anthropogenic and Non-climate Stressors	Potential Climate Change-related Effects	Adaptation and Ecosystem Resilience Options	Key Stakeholders to Support EbA Option Implementation
	• Habitat and biodiversity (mangroves, marine lagoons, coral reefs, marine waters) • Raw materials (lime, coral rock) • Income generation (seaweed farming) • Coastal protection (attenuation and buffering of wave and storm energy by reefs) • *Kastom* medicine (seagrass) • Land (housing, services)	destruction of reefs from anchorage and coral collection • Pollution from poor sanitation and waste management (including solid waste and domestic animal waste) and fuel spills • Clearing of coastal vegetation	acidification, poor water quality (sedimentation due to extreme rainfall events). Exacerbated by more intense tropical cyclones. • Shift in marine ecosystem structure due to rise in sea temperature • Altered capacity for oceans to regulate climate from increased sea temperatures • Coastal erosion of sand islands and beaches from sea-level rise, storm surge and tropical cyclones • Permanent inundation of sand islands	programme • Supporting seaweed farmers to build climate resilience • Coastal vegetation protection and revegetation • Land use planning restrictions on coastal fringe • Installation of fish aggregating devices (FAD) • Environmental awareness and education programmes on the value of coral reefs for ecosystem services and sustainable fishing • Environmental awareness and education programme on the purpose of the local MPAs with a large focus on over-harvesting, especially turtles, sharks and keystone species e.g. parrotfish • Coral and seagrass transplanting trials at coral reefs and marine lagoons. • Development of Coastal and Intertidal Rehabilitation Programme • Marine Lagoon Management Programme • Mangrove Rehabilitation Programme for area located around Fourth River	• Ministry of Infrastructure and Development • The Nature Conservancy • World Wildlife Fund • Church • Women's group • Schools • R-WASH • NPA Provincial member • Rural Development Programme (RDP) • SPREP
Terrestrial	• Provision of	• Population growth	• Soil erosion,	• Designation of protected areas	• Ministry of Environment, Climate Change, Disaster

High-level Ecosystem Type	Most Vulnerable Ecosystem Services to Climate and Non-climate Effects	Anthropogenic and Non-climate Stressors	Potential Climate Change-related Effects	Adaptation and Ecosystem Resilience Options	Key Stakeholders to Support EbA Option Implementation
(forests, plantation and gardens)	food (gardens and plantations) • Habitat and biodiversity • Provision of building materials (sago) • Supports timber milling • Provision of fuelwood • Provision of medicinal plants and trees	• Forest clearing for expanding settlements and cultivation • Unsustainable harvesting for timber, fuelwood and medicine • Encroachment of gardens from expanding settlements • Excessive weed growth, destruction by feral animals • Theft of garden produce	sedimentation and landslip from extreme rainfall events. Exacerbated by more intense tropical cyclones. • Reduction in crop yield and soil cohesion and stability, and an increase in invasive species due to increase in temperature	• Vegetation protection and catchment and riparian revegetation programme • Land-use planning restrictions on steep and unstable soils	Management and Meteorology • Ministry of Forests and Research • Ministry of Education and Human Resources Development • Ministry of Women, Children and Youth • Solomon Islands Water Authority • Ministry of Infrastructure and Development • The Nature Conservancy • World Wildlife Fund • Church • Women's group • Schools • NPA Provincial member • Rural Development Programme (RDP) • SPREP

2 Options analysis and prioritisation methodology

2.1 Overview of approach

The EbA options assessment provides a transparent platform for objectively incorporating decision criteria into the prioritisation process. It provides the opportunity to integrate information about intangible effects, as well as effects that are difficult to measure in monetary terms within decision-making. An options assessment enables a formal process to be undertaken to address the different needs of multiple groups of stakeholders and provides a process whereby the decision to accept or reject a course of action is made through a process of information discovery.

Figure 2-1 outlines the steps undertaken to develop and prioritise EbA options. The sections below provide further detail on each step.

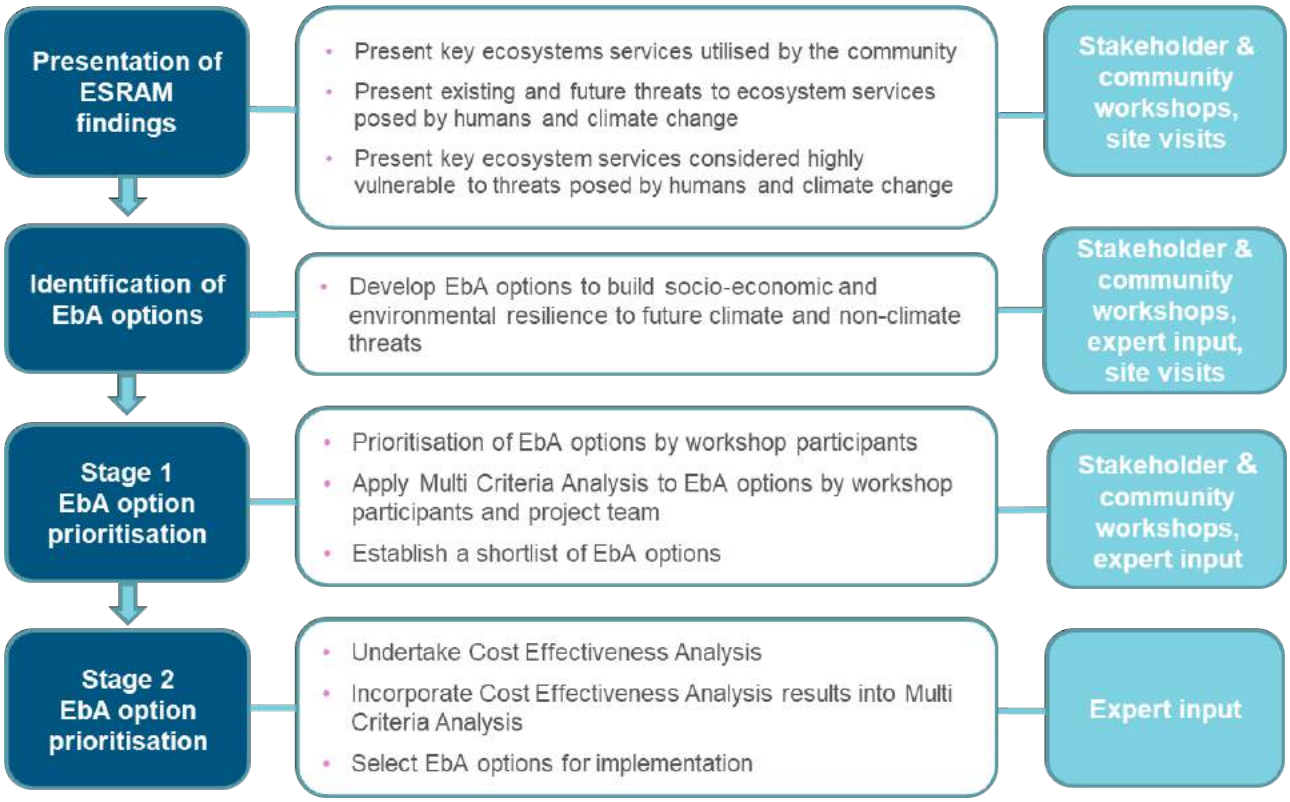

Figure 2-1 Steps undertaken during EbA options development and prioritisation

Stakeholder and community workshops were held with various representatives in Wagina Island to present the findings of the ESRAM studies and commence the process of EbA options identification and prioritisation. The dedicated stakeholder workshops provided the primary means for obtaining information on potential EbA options via a participatory, bottom-up approach. The overall workshop objectives are listed below.

- Present the findings of the draft ESRAM study and seek validation from workshop participants, particularly the results from the interactive mapping exercise completed during the previous workshops and site visits in September 2016.
- Provide a recap on the concept of EbA and benefits of using an ecosystem-focused approach in building resilience to both climate and non-climate effects.
- Identify and prioritise potential EbA options with a focus on obtaining detailed information from workshop participants, e.g. specific location and coverage of adaptation options, the ecosystem services targeted for strengthening resilience, threats affecting the resilience of ecosystem services, key stakeholders to be involved, assistance (if needed) for planning and implementation, etc.
- Build the knowledge and capacity of workshop participants to further understand the value of protecting and enhancing ecosystem services, undertake ESRAM or similar studies, further understand the approach of EbA, and how to analyse and prioritise options that could be implemented to build the resilience of ecosystem services (as identified in an ESRAM study or the like) in the future.

The ESRAM findings on the national scale were presented and discussed during the Honiara workshop but, as per the scope of the PEBACC project, the development of EbA options are focused on the Wagina Island scale.

2.1.1 Options assessment workshops

During the Wagina Island visit, three options development workshops were undertaken: the first at Tekaranga with Tekaranga and Tengangea villages (22 March 2017), the second at Arariki Village (22 March 2017) and the third at Nikumaroro Village (23 March 2017). A mix of village members and representatives participated in the workshops, including elders, the village organiser, school teachers, a church leader and youth leaders. An informal consultation session was undertaken on the main sand/seaweed island, Beniamina Island, which involved seaweed farmers talking about the history of seaweed farming in the local area and their concerns about the industry's future. A reasonable representation of men and women attendees was present at all workshops.

Table 2-1 Wagina Island options development workshop attendees

Workshop Participants	Tekaranga & Tengangea	Arariki	Nikumaroro
Total number of workshop participants	48	27	25
Proportion of men	67% (32)	56% (15)	72% (18)
Proportion of women	33% (16)	44% (12)	28% (7)

- The Wagina Island workshops were also attended by several national and provincial government representatives from the Ministry of Environment, Climate Change, Disaster Management and Meteorology and Choiseul Provincial Fisheries. Representatives assisted the

Project Team in presenting information to workshop participants on the effects of climate change in Solomon Islands and ecosystem services.

The Project Team for the Wagina Island workshops consisted of the following personnel:

- Sophie Hipkin, BMT WBM
- Dr Simon Albert, University of Queensland
- David Boseto, Ecological Solutions Solomon Islands
- Fred Patison, SPREP
- Fred Tabepud, Lauru Land Conference of Tribal Community (LLCTC)
- Fredrick Chöbuna, LLCTC
- Iulah Pitamama – Choiseul Provincial Government

2.2 Presentation of ESRAM findings

The ESRAM process and key findings were presented to workshop attendees. Maps identifying ecosystems and ecosystem services for the relevant scale/location were presented and distributed in hard copy to seek validation from workshop participants. A copy of the draft ESRAM study report was also made available for review during each workshop.

2.3 Identification of EbA options

During the ESRAM workshops in August 2016, an extensive list of adaptation options to address existing and future climate and non-climate threats was developed by participants. To build on these ideas, the Project Team grouped adaptation options into three high-level ecosystem groups (freshwater, forests and coastal/marine) and workshop attendees were asked to join an ecosystem group, based on their preference, with the flexibility to move around to other ecosystem group discussions. For each ecosystem, the ecosystem services considered most vulnerable to climate (by 2030 and beyond) and non-climate effects were presented and the relevant EbA options discussed.

2.4 Stage 1 EbA option prioritisation

EbA option prioritisation was undertaken by workshop participants and the Project Team. During the Wagina Island workshops, options previously developed by local residents in the ESRAM workshops (August 2016) were presented back to workshop participants. Workshop groups (i.e. freshwater, forests and coastal/marine ecosystems), were asked to select two priority EbA options, taking into account the ecosystem services most vulnerable to climate and non-climate threats presented earlier in the workshop. The two options selected by each group were then discussed by workshop participants to compile information in terms of resilience issues being addressed, specific location of adaptation options, and key stakeholders to be involved.

Informal site visits were conducted by the Project Team to further investigate the options shortlisted during the workshops. Sites visited in Honiara included: Honiara Botanic Gardens, Rove Children's Park, the central business district, China Town, various locations along the Mataniko River, Vara

Creek, Barana Village, Honiara coastline and Ranadi. The site visit findings will be explored further after the cost-effectiveness analysis of the shortlist of EbA options (See Section 4).

2.4.1 Application of the MCA

Following the completion of all workshops, the Project Team analysed the complete list of proposed EbA options. The first step in shortening the extensive list of options involved the assessment of each option as a 'true' EbA option. To do this, the Project Team asked the following question: *Does the option involve the protection, restoration or enhancement of an ecosystem or biodiversity to help social and ecological systems adapt to the adverse effects of climate change?* The MCA was then applied to all proposed EbA options to ensure consistency across all options. The Project Team allocated a performance score for each option in meeting the criteria and all scores were summed to establish an initial prioritisation score. All EbA options with a prioritisation score of 9 or less were compiled to the EbA options shortlist (the lower the score the better performing against the MCA). For all analysis, the criteria were given equal weight or importance.

Table 2-2 Stage 1 multi-criteria analysis design

Criteria	Considerations	Scores			
Benefits of implementation	Addresses core objectives of the programme through increasing ecological and social resilience to effects of climate change Protection/enhancement of highly vulnerable ecosystem services identified in ESRAM findings. Provision of new or enhanced services (e.g. increased tourism, education, health improvements) Value-added benefits (i.e. provision of additional benefits other than adaptation)	Very high (1)	High (2)	Medium (3)	Low (4)
Cost of implementation	Implementation, ongoing management and maintenance	Low (<10K USD) (1)	Medium (10-50K USD) (2)	High (50K + USD) (3)	-
Feasibility of implementation	Tenure and landowner considerations Likely timing and logistical requirements Extent of integration with existing policy and/or programmes Stakeholder/Community supports the option	Yes (1)	Uncertain (2)	No (3)	-
Sustainability of implementation	Yields long-lasting benefits with minimal maintenance	Very high (1)	High (2)	Medium (3)	-
Existing projects /activities	Existing projects are addressing this issue/threat	Nil (1)	Few (1-2) (2)	Several (3-5) (3)	Many (6+) (4)

2.5 Stage 2 EbA options prioritisation

Following the development of the shortlist of EbA options for Wagina Island, a cost-effective analysis (CEA) was undertaken for each option to inform the second (and final) stage of the prioritisation of EbA options. The purpose of the CEA is to identify the ecosystems and services that will benefit from implementation of an EbA option, the costs of implementing the option, the expected extent of change (i.e. the improvements from implementing the option compared to not implementing it) and the value for money (the ratio of dollars spent on the option versus the ecosystem service benefits from the option being implemented). The CEA considers the longevity of the EbA option and the benefits created over its lifetime. This approach focusses expenditure on the most valuable assets or services in order to get the greatest net benefits (e.g. 'bang-for-buck').

Cost effectiveness analysis has been undertaken on the four EbA that were shortlisted following an initial MCA. The output of the analysis focussed on determining the relative cost-effectiveness of each option in comparison to other options, as opposed to estimating definitive cost benefit ratios. An overview of the approach that was applied is presented in Figure 2-2. Further details on each step are provided below.

Step	Key Steps
1. Identify and cost options	• Identify options and profile up-front and ongoing costs out to 2039*
2. Identify ecosystem services positively affected by each option	• Determine ecosystem services that will benefit following implementation of each option
3. Categorise impact as high, medium or low for each ecosystem service	• For each option, categorise project impact (benefits) as either high, medium or low • Profile project impact (benefits) for each ecosystem service out to 2039*, including to allow for impact (benefit) to ramp up over time
4. Quantify benefits of each option	• Assume that a high, medium and low impact results in a 30%, 20% and 10% improvement under the option case relative to a 'do nothing' base case • Using these assumptions and the ecosystem service values in the ESRAM report, estimate benefits out to 2039*
5. Discount costs and benefits, calculate cost effectiveness and rank options	• Discount costs and benefits using a 7% discount rate • Divide discounted benefits by discounted costs to estimate the value of benefits for every dollar invested • Rank options and incorporate the results into the multi-criteria analysis

* Costs and benefits are assessed out to 2039, which assumes two years to implement each option and then 20 years for benefits to accrue.

Figure 2-2 Overarching methodology to assess cost-effectiveness of short-listed options

2.5.1 Cost-effectiveness analysis methodology

2.5.1.1 Step 1: Identify and cost options

For each shortlisted option, a profile of up-front and ongoing costs was developed. Profiling costs over time allows costs to be discounted so that the cost of all options is denominated in a constant metric (i.e. present value USD).

2.5.1.2 Step 2: Identify ecosystem services positively affected by each option

The next step was to determine which ecosystem services would be positively affected if each option was implemented. This step effectively maps each option to expected outcomes for each ecosystem service category.

2.5.1.3 Step 3: Categorise impact as high, medium or low for each ecosystem service

For each ecosystem service likely to be positively affected under each option, an assessment of whether the option is likely to deliver a high, medium or low impact was undertaken. Conceptually, this involves considering likely outcomes for each option for each ecosystem service under the project case relative to a 'do nothing' base case. In most cases, implementation of the option will avoid future environmental impacts, the costs (benefits under the project case) were categorised as being high, medium or low. The assessment of high, medium or low impact allowed for benefits to ramp up over time, where appropriate, such that a profile of high, medium or low impact over time was developed.

2.5.1.4 Step 4: Quantify benefits of each option

In this step, the benefits of each option over the appraisal period (i.e. 2017 out to 2039) were quantified in USD. To quantify benefits, the following approach was applied.

(1) High, medium and low impact is assumed to result in a 30%, 20%, and 10% improvement in ecosystem service outcomes respectively under the option case relative to a 'do nothing' base case. The high, medium and low percentage changes were applied consistently across options to facilitate a like-for-like comparison amongst options.

(2) For ecosystem service values denominated in dollars per hectare, the area likely to be positively affected for each ecosystem service category (e.g. forests, mangroves) was estimated using GIS mapping and existing data.

(3) For ecosystem service values denominated in a dollar per person per annum, the number of persons likely to derive benefit was estimated, based on census data and other recent population data (UN-Habitat 2016 and Kronen *et al.* 2010[1]). Historic population growth estimates were applied to future years over the appraisal period.

[1] UN-Habitat (2016a) Honiara Urban Resilience & Climate Action Plan. A joint strategy for the Honiara City Council and the Solomon Islands Government. Prepared for United Nations Human Settlements Programme (UN-Habitat) Cities and Climate Change Initiative (CCCI). Lead authors: Alexei Trundle and Darryn McEvoy, RMIT University Climate Change Adaptation Programme, Melbourne. Kronen (2010) Socio-economic Dimensions of Seaweed Farming in Solomon Islands. Prepared for the UN Food and Agriculture Organisation (FAO) and the Pacific Community (SPC).

(4) Benefits were estimated by multiplying the benefit factor (30%, 20% or 10%) by the area or persons affected by the ecosystem service value (in USD) for each year over the appraisal period.

2.5.1.5 *Step 5: Discount costs and benefits, calculate cost-effectiveness and rank options*

The final step involved the discounting of costs and benefits to present day dollars using a 7% discount rate. The value of benefits for every dollar invested was then estimated by dividing discounted benefits by discounted costs. EbA options were then ranked in order of their cost-effectiveness.

2.5.2 Application of the MCA

The results of CEA were incorporated into the MCA as a final criterion to inform the overall prioritisation score for each EbA option (see final row in **Error! Reference source not found.**). he CEA score for each EbA option was attributed to its CEA rank.

The second stage of the MCA is presented below in **Error! Reference source not found.**.

Table 2-3 Stage 2 multi-criteria analysis design

Criteria	Considerations	Scores			
Benefits of implementation	Addresses core objectives of the programme through increasing ecological and social resilience to impacts of climate change Protection/enhancement of highly vulnerable ecosystem services identified in ESRAM findings. Provision of new or enhanced services (e.g. increased tourism, education, health improvements) Value-added benefits (i.e. provision of additional benefits other than adaptation)	Very high (1)	High (2)	Medium (3)	Low (4)
Cost of implementation	Implementation, ongoing management and maintenance	Low (<10 K USD) (1)	Medium (10-50 K USD) (2)	High (50+ K USD) (3)	-
Feasibility of implementation	Tenure and landowner considerations Likely timing and logistical requirements Extent of integration with existing policy and/or programmes Stakeholder/Community supports the option	Yes (1)	Uncertain (2)	No (3)	-
Sustainability of implementation	Yields long-lasting benefits with minimal maintenance	Very high (1)	High (2)	Medium (3)	-
Existing projects /activities	Existing projects are addressing this issue/threat	Nil (1)	Few (1-2) (2)	Several (3-5) (3)	Many (6+) (4)
Cost Effectiveness	Costs of implementing the option Expected extent of ecosystem change Value for money	Ranked 1st (1)	Ranked 2nd (2)	Ranked 3rd (3)	Ranked 4th (4)

2.6 Capacity building

As part of the options assessment process, the stakeholder and community workshops were held to encourage a two-way process of information discovery and learning. While the workshops provided the Project Team with invaluable information for the development of EbA options, the workshops provided an opportunity for stakeholders to further understand the value of undertaking the ESRAM process and how it can inform the development of climate adaptation options to enhance ecosystem and social resilience.

The options identification and prioritisation process was based on a participatory approach to gain a local perspective while building the capacity of workshop participants to identify options, based on both existing and future non-climate and climate threats, and what each EbA option sets out to achieve in terms of building ecosystem and socio-economic resilience. The application of MCA during the Honiara workshop provided workshop participants with the opportunity to apply a tool for the purpose of option prioritisation. Stakeholders were also given the opportunity to provide input into the criteria used in the MCA.

The lessons learnt at these workshops were aimed at demonstrating a formal process for decision-making that promotes transparency amongst stakeholders. As information is discovered during the planning and decision-making process, the options analysis and prioritisation can be continually revisited by stakeholders in the future and the decision-making updated.

Figure 2-3 Wagina Island workshops undertaken at: Kuksun with Tekaranga and Tengangea villages (22 March 2017) (top row); Arariki Village (22 March 2017) (middle row); and Nikumaroro Village (23 March 2017) (bottom row)

3 EbA options identification

3.1 Master list of EbA options for Wagina Island

This section presents the EbA options developed during the Wagina Island workshops. All options developed during the workshops have been compiled into a master list of EbA options presented in Table 3-1. The master list presents each EbA option and geographical coverage, the ecosystem services expected to benefit from implementing the option, and the proposed EbA activities nominated by workshop participants (where information was provided).

Table 3-1 Master list of EbA options for Wagina Island

EbA Option	Geographical area	Ecosystem and ecosystem services that may benefit from EbA implementation	Existing and future threats to ecosystem services	EbA activities proposed (where info available)
Wagina				
Wagina Education and Awareness Programme	Wagina	Various, with a focus on: Marine/coastal, coral reefs, marine lagoons, beaches, mangroves - Provision of food resources (e.g. fish, shark, turtle, crustaceans, molluscs etc) - Provision of trade and income generation (seaweed, fish, shark, turtle, crustaceans, molluscs) - Supporting habitat and biodiversity - Provision of raw materials (coral rock, lime, timber, fuelwood) - Coastal protection through the attenuation and buffering of wave and storm energy by reefs, mangroves and the shoreline - Provision of kastom medicine (seagrass) Freshwater - Provision of water supply (groundwater wells)	Unsustainable fishing and marine resource management, clearing of vegetation in proximity to water sources, poor sanitation and waste management practices and lack of waste infrastructure, lack of environmental awareness, education and training, increase in population, increase in sea temperature and associated ocean acidification and coral bleaching, sea-level rise, increase in storm surge and coastal erosion	Involve church leaders upfront in the programme and integrate environmental education and awareness raising into church activities to assist in conveying important messages Centralised education and training with a nominated group of elders, youth representatives and community leaders who will then be equipped with the knowledge and resources needed to pass on their learnings to all community members Investigate the current extent of environmental education within the school syllabus and whether additional resources would be valued by the local teachers. Develop community by-laws focused at protecting ecosystems and their services. Establish an Environmental Ranger position(s) to oversee day-to-day activities on the island and new initiatives developed through the environmental education and awareness programme. Develop a 3D model of Wagina Island
Supporting seaweed farmers to build climate resilience	Wagina	Marine lagoons, beaches/sand islands - Income generation from seaweed farming	Clearing of coastal vegetation, sea-level rise, increase in storm surge and coastal erosion, over-harvesting of marine resources	Establish a working group consisting of MFMR and SPREP representatives to oversee the planning and execution of climate resilience initiatives Investigate avenues and initiatives for future-proofing seaweed farming Investigate the process and infrastructure needed to obtain a seaweed export license for the Wagina community to Up-skill (if necessary) existing farmers to

EbA Option	Geographical area	Ecosystem and ecosystem services that may benefit from EbA implementation	Existing and future threats to ecosystem services	EbA activities proposed (where info available)
				increase efficiencies in farming methods.
Pilot shoreline protection of seaweed island	Wagina	Marine lagoons, beaches/sand islands and mangroves - Income generation from seaweed farming - Coastal protection through mangroves and the shoreline	Clearing of coastal vegetation, sea-level rise, increase in storm surge and coastal erosion, over-harvesting of marine resources	Undertake a baseline study to gain an understanding of the existing coastal morphology of the local area. The study will assist in determining the number of reef balls to be installed and the most suitable location for each ball. Develop a logistics plan for transport and installation of the reef balls. Replant coastal vegetation around the island to help reduce the rate of erosion. Design and undertake a monitoring programme on erosion rates, corals and fisheries.
Wagina Island Water Resource Management Plan	Wagina	Groundwater, rivers and streams - Provision of water supply (groundwater wells) - Supporting habitat and biodiversity - Regulating flood flows, water quality, land stability, erosion and sedimentation control Terrestrial forests - Fresh water filtration - Erosion and sedimentation control	Clearing of vegetation in proximity to water sources, poor sanitation and waste management practices and lack of waste infrastructure, lack of environmental awareness, education and training, increase in population, sea-level rise, increase in storm surge, increase air temperature	Develop a Wagina Water Resource Management Plan to provide strategic direction and priorities for the on-ground management of the Wagina's water resources. Establish a Water Resource Governance Committee to oversee the execution of the management plan and initiatives Conduct a household and community level awareness campaign (covering sanitation and waste management and vegetation clearing adjacent to water sources) to help the community better understand the climate and non-climate threats to water resources Undertake a clean-up campaign involving the local community and schools Replant vegetation near water sources to reduce sediment and contaminant entering groundwater and rivers and streams. Coordinate the provision of water tanks to various locations on Wagina Island and the sand islands.

EbA Option	Geographical area	Ecosystem and ecosystem services that may benefit from EbA implementation	Existing and future threats to ecosystem services	EbA activities proposed (where info available)
Sustainable harvesting of marine resources	Wagina	Various, with a focus on: Marine/coastal, coral reefs, marine lagoons, beaches/sand islands, mangroves - Provision of food resources (e.g. fish, shark, turtle, crustaceans, molluscs etc) - Provision of trade and income generation (seaweed, fish, shark, turtle, crustaceans, molluscs) - Supporting habitat and biodiversity - Provision of raw materials (coral rock, lime, timber, fuelwood) - Coastal protection through the attenuation and buffering of wave and storm energy by reefs, mangroves and the shoreline - Provision of *kastom* medicine (seagrass)	Unsustainable fishing and marine resource management, lack of environmental awareness, education and training, increase in population, alternative income sources increase in sea temperature and associated ocean acidification and coral bleaching, sea-level rise, increase in storm surge and coastal erosion	Sustainable harvesting of marine resources including coral, parrotfish, bêche-de-mer and trochus shells
Educate and support the establishment of new MPAs and the enforcement of existing MPAs	Wagina	Various, with a focus on: Marine/coastal, coral reefs, marine lagoons, beaches, mangroves - Provision of food resources (e.g. fish, shark, turtle, crustaceans, molluscs etc) - Provision of trade and income generation (seaweed, fish, shark, turtle, crustaceans, molluscs) - Supporting habitat and biodiversity - Provision of raw materials (coral rock, lime, timber, fuelwood) - Coastal protection through the attenuation and buffering of wave and storm energy by reefs, mangroves and the shoreline - Provision of *kastom* medicine (seagrass)	Unsustainable fishing and marine resource management, lack of environmental awareness, education and training, increase in population, alternative income sources, increase in sea temperature and associated ocean acidification and coral bleaching	Awareness and education on the purpose of the local MPAs with a large focus on over-harvesting, especially turtles, sharks and keystone species e.g. parrotfish. Investigate the establishment of new MPAs Increase the support for enforcing existing MPAs
Investigation of alternative water source and	Wagina	Groundwater, rivers and streams - Provision of water supply (groundwater wells)	Clearing of vegetation in proximity to water sources, poor sanitation and waste	Cooksin Village - Spring water source located near Seleana River Suggested people to be involved: R-Wash,

EbA Option	Geographical area	Ecosystem and ecosystem services that may benefit from EbA implementation	Existing and future threats to ecosystem services	EbA activities proposed (where info available)
support watershed management			management practices and lack of waste infrastructure, lack of environmental awareness, education and training, increase in population, sea-level rise, increase in storm surge, increase air temperature.	Choiseul Provincial Government, national government, community Arariki Village - Village elders to consult land owner: Kiatoa Suggested people to be involved: R-Wash, Honourable Movete (ward member), Honourable Elijah Doromoala (Constituency member) Nikumaroro Village - Land owner: Tabao.
Sustainable harvesting of mangroves and mangrove shells	Wagina	Mangroves - Provision of food resources (e.g. mangrove shells, fruit) - Provision of trade and income generation (timber) - Supporting habitat and biodiversity mud crab, fish, crocodile, birds) - Provision of raw materials (timber, fuelwood, seaweed farms) - Coastal protection	Unsustainable/concentrated harvesting, lack of environmental awareness, education and training, increase in population, alternative income sources, increase in sea temperature, sea-level rise, increase in storm surge and coastal erosion	Focus on Crocodile Passage and coastal village areas Suggested people to be involved: Community, NGOs
Eco-stove	Wagina	Terrestrial forest - Supporting habitat and biodiversity - Provision of raw materials (timber, fuelwood, canoe making - Income generation (timber) - Regulating flood flows, water quality, carbon and nutrient cycling, land stability, erosion and sedimentation control	Unsustainable management of forests, lack of environmental awareness, education and training, increase in population	Seek alternative stove type for cooking that promotes the use of less firewood Eco-stoves estimated at $500 SBD - can order in bulk
Enrichment planting and forest replanting (inland)	Wagina	Terrestrial forest - Supporting habitat and biodiversity - Provision of raw materials (timber, fuelwood, canoe making - Income generation (timber) - Regulating flood flows, water quality, carbon and nutrient cycling, land stability, erosion and	Unsustainable management of forests, lack of environmental awareness, education and training, increase in population	Provision of seeds and seedlings for fruit trees to promote food security, wind breaks and shade trees Replanting around community areas and gardens

EbA Option	Geographical area	Ecosystem and ecosystem services that may benefit from EbA implementation	Existing and future threats to ecosystem services	EbA activities proposed (where info available)
		sedimentation control		
Coastal revegetation	Wagina	Mangroves and coastal vegetation - Provision of food resources (e.g. mangrove shells, fruit) - Provision of trade and income generation (timber) - Supporting habitat and biodiversity mud crab, fish, crocodile, birds) - Provision of raw materials (timber, fuelwood, canoe making) - Coastal protection	Unsustainable/concentrated harvesting, lack of environmental awareness, education and training, increase in population, alternative income sources, increase in sea temperature, sea-level rise, increase in storm surge and coastal erosion	Revegetation of the coastal areas of the three villages Suggested people to be involved: coastal residents and national government
Replanting in over-harvested mangrove areas	Wagina	Mangroves - Provision of food resources (e.g. mangrove shells, fruit) - Provision of trade and income generation (timber) - Supporting habitat and biodiversity mud crab, fish, crocodile, birds) - Provision of raw materials (timber, fuelwood, seaweed farms) - Coastal protection	Unsustainable/concentrated harvesting, lack of environmental awareness, education and training, increase in population, alternative income sources, increase in sea temperature, sea-level rise, increase in storm surge and coastal erosion	Replant mangroves from Fisheries Office to the mouth of Fourth River area. Dedicate specific areas for mangroves protection and mangrove harvesting Suggested people to be involved: MECDM, community with the help of government
Assistance in obtaining a Wagina seaweed export license	Wagina	Marine lagoons, beaches/sand islands and mangroves - Income generation from seaweed farming	Clearing of coastal vegetation, sea-level rise, increase in storm surge and coastal erosion, over-harvesting of marine resources	Provide assistance to the community in obtaining a seaweed export license to allow business dealings to be conducted directly with seaweed buyers Suggested people to be involved: Wagina Association (yet to be established), Honourable Movete (ward member), Honourable Elijah Doromoala (Constituency member), Choiseul Provincial Fisheries, Ministry of Fisheries and Marine Resources
Control gravel and sand removal	Wagina	Sandy beaches and islands - Sand and gravel for building material, includes coral rubble on beaches - Supporting habitat and biodiversity (turtles, crabs)	Unsustainable harvesting of gravel and sand, clearing of coastal vegetation, lack of environmental awareness, education and training,	Community by-law limiting the amount of gravel and sand removal Suggested people to be involved: community

EbA Option	Geographical area	Ecosystem and ecosystem services that may benefit from EbA implementation	Existing and future threats to ecosystem services	EbA activities proposed (where info available)
		- Food source (turtles, crabs) - Coastal protection	increase in population, sea-level rise, increase in storm surge and coastal erosion, increase in sea temperature and associated ocean acidification	
Ban plastic bags	Wagina	Various, with a focus on: Marine/coastal, coral reefs, marine lagoons, mangroves - Provision of food resources (e.g. fish, shark, turtle, crustaceans, molluscs etc) - Provision of trade and income generation (seaweed, fish, shark, turtle, crustaceans, molluscs) - Supporting habitat and biodiversity	Poor waste practices and lack of waste infrastructure, lack of environmental awareness, education and training, increase in population	Community by-law in prohibiting the importation and selling of plastic bags on the island Provision of waste bins Suggested people to be involved: Community with SPREP's help in providing bins
Forest Management Plan	Wagina	Terrestrial forest - Provision of food (wild fruits) - Supporting habitat and biodiversity - Provision of raw materials (timber, fuelwood, canoe making - Income generation (timber) - Regulating flood flows, water quality, carbon and nutrient cycling, land stability, erosion and sedimentation control	Unsustainable management of forests, lack of environmental awareness, education and training, increase in population, sea-level rise, increase in storm surge and coastal erosion	Introduce protected areas for forests, including cultural sites
FADs	Wagina	Various, with a focus on: Marine/coastal, coral reefs, marine lagoons - Provision of food resources (e.g. fish, shark, turtle, crustaceans, molluscs etc) - Provision of trade and income generation (seaweed, fish, shark, turtle, crustaceans, molluscs) - Supporting habitat and biodiversity	Unsustainable fishing and marine resource management, lack of environmental awareness, education and training, increase in population, increase in sea temperature	Installation of fish aggregating devices to increase fish abundance and biodiversity and reduce pressure on the marine environment

4 Stage 1 EbA options prioritisation

4.1 Shortlisted EbA options following application of the MCA

After the application of the MCA (**Error! Reference source not found.**) to prioritise options, all bA options were ranked in ascending order of their overall prioritised score (the lower the score the better performing against the MCA). EbA options with a rank of 9 or less were compiled as the EbA shortlist and are presented in Table 4-1 below in order of ranking. The purpose of establishing a shortlist of EbA options is to identify and objectively prioritise key options to be further assessed for their cost-effectiveness.

The EbA shortlist table outlines a brief description of each option, the key ecosystem services each option aims to target in building ecosystem and social resilience, and the performance score against each MCA criteria. Ecosystems services bolded correspond to the services likely to be less resilient to future climate and non-climate threats as identified in the ESRAM findings.

Shortlisted options for Wagina Island include livelihoods support to seaweed farmers, a community environmental education and awareness programme, shoreline protection of seaweed island, development of a water resource management plan, and establishment of support networks.

Table 4-1 Wagina Island shortlisted EbA options (Stage 1 options prioritisation using MCA)

EbA Option	Description	Targeted Ecosystems and Ecosystem Services	Benefit VH-1, H-2, M-3, L-4	Cost L-1, M-2, H-3	Feasibility Y-1, U-2, N-3	Sustainability VH-1, H-2, M-3, L-4	Other projects Nil-1, Few-2, Sev-3, Many-4	Prioritisation Score
Wagina Island								
Support seaweed farmers to build climate resilience	Provide support to the seaweed farming community to build resilience to the effects of climate change. Partner with the Ministry of Fisheries and Marine Resources (MFMR) who are in the process of investigating avenues to assist seaweed farmers in exploring potential solutions to future-proof the local farming industry.	Marine lagoons, beaches/sand islands and mangroves - **Income-generation from seaweed farming**	2	2	1	2	1	**8**
Wagina environmental education and awareness programme	Develop and deliver an environmental education and awareness programme for schools and community members that involves strong leadership from church and village leaders. The programme is to focus on key issues facing Wagina, including over-harvesting of marine resources, concentrated vegetation clearing and pollution, as well as a strong focus on the purpose of marine protected areas. It will also include the creation of a 3D model for Wagina	Marine/coastal, coral reefs, marine lagoons, beaches, mangroves - **Provision of food resources (e.g. fish, shark, turtle, crustaceans, molluscs etc)** - **Provision of trade and income generation (seaweed, fish, shark, turtle, crustaceans, molluscs)** - **Supporting habitat and biodiversity** - **Coastal protection through the attenuation and buffering of wave and storm energy by reefs, mangroves and the shoreline** Freshwater - **Provision of water supply (groundwater wells)**	3	2	1	2	1	**9**
Pilot shoreline protection of seaweed island	Undertake a pilot project on a hybrid approach to shoreline protection of highly vulnerable sand islands adjacent to Wagina. This would involve the installation of a submerged artificial reef (constructed of approximately 300 ‘reef balls’) around the shoreline of the main sand island, Beniamina	Marine lagoons, beaches/sand islands and mangroves - **Income-generation from seaweed farming** - **Coastal protection through mangroves**	1	3	2	2	1	**9**

EbA Option	Description	Targeted Ecosystems and Ecosystem Services	Benefit VH-1, H-2, M-3, L-4	Cost L-1, M-2, H-3	Feasibility Y-1, U-2, N-3	Sustainability VH-1, H-2, M-3, L-4	Other projects Nil-1, Few-2, Sev-3, Many-4	Prioritisation Score
	Island, to reduce the impacts of coastal erosion. The reef balls aim to mimic natural reef systems and their ability to attenuate waves while providing a diverse ecosystem through the attraction of marine life. This would be coupled with re-vegetation of shoreline vegetation to further consolidate these vulnerable islands. By slowing down the rate of coastal erosion and allowing seaweed farming to continue on sand islands, the over-harvesting and poaching of marine resources as an alternative income means is less likely to occur. The increase in marine life diversity and abundance will also provide additional benefits to the marine ecosystem and may increase food resource availability.	**and the shoreline**						
Wagina Island water resource management plan	Development of a water resource management plan to improve the provision of fresh water supply and reduce the risk of pollution and contamination of water sources currently safe to drink.	Ecosystem and ecosystem services targeted: Groundwater, rivers and streams - **Provision of water supply (groundwater wells)** - Supporting habitat and biodiversity Terrestrial forests - **Fresh water filtration** - **Erosion and sedimentation control**	1	3	1	3	1	**9**

		waste) and fuel spills • Habitat destruction by wild pigs (lowland swamps)			
Coastal and Marine (mangroves, reefs, seagrass, marine lagoons, rocky shores, sandy beaches and islands, and marine waters)	• Marine resources as a source of food, trade and income (turtle, shark, fish, molluscs, crustaceans)	• Population growth • Depletion of marine resources and loss of biodiversity from over-harvesting and poaching in protected areas • Physical	• Decline in reef ecosystem condition and coral dieback due to coral bleaching (rising temperature), ocean	• Designation of coastal and marine protection areas • Implementation of species management plans (turtles, sharks) • Sustainable fisheries management • Sand island protection	• Mini • Choi • Mini Man • Mini Deve • Mini

5 Cost-effectiveness analysis

Following the establishment of the shortlist of EbA options for Wagina Island, a cost-effective analysis (CEA) was undertaken for each option. The results of the CEA are presented below in **Error! Reference source not found.**.

Cost-effectiveness is reported in USD (2017) and provides an indication of the potential monetary benefit for each option per dollar invested.

Table 5-1 Wagina Island CEA results

Wagina Island EbA Option	Cost (USD)	Cost effectiveness (USD) (per $ invested)	Wagina Island EbA option rank
Wagina environmental education and awareness programme	62,000	38,969.00	1
Wagina Island water resource management plan	100,000	5,444.00	2
Pilot project for shoreline protection of seaweed island	338,500	1,706.00	3
Supporting seaweed farmers to build climate resilience	55,000	15.00	4

The CEA results for Wagina Island illustrate that all options are estimated to deliver benefits that exceed implementation costs. Options that are more holistic, i.e. the *Wagina environmental education and awareness programme* are assumed to benefit a broader suite of ecosystem services than the more discrete options, such as *Supporting seaweed farmers to build climate resilience*. The latter option affects fewer ecosystems given it is located further downstream of the other options, and therefore has limited positive effect in the upper reaches of the catchment.

Options developed for Wagina Island are estimated to deliver considerable value for every dollar invested. In particular, the *Environmental education and awareness programme* and the *Water resource management plan* options perform particularly well, as they provide long-term solutions designed to improve natural resource management. Other contributing factors to Wagina's high CEA results are that the ecosystems that will benefit from option implementation cover a large area, and also several ecosystem services have high economic values. For example, on Wagina Island, erosion prevention provided by reefs is valued at USD 175,423 per hectare (ha) (far higher than any other service) and are estimated to cover 2,460 ha. This makes up approximately 50% of the benefits of the two Wagina options listed above. The second key driver is erosion prevention in the marine lagoons/coastal ecosystems, which is valued at USD 28,920 per ha and will potentially benefit approximately 12,000 ha. This contributes between 30%–40% of the total benefit for the aforementioned options on Wagina Island.

Based on the CEA results alone, and with a project budget of USD 155,000 for each location, the CEA results suggest that implementing the top two ranked options for Wagina would result in the best value for money within or close to the available budget.

As part of the CEA process, the approximate costs of implementing each EbA option was investigated by the Project Team. The initial scoring under the 'cost' criterion during the Stage 1 option prioritisation had allocated several options as being 'medium' (USD 10,000–50,000) (see Section 4.1). However, further cost investigations indicate that all shortlisted options are estimated to cost more than USD 50,000 and therefore should be scored as 'high' (>USD 50,000). The cost criterion performance scores have been updated for the shortlisted options in the Stage 2 option prioritisation to reflect these findings (see Section 6).

The CEA ranking for each option will inform the final step in the EbA options prioritisation. Each option's rank represents the performance score attributed to the CEA criterion in the multi-criteria analysis (see Section 6).

6 Stage 2 EbA options prioritisation

The cost-effective analysis (CEA) provides the expected value for money (the ratio of dollars spent on the option versus the ecosystem service benefits from the option being implemented) for the implementation of each EbA option, i.e. 'bang-for-buck'. The CEA considers the longevity of the EbA option and the benefits delivered over its project life.

Results from the CEA were incorporated into the existing MCA as performed as part of the Stage 1 EbA options prioritisation (see Section 4.1) and represents the final step in the options prioritisation process. Table 6-1 presents the results of the final MCA for Wagina Island.

Table 6-1 Stage 2 EbA options prioritisation (using MCA and CEA)

EbA Option	Benefit VH-1, H-2, M-3, L-4	Cost * L-1, M-2, H-3	Feasibility Y-1, U-2, N-3	Sustainability VH-1, H-2, M-3, L-4	Other projects Nil-1, Few-2, Sev-3, Many-4	Cost-effectiveness Analysis Rank 1, 2, 3, 4, 5	Prioritisation Score
Wagina Island							
Wagina environmental education and awareness programme	2	3	1	2	1	1	**10**
Wagina Island water resource management plan	1	3	1	2	1	2	**10**
Pilot shoreline protection of seaweed island	1	3	2	2	1	3	**12**
Support seaweed farmers to build climate resilience	3	3	1	2	1	4	**14**

* The performance scores attributed to the cost criterion have been updated to reflect further information sourced on the cost associated with implementing each EbA option.

Project concept notes for the above shortlisted EbA options were developed and are described in Appendix A. Options one – Wagina environmental education and awareness programme – and option two – Wagina Island water resource management plan – are combined into one project concept note.

7 EbA options for implementation by PEBACC

Informed by the results of the MCA, the EbA options to be implemented by PEBACC on Wagina Island are:

- Wagina environmental education and awareness programme
- Wagina Island water resource management plan.

The above EbA options selected for implementation will have detailed implementation plans developed and will consider project elements, such as (but not limited to): preferred site selection; aims and outcomes; justification of implementation; major tasks, roles and responsibilities; implementation schedule; constraints to implementation; permit and/or approval requirements; ecological and social indicators that could be used to monitor and evaluate the effect of the EbA activities proposed; and indicative cost estimates.

Appendix A Project concepts for shortlisted EbA options

A.1 Environmental Education and Restoration Programme

A.1.1 Background information

The key ecosystems on and around Wagina Island are heavily utilised by local residents for provisioning services such food, water and shelter, and many of them have unique and significant biodiversity and existence values. These ecosystems also support other activities and social values such as cultural and traditional practices, medicinal purposes and recreation. Wagina's ecosystems are critical to the long-term resilience and prosperity of local communities, particularly in terms of building community resilience to climate change. However, current anthropogenic pressures, in addition to the existing and future impacts of climate change, are threatening the services these ecosystems provide to the local community. Unsustainable practices such as overharvesting of marine resources, ignoring protected area policies, vegetation clearing along coastal areas, pollution, and inappropriate solid waste management and sanitation, all combined with population increase, is detrimentally impacting upon the health of Wagina's ecosystem values and the health of the local community.

Reliable and safe drinking water is a critical issue to the resilience of Wagina Island's residents. Water sources for drinking and domestic uses on Wagina Island are limited to rainwater (a small number of tanks), groundwater, freshwater springs and streams. During dry periods (one to two months), rainwater tanks dry out and residents are forced to rely on groundwater wells and springs as the only source of drinking water. Household wells are also continually used on a daily basis for non-drinking water uses (i.e. washing, cooking).

Approximately 30 years ago, simple water infrastructure was installed to assist residents to better utilise freshwater springs as an accessible water source. This included a small concrete, spring-fed 'tank' (Figure A-1) on high ground behind Tengangea village with a pipe to the village. However, with inadequate maintenance and repairs, this water supply infrastructure was damaged and has not been functional for a number of years.

Figure A-1 Spring-fed freshwater supplies on high grounds behind Tengangea and Tekaranga feed local streams

A.1.2 Proposed EbA option

Description

Develop and deliver an environmental education and awareness programme for schools and community members with strong leadership from church leaders and elders, as well as conduct participatory environmental restoration activities that have a high proportion of women participants. The programme is to focus on key issues facing Wagina, including pollution and sanitation (especially of water sources), overharvesting of marine resources, vegetation clearing, as well as a strong focus on the purpose of the Marine Protected Area (Arnavon Community Marine Conservation Area). An increased awareness of the long-term damaging impacts these activities can have on local ecosystems and services is critical to the future health (e.g. *via* pollution and contamination of water sources) and livelihoods of people living on Wagina Island. Awareness and education is essential for local communities to further understand the impact their activities can have on their health and local ecosystems, and how to better manage natural resources and engage in sustainable practices.

Project aims and outcomes

- Sustainable marine and freshwater resource management with an aim of changing the mind set of local residents to sustain local natural resources
- Improve human safety of freshwater supply (water quality)
- Reduce the diffuse and point source pollution to streams and coastal ecosystems from inadequate sanitation and waste and management practices
- Improve the adherence to MPA guidelines
- Protection and restoration of vegetation adjacent to water resources.

Output indicators

- Reduction in marine resource harvesting rates for unsustainable species, including within MPA
- Marine resource species targeted (e.g. a move away from targeting unsustainable species, particularly those with a high conservation significance)
- Improved water quality conditions (e.g. electrical conductivity, faecal coliforms, *E. coli*)
- Reduction in litter/waste coverage
- Number of participants attending educational and restoration activities
- Acceptable rate of vegetation clearing relative to regrowth/replanting
- Improved sustainability/conservation advocacy.

Site specifications

Wagina Island, focusing on freshwater resources servicing (and/or with the potential to service) water supply of local community, as well as surrounding marine environments, including Arnavon Community Marine Conservation Area. It is anticipated that most of the education programme will be delivered at key learning and community centres (i.e. schools, *maneaba*, churches) at each of

the four villages on Wagina Island, complemented by the field-based restoration and training components as relevant.

Proposed activities

1) Integrate environmental education into church activities.
2) Centralised education and training with a nominated group of elders, youth representatives and community leaders who will then be equipped with the knowledge and resources needed to pass on their learnings to all community members.
3) Develop a basic Water Resource Management Plan for strategic direction and management of freshwater resources at Wagina.
4) Investigate the current extent of environmental education within the school syllabus.
5) Dissemination of environmental education to broader community, focusing on key messages, and noting that some education will be incorporated with practical 'hands-on' involvement of the community in the water quality and restoration activities below.
6) Conduct a household and community level awareness campaign, incorporating participatory hands-on training during restoration activities (below).
7) Conduct a clean-up campaign involving local communities and schools.
8) Replant vegetation near water sources to reduce sediment and contaminants from entering rivers and streams.
9) Develop community by-laws focused at protecting ecosystems and their services.
10) Establish an Environmental Ranger position(s) to oversee day to day activities on the island and new initiatives developed through the environmental education, restoration and Water Resources Plan development activities.
11) Develop a 3D model of Wagina.

Stakeholder involvement

- SPREP
- Churches
- Women's groups (e.g. Choiseul Women's Network)
- LLCTC
- Schools
- Ministry of Fisheries and Marine Resources and Choiseul Provincial Fisheries
- Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM)
- The Nature Conservancy (TNC)
- SICCP
- Ministry of Tourism and Culture, including Tourism Officer for Choiseul Province.
- Ministry of Education and Human Resource Development
- Ministry of Health and Medical Services

- R-WASH – Choiseul Province
- NPA Provincial member
- Rural Development Programme (RDP)
- Solomon Island Water Sector Adaption Programme (SIWSAP)
- Broader Wagina Island community (i.e. Tekaranga, Arariki, Tengangea and Nukumaroro villages).

Potential constraints to implementation

- Failure of the project to deliver a significant/positive shift in the culture of local residents towards improved environmental management and/or conservation practices
- Community tensions increase as a result of the approval of the proposed mining development
- Environmental damage from the mine's activities poses a detrimental risk to the long-term objectives and/or sustainability of the program
- Unsustainable marine harvesting by visitors to the area

Timing

The implementation of the proposed EbA option is expected to require the full two-year time allocation.

Costs

Estimated costs for the implementation of the EbA option are:

Activities	Cost (SBD)	Cost (USD)
Site visit	77,200	10,000
Education programme design	115,800	15,000
Education programme delivery	154,400	20,000
Printing of programme materials	23,160	3,000
Development of basic Water Resources Management Plan	77,200	10,000
Baseline water quality assessment and monitoring programme	193,000	25,000
Delivery of a clean-up campaign	46,320	6,000
Replanting of vegetation	77,200	10,000
Assignment and training of a community environmental Ranger	46,320	6,000
Development of 3D model	84487	10,944
Total	**895,087**	**115,944**

A.2 Supporting seaweed farmers to build climate resilience

A.2.1 Background information

Seaweed farming is the main commercial industry for the Wagina community, with Wagina being the number one exporter of seaweed in the country (Kronen 2010). Seaweed farming commenced in 2004–2005 as a means of deterring turtle poaching (primarily the commonly harvested green turtles *[Chelonia mydas]* and hawksbill turtles *[Eretmochelys imbricata],* which are listed as Endangered and Critically Endangered respectively by IUCN) from the Anarvon Marine Conservation Area (AMCA) and for diversification of household income (Kronen 2010). The seaweed farms are solely located in the marine lagoons (see **Error! Reference source not ound.**) of the island and a high proportion of Wagina households are directly dependent on seaweed farming for their livelihoods (Kronen 2010).

The seaweed species farmed is *Kappaphycus alvarezii*. Globally, it is one of the main commercial sources of carrageenans, which are used as gelling agents in food, cosmetic and medical products, and other industries. It is not native to the local area, with the original seaweed farming trials in Solomon Islands imported this species from Fiji (Kronen 2010).

In 2005, there were approximately 300 seaweed farmers/workers on Wagina Island. However, in recent years, fluctuations in price have reduced the viability of seaweed farming, severely affecting the local industry (Kronen *et al*. 2010, and pers. comm. from Wagina Island site visit).

Figure A-2 Seaweed farm at Wagina Island

Threats / Issues

Several key issues pose threats to the local seaweed farming community. The sand islands that are used to service the seaweed farming industry, including settlements for the seaweed farmers and their families and the construction of drying beds, are affected by sea-level rise and coastal erosion. For farming to be profitable, farmers are required to live on the island to reduce the cost of travel to and from Wagina Island each day. As these sand islands are rapidly being inundated by rising sea levels, the adaptive capacity of the islands to provide the necessary land for seaweed farming is decreasing. It is estimated that the inhabitable area of these islands has decreased by over 50% over the past decade.

Cyclones are also a key concern as they can completely destroy seaweed farms. Rebuilding takes approximately three to four months for a farm to become operational again (i.e. obtain and replant seaweed, then rebuild drying tables and housing while waiting for seaweed to be harvested), during which time farmers do not receive income. Similarly, strong currents and storm events can disturb farms and/or cause the seaweed to detach and float away, while tsunamis would have an even greater impact. Seaweed can also be vulnerable to extreme low tides if not planted in waters sufficiently deep, and is also thought to be affected at times by increased sea temperatures. Furthermore, preliminary evidence suggests that warmer lagoonal water in recent years has led to contamination of the seaweed farms by fast-growing cyanobacteria that reduce the quality and therefore the price of the harvested seaweed.

The large reduction in seaweed prices that has occurred recently has drastically affected the local industry. Seaweed prices have reduced from approximately SBD 5/kg dry weight to around SBD 1.50/kg in recent years. The community is also limited to selling the seaweed produce to the sole seaweed broker in Solomon Islands who is therefore able to set the market price. The effect on seaweed pricing not only drastically affects income-generation and livelihoods, it also has negative flow-on effects to other marine resources and ecosystems, as the community supplements their income from other sources, such as harvesting of sharks, turtles and fish.

Lastly, and potentially the greatest threat to Wagina's seaweed farming, is the proposed mining development that could see over 40% of Wagina Island developed, including areas directly adjacent to the marine lagoons in which seaweed farms are located.

A.2.2 Proposed EbA option

Description

Provide support to the seaweed farming community to build resilience to the effects of climate change. The Ministry of Fisheries and Marine Resources (MFMR) is in the process of investigating avenues to assist seaweed farmers in exploring potential solutions to future-proof the local farming industry. An MFMR staff member has recently completed a thesis on climate change impacts to Wagina's seaweed. The research could form the building blocks of future collaboration between SPREP and MFMR to build an innovative working group to further develop and implement initiatives to support seaweed farmers.

Figure A-3 Informal settlement on one of the larger sand islands near Wagina Island (source: Simon Albert)

Project aims and outcomes

- Establish a working group to develop initiatives to future-proof seaweed farming for Wagina Island residents.
- Implement pilot projects that support and sustain seaweed farming.
- Reduce pressure on overharvested marine resources.

Output indicators

- Establishment of working group
- Number of pilot projects implemented
- Seaweed production

Proposed activities and implementation considerations

- Establish a working group consisting of MFMR and SPREP representatives to oversee the planning and execution of climate resilience initiatives and support the Wagina Seaweed Association (currently in the process of becoming established).
- Investigate avenues and initiatives for future-proofing seaweed farming.
- Investigate the process and infrastructure needed to obtain a seaweed export license for the Wagina community.
- Up-skill (if necessary) existing farmers to increase efficiencies in farming methods.

Stakeholder involvement

- Wagina Seaweed Association (in the process of becoming established)
- Ministry of Environment
- Choiseul Provincial Government
- Lauru Land Conference of Tribal Community (LLCTC)
- Ministry of Fisheries and Marine Resources
- SPREP
- ESSI and SICCP
- Constituency and ward members
- Choiseul Provincial Fisheries

Potential constraints to implementation

- Disagreement within the working group and informal sand island settlements on executing initiatives
- Commencement of the proposed mining development

Timing

The implementation of the proposed EbA option is expected to require the full two-year time allocation.

Costs

Estimated costs for the implementation of the EbA option

Tasks	Cost (SBD)	Cost (USD)
Establishment of working group	39,500	5,000
Site visits and stakeholder engagement	197,500	25,000
Investigation into seaweed export license	39,500	5,000
Trial of initiatives	158,000	20,000
Total	**434,500**	**55,000**

A.3 Pilot project for shoreline protection of seaweed islands

A.3.1 Background Information

Wagina Island is the number one exporter of seaweed in the country (Kronen 2010). Seaweed farming is the main commercial industry for the Wagina community with a high proportion of Wagina households directly dependent on seaweed farming for their livelihoods (Kronen 2010).

The seaweed farms are solely located in the marine lagoons of the island. Sand islands play a critical role in supplying land used as a base to service the seaweed farming. Seaweed drying tables are constructed on sand islands and informal settlements have been established to enable workers to directly access the seaweed farms.

Figure A-4 (a) Seaweed drying tables on a sand island (b) informal settlement constructed on a sand island for seaweed farmers and their families

Threats / Issues

Sand islands and the local seaweed farming community are under threat from several factors. Sand islands are experiencing the effects of sea-level rise, coastal erosion through cyclones, storm surge and rough seas, while the predicted increase in the frequency and/or intensity of cyclones will exacerbate conditions. Rising sea levels are likely to permanently inundate sand islands further, reducing the adaptive capacity of the islands to provide the necessary land for seaweed farming.

In considering both existing and future threats, it is important to note that sandy shores are a highly dynamic environment that naturally undergo processes of sediment erosion and accretion. Even in the absence of climate change, the implications of this high dynamicity are that the construction of built structures in this environment can be hazardous in terms of coastal erosion.

The clearing of vegetation on sand islands to provide more land for seaweed drying beds, particularly on the coastal fringe, is likely to have increased the rate of coastal erosion.

A.3.2 Proposed EbA option

Description

Undertake a pilot project using a hybrid approach to shoreline protection of highly vulnerable sand islands adjacent to Wagina. This would involve the installation of a submerged artificial reef (constructed of approximately 300 'reef balls') around the shoreline of the main sand island, Beniamina Island, to reduce the impacts of coastal erosion. Given these risks and the likelihood that the islands will be completely lost within the next decade, a hybrid approach of engineered and natural structures is proposed to stabilise the shoreline. The reef balls are concrete structures that aim to mimic natural reef systems and their ability to attenuate waves, while providing a diverse ecosystem through the attraction of marine life. The reef balls are hemispherical, hollow, concrete units that are placed up to 100 m seaward from the shoreline. This would be coupled with replanting of shoreline vegetation to stabilise the sand that accretes behind the reef balls. By slowing down the rate of coastal erosion and allowing seaweed farming to continue on sand islands, the over-harvesting and poaching of marine resources as an alternative income means, is less likely to occur. The increase in marine life diversity and abundance will also provide additional benefits to the marine ecosystem and may increase food resource availability.

Project aims and outcomes

- Reduce the rate of coastal erosion of seaweed islands
- Restoration and protection of shoreline vegetation
- Reduce pressure on over-harvested marine resources.

Output indicators

- Rate of coastal erosion
- Number of trees planted
- Seaweed production

Proposed activities and implementation considerations

- Undertake a baseline study to gain an understanding of the existing coastal morphology of the local area. The study will assist in determining the number of reef balls to be installed and the most suitable location for each ball. Local knowledge of currents and sand movement is to be utilised. Obtain aerial imagery of the current sand island morphology.
- Develop a logistics plan for transport and installation of the reef balls.
- Replant coastal vegetation around the island to help reduce the rate of erosion. Replanting should take place as a priority over seaweed drying beds.
- Design and undertake a monitoring programme on erosion rates, corals and fisheries.

Stakeholder Involvement

- NGOs
- Wagina Seaweed Association (in the process of becoming established)

- Ministry of Fisheries and Marine Resources
- SPREP
- Choiseul Provincial Fisheries
- NGOs and universities.

Potential constraints to implementation

- Costs drastically exceed quoted figures
- Results from the baseline study indicate the installation of reef balls in not appropriate
- Logistics

Timing

The implementation of proposed EbA option is expected to require the full two-year time allocation.

Costs

Estimated costs for the implementation of the EbA option

Tasks	Cost (SBD)	Cost (USD)
Baseline study	118,500	15,000
Development of logistics plan	39,500	5,000
Construction of reef balls	1,975,000	250,000
Transportation and deployment of reef balls	434,500	55,000
Replanting	59,250	7,500
Design of monitoring programme	47,400	6,000
Total	**2,674,150**	**338,500**

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