Mangrove EcoSystems for Climate Change Adaptation and Livelihoods (MESCAL)

Biodiversity Assessments Technical Report (Eratap and Amal/Crab Bay)

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Glossary

DEPC	Department of Environmental Protection and Conservation
DGMWR	Department of Geology, Mines and Water Resources
DLSR	Department of Lands, Survey and Registry
GPS	Global Positioning System
GSM	Geodetic Survey Maps
NGO	Non-Governmental Organization
CGPS	Continuous GPS Stations
GNSS	Global Navigation Satellite Systems
HHWM	Highest High Water Mark
HWMB	High Water Mark Boundary
IRD	Institute Researche de Development
IUCN-ORO	International Union for Conservation of Nature – Oceania Regional Office
JCU	James Cook University
MESCAL	Mangrove Ecosystems for Climate Change Climate Adaptation and Livelihoods
MBB	Mangrove Back Boundary
MLNR	Ministry of Lands and Natural Resources
NCC	National Country Coordinator
OM	Offshore Mangrove
OMVB	Offshore Mangrove Vegetation Boundary
PMU	Project Management Unit
PSM	Permanent Survey Mark
PT	Prism Target
STMs	Survey Traverse Marks
USP	University of the South Pacific
TS	Total Station
UTM	Universal Transverse Mercator
VCC	Vanuatu Cultural Centre

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The MESCAL Vanuatu project would like to extend its acknowledgement to the Government departments and other organizations that made this work possible in particular:

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- Department of Lands, Survey and Registry (DLSR)
- Department of Geology, Mines and Water Resources (DGMWR)
- Department of Forestry
- Department of Fisheries
- Department of Finance
- Vanuatu Cultural Centre (VCC)
- Villagers surveyed in the Shefa and Malampa province

We also acknowledge the team members who have contributed tremendously towards the successful collection of data at the two demonstration sites, Eratap on Efate and Amal/Crab Bay on Malekula:

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- Mr. Jayven Ham, Mr. Jeremy Kaltevara, Mr. Keven Morris, Mr. Rodrick (Department of Fisheries)

We also highly appreciate the effort of Ms. Rinah Japheth Finance Officer at the Ministry of lands Cooperate Services who has put in a lot of effort to ensure requests were met on time while we were away doing field work.

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- German Federal Ministry for Nuclear Safety and Environment (BMU) for funding the MESCAL project and its implementation and activities in Vanuatu.
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- Dr. Marcus Sheave, Dr. Norman Duke, Mr. Ross Johnston and Mr. Jock Mackenzie of James Cook University (JCU) for their guidance in the technical aspects of the baseline surveys and for their in-depth analysis of the biodiversity data.

We would like to acknowledge the other external partners such as IRD (Noumea, New Caledonia) for providing us with the data needed for Mapping and species list. We would like to extend a special thank you also to the Communities of both demonstration sites, who have contributed tremendously to the field activities and especially for making this work possible.

Foreword

Mangroves ecosystems play a vital ecological role and are highly valued by coastal communities of Vanuatu. However, for many years mangroves have been regarded as just trees and not an important aspect of the coastal ecosystem which is interconnected and vital to the survival of biota in connecting catchments and surrounding reefs. Attempts in the past to protect Vanuatu's mangroves have proven futile as there are still key knowledge gaps such as important scientific and technical baseline information. The effects of limited knowledge and information also led to the difficulty in the development of proper mangrove management regimes and therefore the reliance on outdated policies and legislations. The National Biodiversity strategy action plan (NBSAP) has highlighted the mangroves ecosystem as a critical ecosystem and one that must be protected.

The German Government funded Mangrove EcoSystems for Climate Change Adapatation and Livelihoods (MESCAL) project which is implemented by the International Union for Conservation of Nature-Oceania Regional Office (IUCN-ORO) in 5 countries in the Pacific region (Samoa, Tonga, Vanuatu, Fiji Solomon Islands) aimed to help community's understand that mangroves are important and that this can be achieved through the initial step of gathering baseline social and scientific information. With the information collected from the action research, the MESCAL project in Vanuatu hopes to provide the research-based platform with which to aid decision makers make informed decisions on the development and implementation of adequate mangrove management strategies and policies to properly address issues on management of Vanuatu's mangroves. This technical report combines the results of mangrove mapping, forestry surveys, fish assemblage surveys, traditional mangrove uses and a Climate Change scenarios report.

I hope that with the information given in this technical report, future generations of this country will appreciate the goods and services the mangrove ecosystems provides and encourage them to work towards managing and protecting Vanuatu's mangrove ecosystems.

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Background

The International Union for Conservation of Nature, Oceania Regional Office (IUCN-ORO) developed the Mangrove EcoSystems for Climate change adaptation and Livelihoods (MESCAL) project. This project is a German Government funded initiative that is aimed at addressing the key challenges of mangrove management and conservation in five Pacific Islands, Vanuatu, Fiji, Tonga, Samoa and the Solomon Islands. The overriding goal of this project is to increase resilience to climate change for the people of the Pacific Island countries through adaptive co-management of mangroves and associated ecosystems in each of the selected countries. This project is both a research and a development project. Some of its key activities include the selection of demonstrations sites, capacity building, review of existing governance systems, economics and carbon sequestration.

There are four main outcomes for this project, these are:

1. National Baseline Information about Climate Change Scenarios, use and values of Mangroves and Associated Ecosystems
2. Co-management of mangroves for adaptation to Climate Change Governance
3. Improved conservation and/or restoration of mangroves at selected demonstration sites
4. Increased Awareness, Advocacy and Capacity development

Each MESCAL country also appointed a National Country Coordinator (NCC) who are government staff. National Implementing Committee's (IC) responsible for developing, implementing and monitoring MESCAL activities were established in each country with national networks also established with partners responsible for jointly implementing national activities. After site assessments in 5 sites in Vanuatu the project technical group selected two demonstration sites (*1*) Eratap on Efate and (*2*) Amal Crab Bay on Malekula. MESCAL Vanuatu wanted to be able to compare the results of a highly disturbed site and a protected site and the impacts on mangroves and the services in which it provides to the communities. Data from these two sites will be extrapolated and will help in the provision of a model for the monitoring, evaluation and awareness of mangrove ecosystems on the main island of Vanuatu. The projects' Implementation Committee has had several meetings to agree on a project implementation plan in order to achieve the 4 outcomes of the project. The project had community consultation workshops in 2011 where each community developed an action plan alongside the projects action plan. Establishment of this locally based committee has been effective in building networks between government and the traditional landowners. Baseline biodiversity surveys were undertaken in September and October, 2012. PMU hired consultants from James Cook University to provide a feasible method on the regional biodiversity surveys, provide in-country training, analysis of the baseline data and the preparation of appropriate reports. Policy review was undertaken in November, 2012 with discussions held between MESCAL Vanuatu, IUCN policy review team and various Governmental departments. The purpose of this report is to provide a brief overview of the Action Research Component at the demonstration sites that were selected for MESCAL Vanuatu under Outcome 1 of the project document.

Introduction

A team of 18 Government officers (6 teams) were engaged over a 2 month period (August 27-October 26 2012) to carry out a mangrove mapping and biodiversity assessment at both Project demonstration sites. The mapping team began in September 17th – January 10th on Malekula and on Eratap Efate. The officers came from Natural Resource Management sectors within the government; including the Department of Forestry, the Department of Fisheries, the DEPC and DSLR. NGO's involved were VCC, Government extension Officers based on Lakatoro also assisted the team on site. Activities that were carried out at the time frame included Long Plots (lead - Department of Forestry), the Fish assessment (lead - Department of Fisheries), the fauna assessment (lead – DEPC), a Socio Economic Assessment (lead - DEPC), Traditional knowledge documentation (lead by the VCC) and Mangrove Mapping (lead - DSLR). Training on fisheries and forestry related activities were carried out prior to the action research by the mangrove experts and specialists from James Cook University.

Aim and objectives of research

The objective of this activity was to collect baseline information on mangroves to help local communities understand the importance of mangroves and that it can help build resilience to some effects of climate change. In addition, the data collected will aid in the development of adequate and appropriate policies that are targeted at sustainably managing mangrove ecosystems.

Expected outcomes of the trip

It is hoped that after completing the assessment the information will be used for;

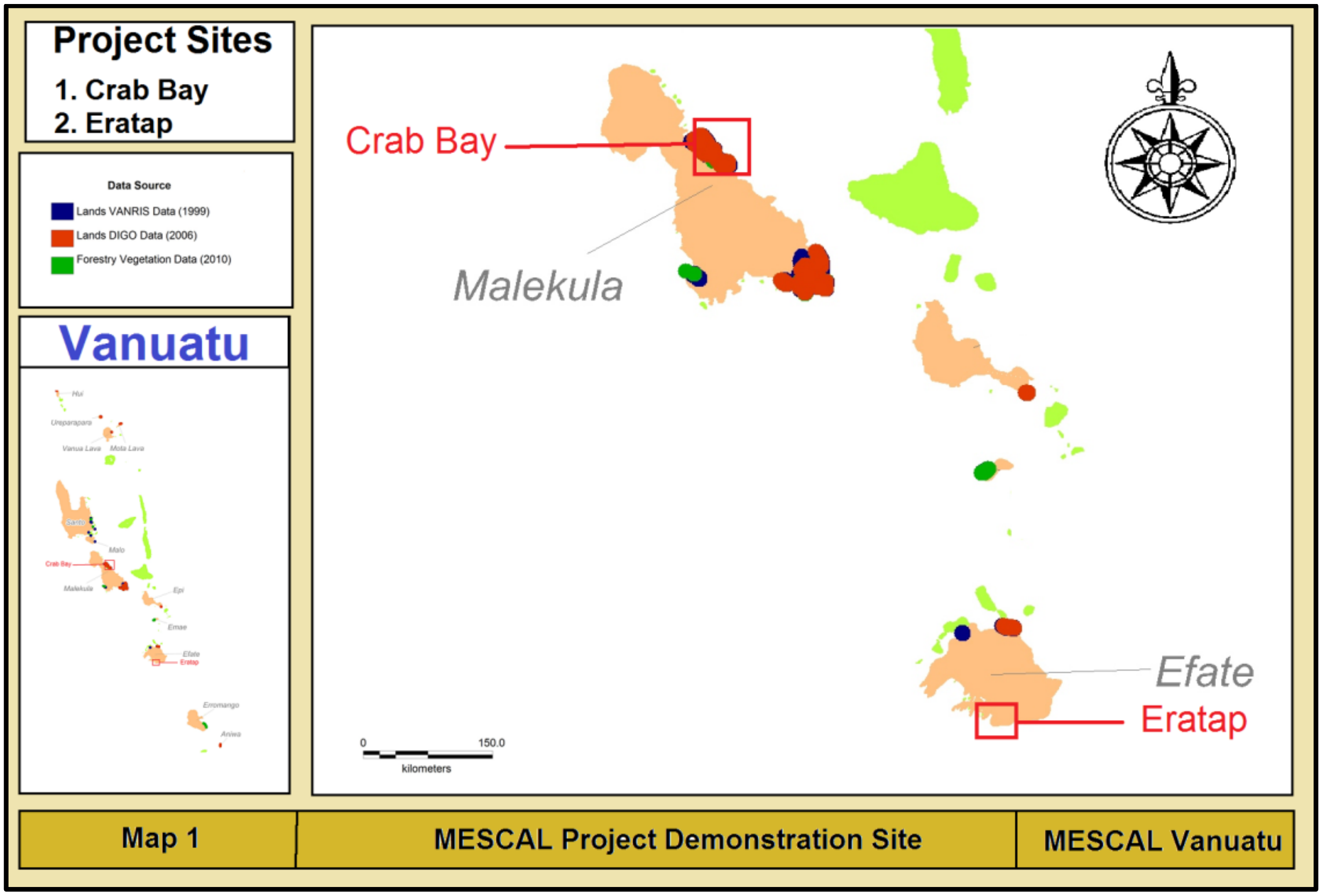
- Development of appropriate and adequate mangrove management policies;
- Total area of Mangroves in the demonstration sites;
- Update the Mangrove dependent fauna species list for Vanuatu;
- Update Mangrove species list for Vanuatu on each Island;
- Map out the Permanent Boundary of Mangrove for future Monitoring.

Assessment team

There were 6 Teams altogether: (i) Forestry, (ii) Fisheries, (iii) Water Resource, (iv) Surveyors, (v) S-VAM and (vi) Fauna Assessment Team

Demonstration Sites

Eratap is located on the island of Efate (E 168° 21'0.266"; S 17 ° 47 '16.032") and Amal/Crab Bay is located on the island of Malekula (E 167 31' 33.379; S 16 10' 28.956).



Map 1: MESCAL Vanuatu Demonstrations sites

Eratap Community is situated on the South-East of Efate Island (please refer to Map 1). Eratap was identified as a demonstration site by the project in January 2011 and MESCAL is one of the first projects to be implemented at this site. Compared to the Amal/Crab Bay site, Eratap has more human influence as there are resorts and also small settlements within and around the demonstration site.

The field team began working with the 16 communities of Crab Bay in April 2011 after an initial community consultation workshop. At Eratap the work began later in the year, in November 2011 also conducting community consultations. These two workshops had identified some important gaps that urgently needed to be addressed therefore an Action Plan was developed and implemented. To undertake projects in Vanuatu, it is important to consult the all stakeholders, especially the resource owners who could ultimately determine the success of the project.

Section 1. Mapping of Demonstration Site (Amal/Crab Bay & Eratap)

Tony Kanas

Department of Lands, Surveying and Registry, Ministry of Lands and Natural Resources, Vanuatu.

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I would particularly like to express my sincere acknowledgement to the following people, Mr. Martin Sokomanu (Surveyor General) Mr. Philip Koroka, Mr. Isaac Nango, Mr. Rodson Aru and Mr. Jean Claude Willy (Department of Lands Survey and Registry) for their tireless effort in helping to complete the field work. Mrs. Rolenas Baereleo and Mr. Molu Bulu (MESCAL project, DEPC) for their support in providing external support and making sure we have funds to complete the work as well as helping us with the identification of the of the Mangrove Back boundary species. We would like to extend our gratitude to the extension officers at Lakatoro who provided support during this work Mr. Keven Morres, Fisheries Development officer, for doing logistical arrangement with the AKTE Committee and also allowing us to use the Fisheries Department Vehicle to complete this field work also Mr. Daniel Layang from the Forestry Department for his support when we urgently need supplies from Lakatoro. I would also like to express my gratitude to the AKTE Committee who have allowed the team to camp Crab bay and also community members who have helped us at both sites as our guide into the mangroves forest as well as helping us to complete our field work. The German Federal Government provided funds through IUCN/MESCAL project for the successful completion of this work.

Introduction

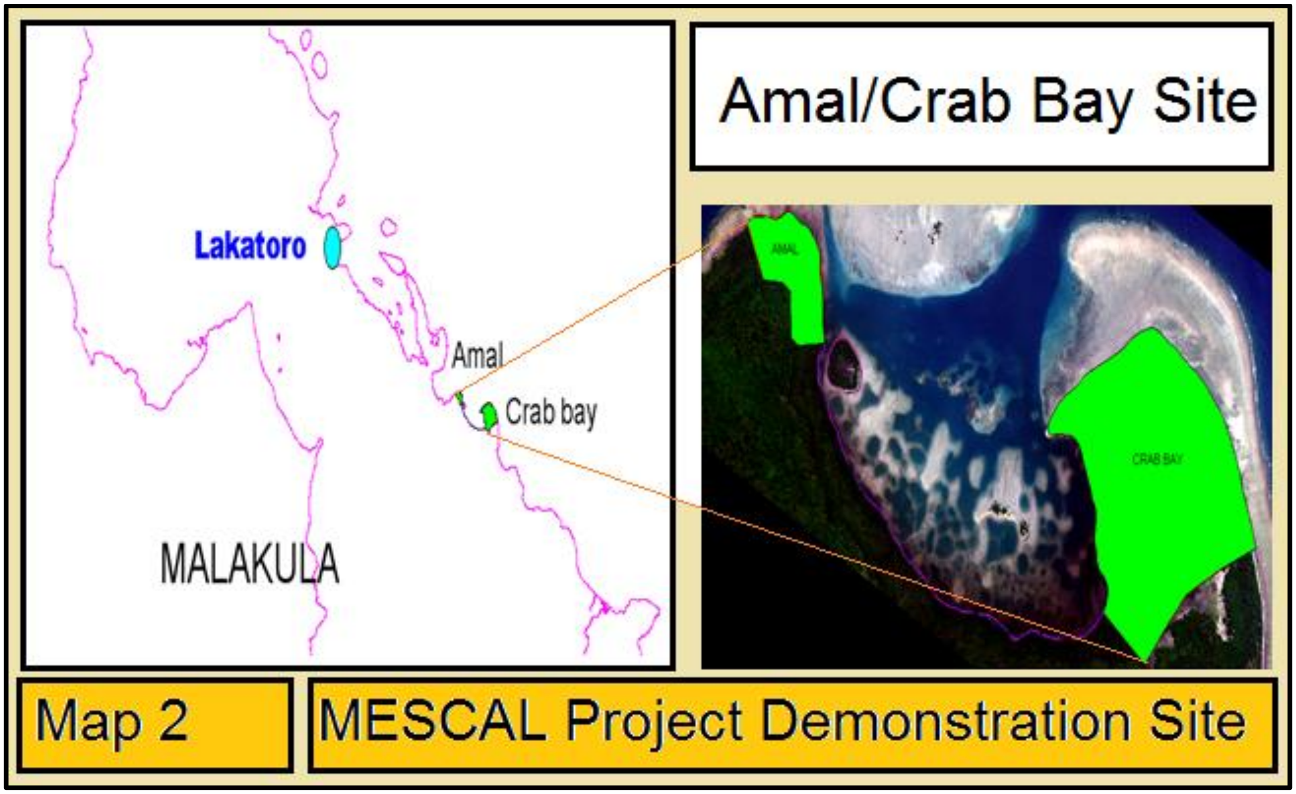
The Land Survey Division of the Department of Lands and Surveying and Registry assisted MESCAL Vanuatu in the implementation of Outcome 1 of the Project through the updating of mangrove vegetation maps at the 2 demonstration sites. This is an important component towards achieving Indicator 2 of the project which is calculating the deforestation net loss of the mangroves at the demonstration site, in this case the Eratap demonstration site on Efate. The Baseline surveys and Mapping activity commenced from July 2012 through to March 2013. This included a lot of different stages of surveying and mapping which will later be elaborated in this final report.

Mapping of mangrove at the demonstration site is a key component of this project to ensure the total area of mangrove at the demonstration site is determined. Although there have been a lot of work done together with the Lands Survey division in Vanuatu there is no work to identify mangrove areas from offshore mangroves to the back boundary species mangroves. This activity was successfully completed with the use of GPS for geodetic control and total stations for survey traverse and detail survey in the three sites. With the baselines that have been created, we are now able to determine the total area of mangroves at the two demonstration site, from the offshore Mangroves to the high water mark and to the back boundary species. This information is useful to us to be able to identify the threats on the mangrove ecosystems and with this information we can be able to help communities sustainable manage their mangrove ecosystems.

Mapping sites and Methods

Amal/Crab Bay, Malekula Island (Malampa Province)

Amal and Crab bay Mangrove pilot sites are located approximately 2 kilometers apart. Approximate areas of pilot sites are 23 hectares and 150 hectares respectively. More detailed area calculations will be discussed later in this report.



Map 2: Amal/Crab Bay Demonstration Site (Malekula Island)

Baseline surveys for these two mangrove sites will be based on static GPS observations on strategic location determined by the Surveyor. This will be followed by Total station Traversing and detail surveys.

Activity 1 Geodetic Control Survey

Three (3) Geodetic Survey Marks are created at Crab Bay using Dual frequency GPS receivers. The Geodetic Survey Marks are cemented with galvanized pipe at the center. Two Institute Researche de Development (IRD) Geodetic points, at Norsup and Ransari, are used as Base points to control the geodetic control survey at Crab bay.

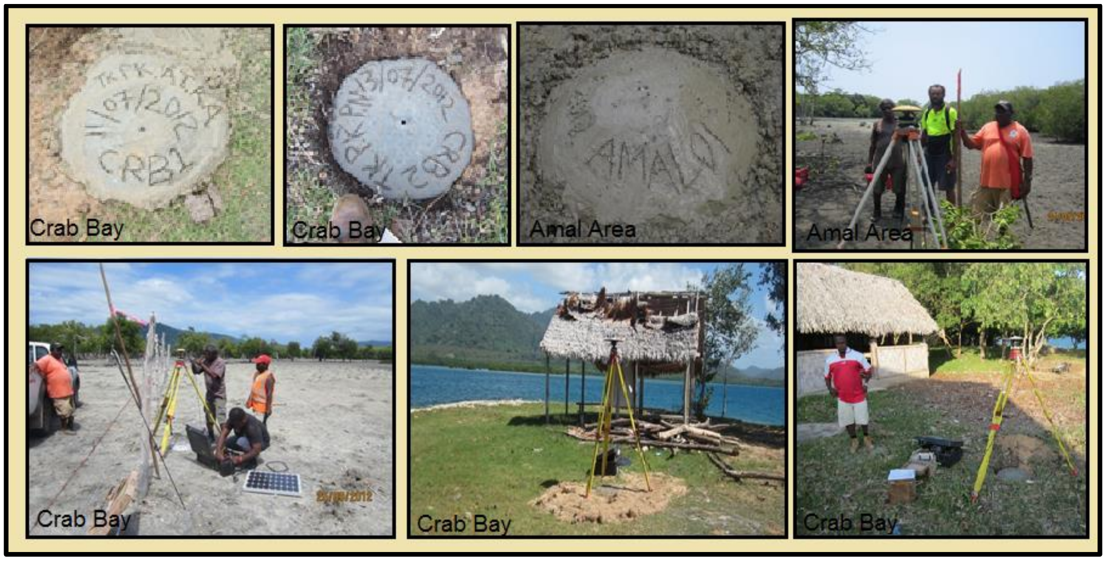


Figure 1: Geodetic Survey Marks at Crab Bay

At Amal, four (4) Geodetic Survey Marks (GSM) are established and observed using Dual frequency GPS receivers on static mode. The Geodetic Survey is controlled or based on the Crab bay geodetic survey mark (CRB1).

Activity 2 GPS Processing and Network Adjustment

Crab Bay

Topcon Link software was used to convert Topcon raw data to RINEX format before converting to Ashtech format using GNSS Solutions software. WinPrism (Ashtech) software was used for gps processing. Network Adjustment was done using Fillnet adjustment program.

Ransari (RANS) IRD ITRF96 coordinates are used as Fixed Point and Norsup (NSUP) ITRF coordinates as check Point during processing (please refer to figure 2 below).

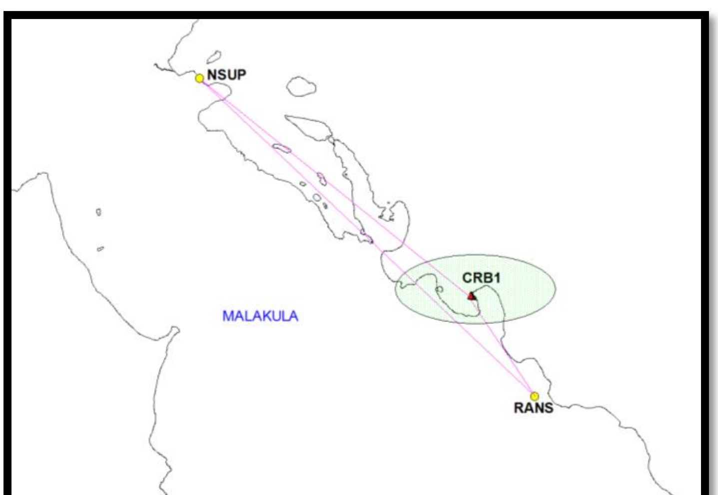


Figure 2: Figure showing Geodetic Coordinates of Ransari and Norsup IRD points.

Final and adjusted geodetic coordinates for Crab bay pilot site are then placed into the Geographic calculator, which then transforms from Geographical to Universal Transverse Mercator projection (UTM), Zone 58 of the Southern Hemisphere. The following table shows these results:

ACRONYM	LOCALITY	LATITUDE	LONGITUDE	ELLIP/HEIGHT	GEODETIC SPEROID	PROJECTION
CRB1	CRAB BAY	-16 10 00.34762	167 32 00.13680	65.971	ITRF96	
		N 8210949.742	E 770898.517		WGS84	UTM (58 S)
		N 59482.562	E 54516.956		International	TM Malakula
CRB2	CRAB BAY	-16 09 59.70241	167 32 01.77053	65.970	ITRF96	
		N 8210968.986	E 770947.316		WGS84	UTM (58 S)
		N 59502.386	E 54565.493		International	TM Malakula

Table 1: Geographical to Universal Transverse Mercator projection (UTM) , Zone 58 of the Southern Hemisphere.

Amal Area

Geodetic control for Amal site was based from Crab bay (CRB1) geodetic survey mark.

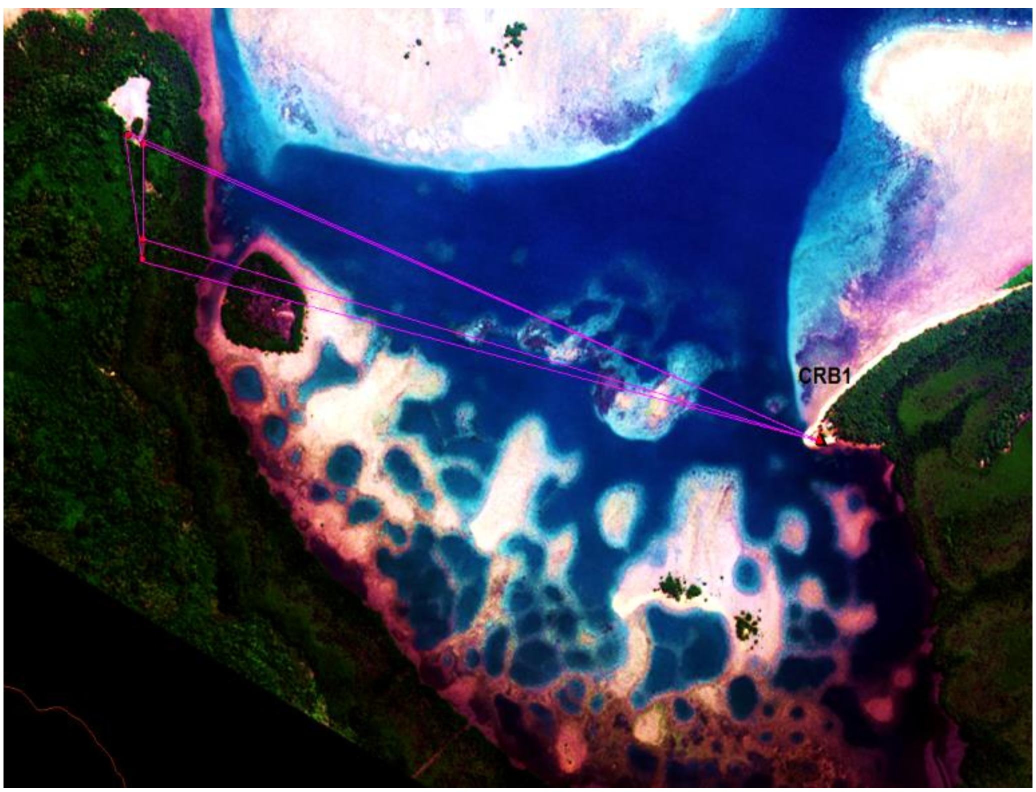


Figure 3: Figure showing geodatic coordinates on Amal Area

The table below shows the conversion of the Geographical to UTM, Zone 58 of the Southern Hemisphere.

ACRONYM	LOCALITY	LATITUDE	LONGITUDE	ELLIP/HEIGHT	GEODETIC SPEROID	PROJECTION
AML1	AMAL	-16 9 35.77076	167 30 52.48783	65.497	ITRF96	
		N 8210949.742	E 770898.517		WGS84	UTM (58 S)
AML2	AMAL	-16 9 36.46352	167 30 54.17845	65.519	ITRF96	
		N 8210968.986	E 770947.316		WGS84	UTM (58 S)
AML3	AMAL	-16 9 44.38940	167 30 54.19428	65.581		
AML4	AMAL	-16 9 46.39100	167 30 53.93948	65.568		

Table 2: Geographical to Universal Transverse Mercator projection (UTM) , Zone 58 of the Southern Hemisphere.

The outcome of this exercise was that Amal and Crab Bay now have finalized and adjusted geodetic coordinates that will prove to be very useful for further mapping and land surveys.

Activity 3 Traverse of Mangrove Back Boundary and Mean High Water Mark

The first step is to establish the Survey Traverse Route. This requires a lot of a head bush clearing for line of site. Each line of site is required to be one hundred meters however it was difficult to achieve this in a lot of areas. A few line of sites had to be reduced to fifty meters due to the conditions along the coastline. At the end of each line of site, STM is constructed at ground level by cementing a (30 mm) construction pipe to ground level. The survey traverse task is undertaken using Total Station (TS) Instrument and Prism Target (PS) set ups in order to obtain more accurate and precise measurement of baseline data within thick vegetation cover. The Survey crew comprised of two surveyors two survey field technicians and three laborers that were contracted from the nearby village. At times there would be two Survey teams lead by a surveyor each doing line of sight establishment, traverse observations etc. Back species boundary was identified with color ribbons by the mescal country coordinator before survey teams are able to establish these positions. For crab bay the survey route was approximately four (4) kilometers and for the Amal site the use of three geodetic receivers reduced the time required to determine the Baseline Boundaries.

Activity 4 Total Station Survey of Offshore Mangrove Vegetation Boundary

This Stage involves Total Station observations at strategic locations at each site to observe and record distance and angular readings to a multiple Prism on a boat, for Amal and Crab Bay and on a canoe, for Eratap, in order to determine precise offshore mangrove vegetation positions that will determine offshore mangrove vegetation boundaries. Overlay of remote sensing images, satellite or aerial photography will enhance this baseline determination.

Figure 4: Total Survey Stations of Offshore Vegetation Boundary (Amal/Crab Bay)

As the Amal and Crab Bay sites have just over a two kilometer line of sight from CRB1 (green point on Figure 4), we identified CRB1 as our only safe strategic point throughout the whole bay. From CRB1 we observed that most of the offshore vegetation growth could be successfully surveyed using a total station setup, a boat and triple prism handled by a survey assistant on the boat. This work required the team of three to start early in the morning and later during the day to avoid the midday sun and heat. We managed to complete this activity in one and half days. Areas that we could not observe we used the satellite overlay to assist with odd spots that we picked up from total station traverse.

Activity 5 Data Entry into LISCAD (Surveying Package)

Total station traverse data was entered manually from field book into Liscad Surveying software. Coordinates are on UTM grid, zone 59 south. As a result we are able to graphically display high water mark line boundary, offshore mangrove vegetation line boundary and Mangrove Back Boundary species line boundaries.

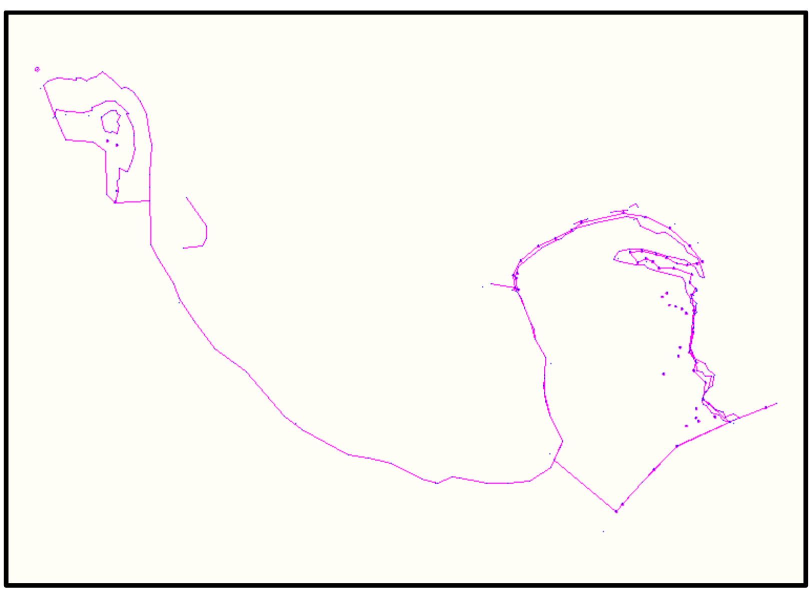


Figure 5: LISCAD Output for Amal/Crab Bay

Remote sensing overlay will validate and close certain gaps that our ground survey cannot determine.

Activity 6 Overlay of Remote Sensing Imagery

The overlays helps identify and compare the ground surveys with remotely sensed imagery. The yellow line indicates the total station traverse route and the red line indicates the edge of major mangrove boundary. This boundary on land is where the highest tides would reach. Normal tides boundary is not indicated clearly beginning at point A to point B. This boundary still needs to be identified and overlaid.

Figure 6: Overlay of ground survey and remote sensing imagery data (Amal/Crab Bay).

With these overlays we are also able to visualize and relate our Ground surveys with registered leases (pink), unregistered leases (yellow) and road networks (red) to give us some idea on Governmental decision making process.

Activity 7 Determination of Major Mangrove Baseline Boundary Areas

This stage required utilizing the remote sensing overlays with ground surveys to determine polygon areas. At this stage we realized that additional field work needed to be carried out on Crab bay. The survey team did not determine the normal high water mark boundary within the salt marsh area due the accessibility of the area. Mangrove Back Boundary (MBB), High High Water Mark (HHWM) boundary and Offshore Mangrove Boundary (OMB) was clearly identified using Total station traverse and detail pick up technique.

Figure 7: Validation of Ground Surveys is done on Overlays

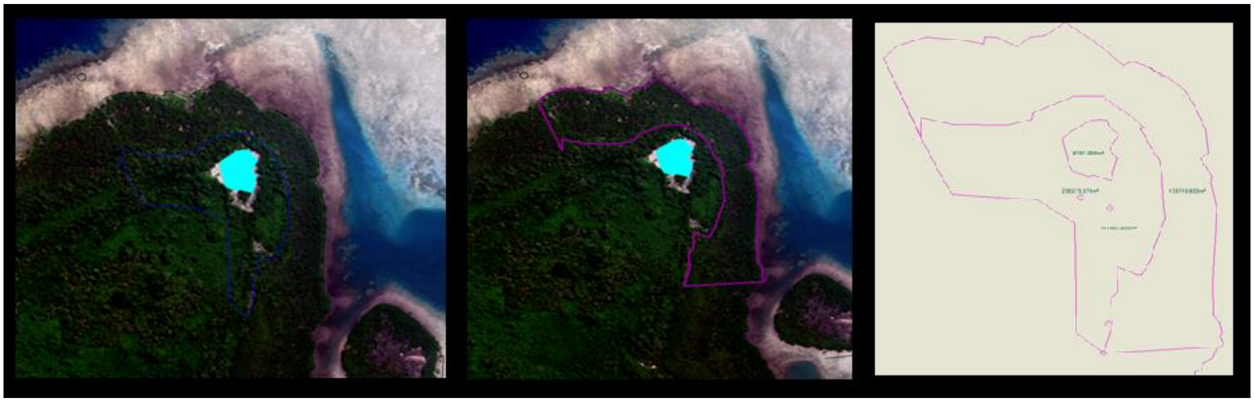


Figure 8: Back species boundary to high water mark boundary and High water mark to offshore vegetation boundary

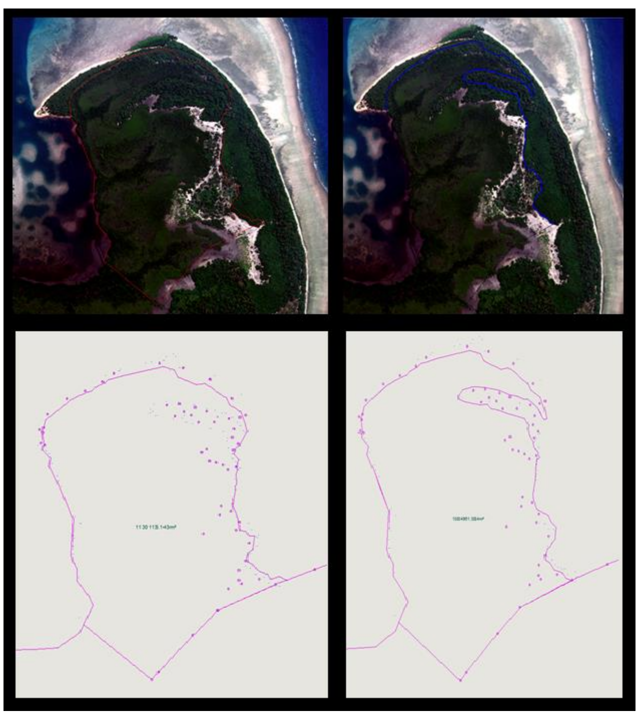


Figure 9: Total boundary of Mangrove vegetation and HHWM Boundary

Activity 8 Overlay of Existing Vegetation Maps

The vegetation map produced by the department of forestry in 2011 shows that light blue colored areas are mangrove vegetation areas. The overlay of Mangrove our Vegetation Boundary survey at Amal site and Crab bay site clearly shows that the vegetation map is too general in terms of mangrove vegetation and highlights the necessity of proper ground Surveys for Mangrove Baseline boundaries.

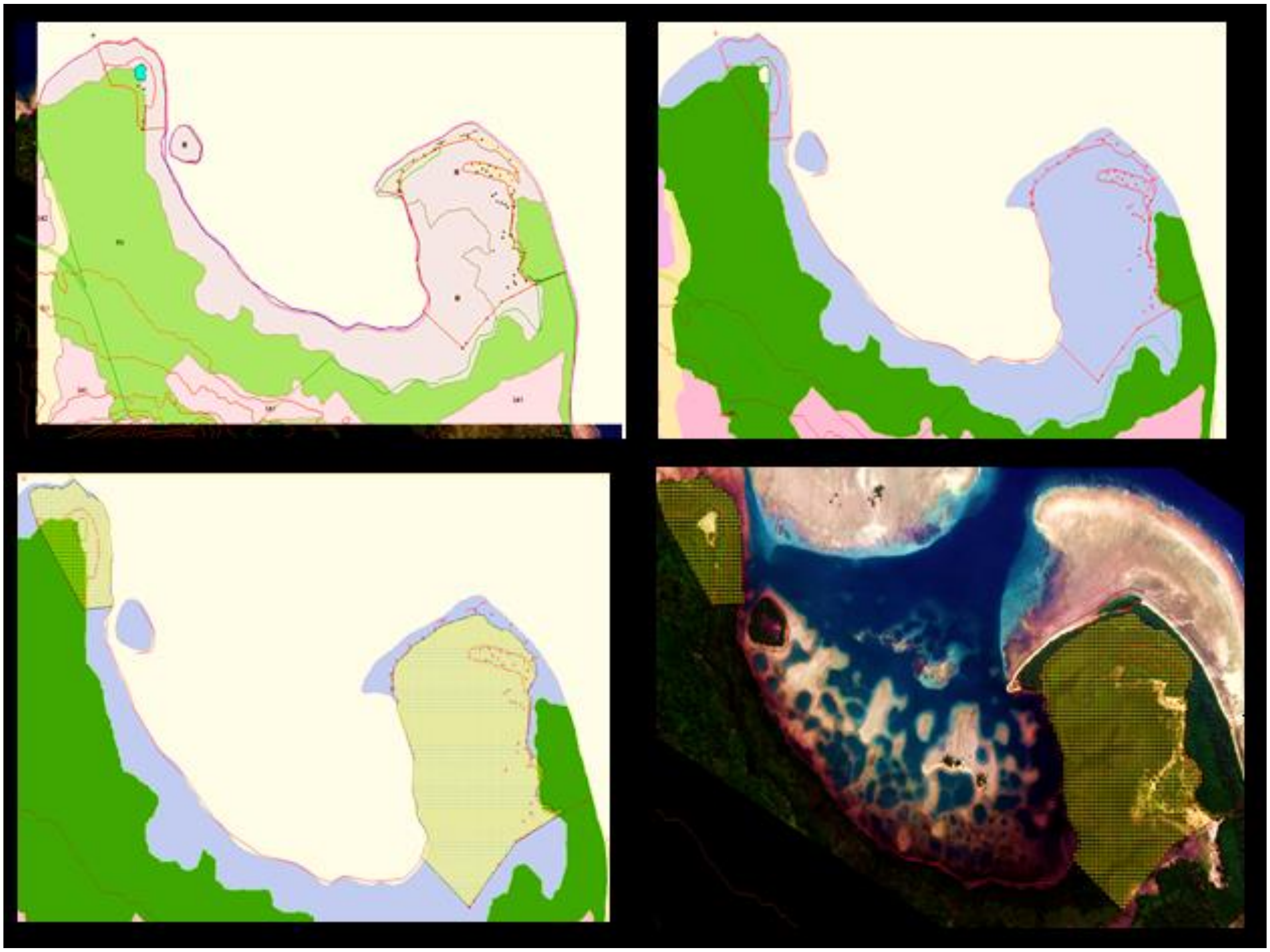
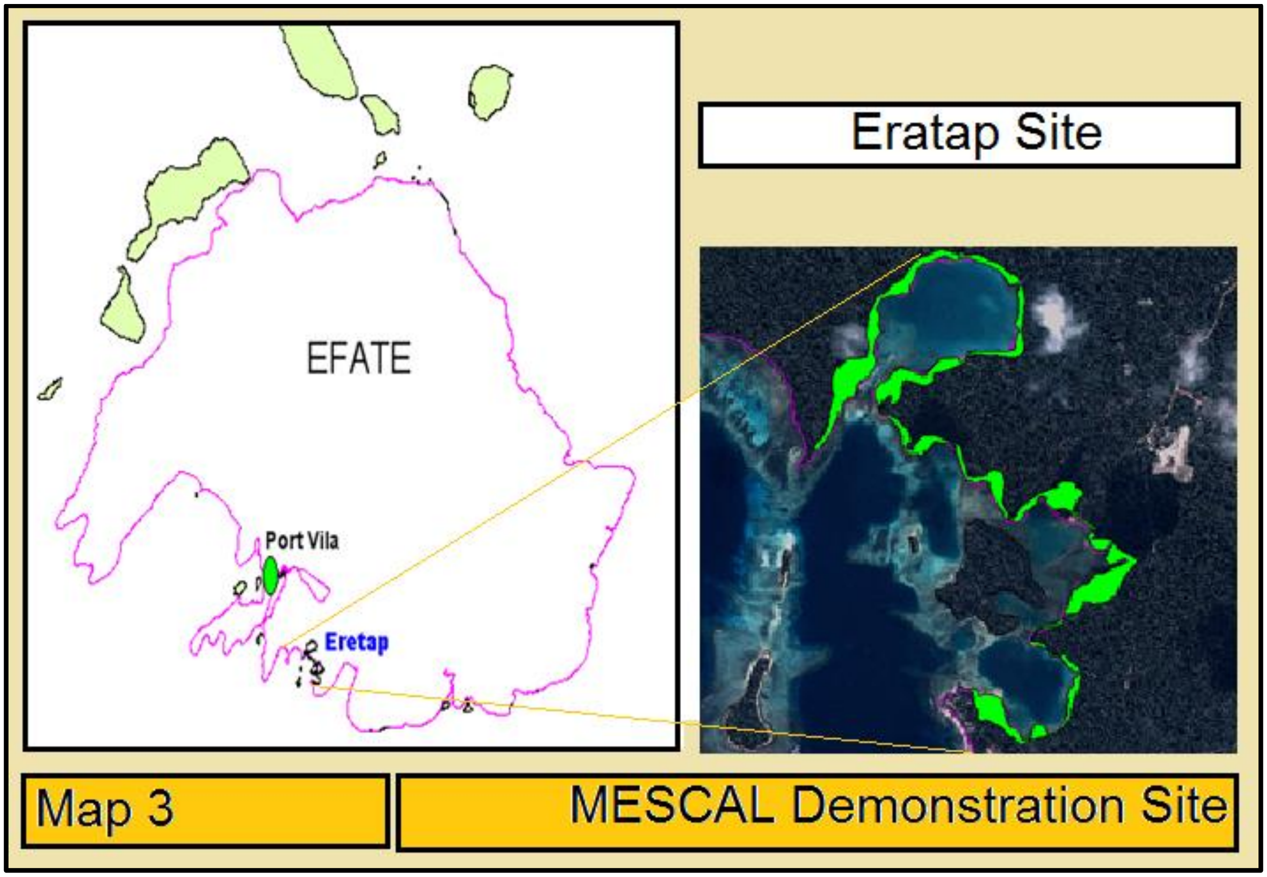


Figure 10: The Red lined polygons are Amal and Crab bay major mangrove vegetation Boundaries.

Eratap, Efate Island (Shefa Province)

The Eratap Site on south coast of Efate is located approximately five kilometers from the Capital Port Vila.



Map 3: Eratap Demonstration Site (Efate Island)

The Mangrove area to be ground surveyed is approximately 33 hectares. Coastal length to be ground surveyed at this site is approximately seven kilometers and covers at least three separate bays.

Activity 1 Geodetic Control Survey

Establishment of Seven (5) Geodetic Survey Marks (GSM) was carried out successfully at strategic locations within Eratap Mangrove Pilot Site. The GSMs are essential so that higher order surveys can be achieved to establish current Coastline boundary, back species boundary and offshore mangrove species boundaries. The role of the GSMs is to maintain baseline surveys or measurement accuracies and precision during this initial baseline survey. In addition the GSMs will support remote sensing and GIS overlays as well as future monitoring of high water mark boundary and change in mangrove vegetation boundaries. The following table shows the Total Station instrument and accessories required to complete the detail and traverse Survey at Eratap mangrove Pilot site.

Figure 11: Geodetic Survey Marks at Eratap

To strengthen our Traverse Closure, we identified two Survey Traverse Marks (STMs) along the traverse route that required additional static GPS observations. This increases the number of GSMs to Seven (7). The importance of strengthening our Traverse Closure is to obtain more accuracy and precision of feature positions in relation to each other. For example Short distances that are fifty meters or less will incur target sighting errors that will affect the ability of measuring our angles to a certain precision and accuracy. Where short distance can't be avoided we construct and observe GPS positions to strengthen the traverse closure. The following table describes the geodetic receivers and antennas that we use for our static GPS observations.

Receiver Model /TYPE	Qty.	Frequency	Antenna Model/TYPE	Ownership
TOPCON-GB1000	2	DUAL	TOPCON-PG-A1	IRD-FRANCE
ASHTECH-Z SURVEYOR	1	DUAL	GEODETIC IIIa	MOL
Total	3	DUAL		

Table 3: GPS Reciever Summary

(CGPS – Continuous GPS station) BASE STATIONS AS BASE FOR GEODETIC NETWORK CONTROL

The Eratap site is located only 5 km's from Port Vila, the Capital of Vanuatu. Port Vila currently accommodates 2 of the 11 Permanent CGPS Stations in Vanuatu. These two sites are VANU, which is part of the Regional Sea Level Rise Monitoring program, coordinated by Geosciences Australia and VILA, which is part of the CGPS Global network that is coordinated by the Institute Recherché de Development (IRD) in France. The VANU CGPS station data is used as geodetic base control for all geodetic positioning at Eratap pilot site.

Figure **12**: 'Vanu' and 'Vila' CGPS Stations on Efate.

The opportunity of utilizing these 2 CORE stations enhances our geodetic capacity and capability in relation to GIS, Remote Sensing overlays and baseline monitoring purposes.

GPS Processing results and adjustment of Geodetic Control Network results were then used to reduce Survey Traverse data that will determine 2012 High Water Mark Boundary (HWMB), Mangrove Back Boundary Species (MBBS) and Offshore Mangrove Vegetation Boundary (OMVB) for 2012.

The VILA CGPS station data is used as check during Processing and adjustment for the Eratap Geodetic control network.

Activity 2 GPS Processing and Network Adjustment

The GPS Data was processed on WGS 84 ITRF2008 Coordinates. The Geosciences CGPS Base station, VANU, in Port Vila Geodetic coordinates is used to fix baseline processing. The IRD CGPS base station, VILA, in Port Vila was used, along with a local Permanent Survey Mark (PSM 12.6.81) at the USP roundabout, as cross checks on the processed results. It is important to have cross check points during processing to reduce the probability of blunder errors and significant random errors during field survey and post processing of results.

The VANU cgps station coordinates are used as base coordinates during baseline processing. The VILA CGPS base station and traverse point at the USP (University of the south Pacific) extension center roundabout was crosschecked. The results indicate that the GPS processing and results are to a millimeter difference in latitude and longitude and centimeter difference in ellipsoid height which therefore is an indicator that our network of adjusted coordinates can be used for further reduction of traverse data. Final and adjusted geodetic coordinates and extra geodetic positions were established so as to strengthen geodetic control network. The locations of the geodetic positions are shown below. The Total Station Traverse had to be done from ERT4 to ERT1 in order to determine the Baseline boundaries for Eratap mangrove vegetation.

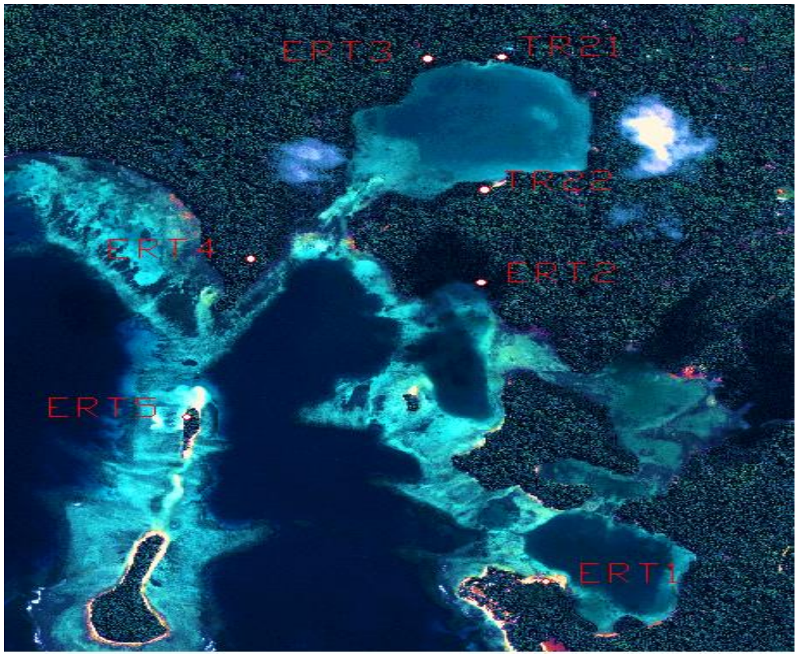


Figure 13: Geodetic Positions on Eratap

The total shoreline length is approximately seven kilometers of vegetation cover with pockets of few settlements and two tourist resorts.

Activity 3 Traverse of Mangrove Back Boundary and Mean High Water Mark

Traverse route was constructed along the coast from ERT4 through to ERT1. By the end of the traverse route, 80 STMs were established for the Eratap Baseline Surveys. All survey traverse recordings are done manually on field book which required high concentration by the Surveyors. Field survey technicians were responsible Prism Target Setups, line of sight intersection points, cementing of traverse marks and general maintenance of survey equipment and tools.

Figure 14: Traversing the Mangrove Back Boundary

Activity 4 Total Station Survey of Offshore Mangrove Vegetation Boundary

On Eratap mangrove pilot site we managed to determine the OMVB at six (6) different strategic positions. Two of these positions are part of our established geodetic control network and the other four (4) positions are from our Total station traverse network.

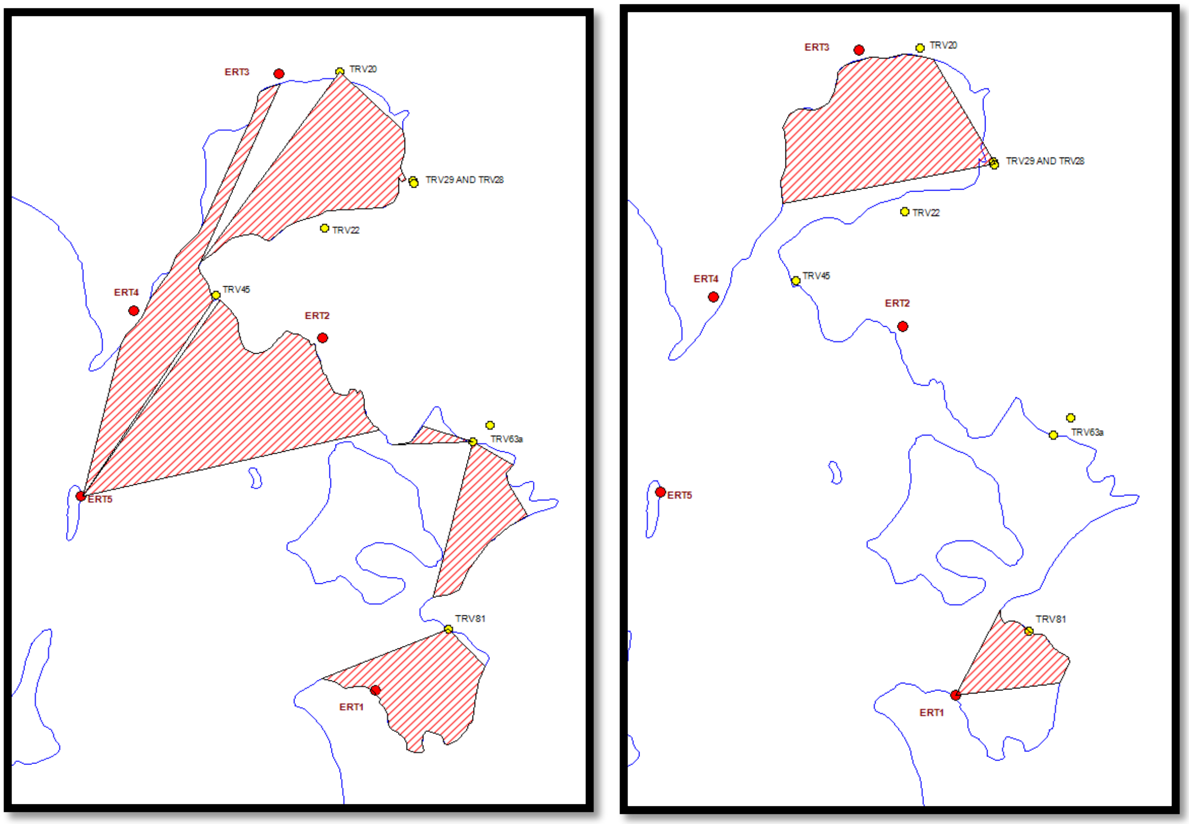


Figure 15: Total Survey Stations of Offshore Vegetation Boundary (Eratap)

Figure 16: TTS of Offshore Mangrove Vegetation Boundaries (Eratap)

Activity 5 Data Entry into LISCAD (Surveying Package)

Total station traverse data was entered manually from field book into Liscad Surveying software. Coordinates are on UTM grid, zone 59 south. As a result we are able to graphically display high water mark line boundary, offshore mangrove vegetation line boundary and Mangrove Back Boundary species line boundaries.

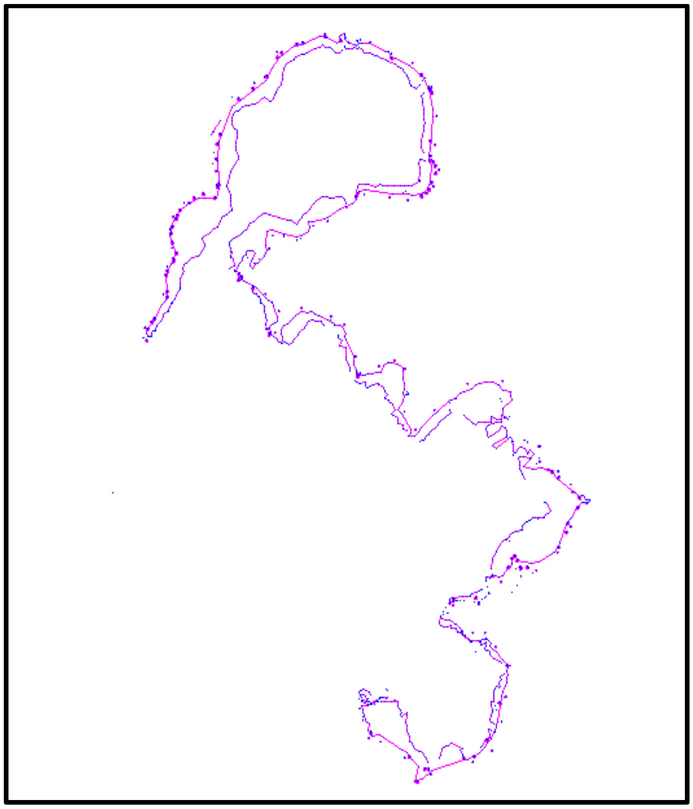


Figure 17: Output of LISCAD Package for Eratap

Remote sensing overlay will validate and close certain gaps that our ground survey cannot determine.

Activity 6 Overlay of Remote Sensing Imagery

The yellow line indicates the total station traverse route and the red line indicates the edge of major mangrove boundary. This boundary on land is where the highest tides would reach. Normal tides boundary is not indicated clearly beginning at point A to point B. This boundary still needs to be identified and overlaid.

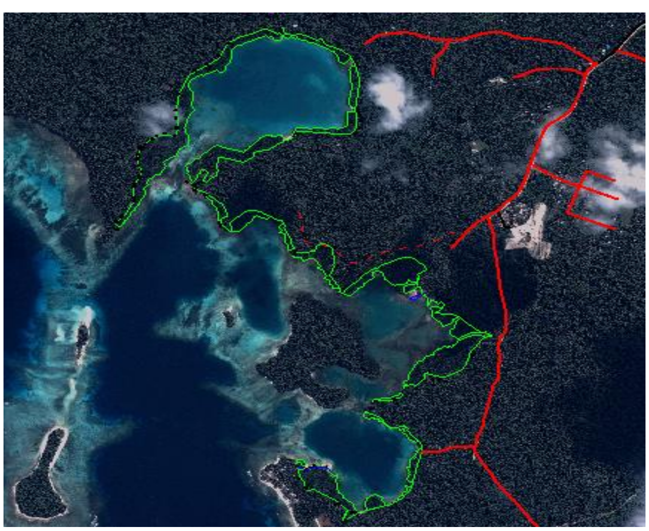
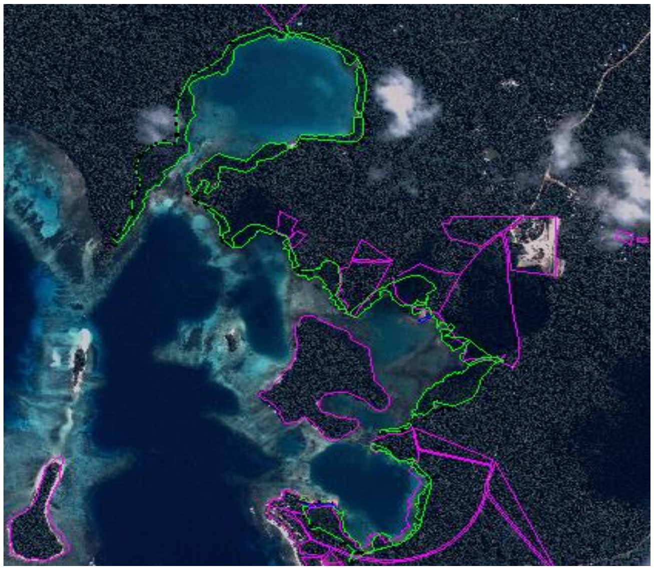


Figure 18: Existing Road Networks on Eratap (Red)



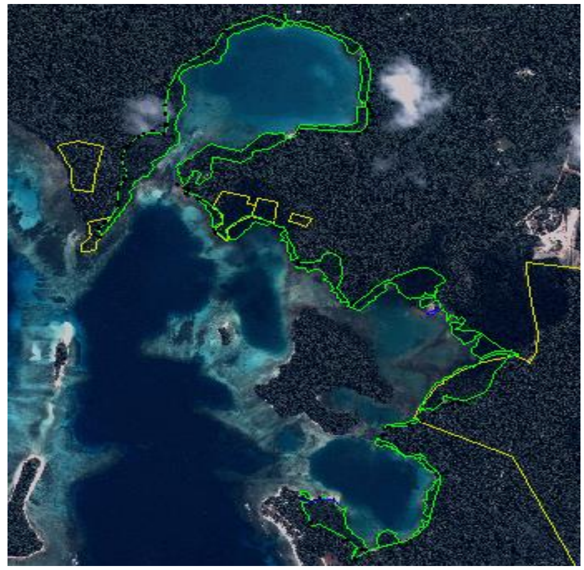


Figure 19: Registered Leases (Pink) **Figure 20**: Unregistered Leases (Yellow)

With these overlays we are also able to visualize and relate our Ground surveys with registered leases (pink), unregistered leases (yellow) and road networks (red) to give us some idea on Governmental decision making process.

Activity 7 Determination of Major Mangrove Baseline Boundary Areas

Mangrove Back Boundary (MBB), High High Water Mark (HHWM) boundary and Offshore Mangrove Boundary (OMB) was clearly identified using Total station traverse and detail pick up technique. WorldView (2009) and Arial photography from the Department of Land surveys (2007) overlay's of mangrove baseline Surveys assisted the surveyors to stitch polygon gaps into Liscad Surveying software to determine the Polygon Areas.

The final product from Liscad indicated 21 mangrove polygons with a total area of 312,372 square meters of Mangrove vegetation (31.2 Hectares).

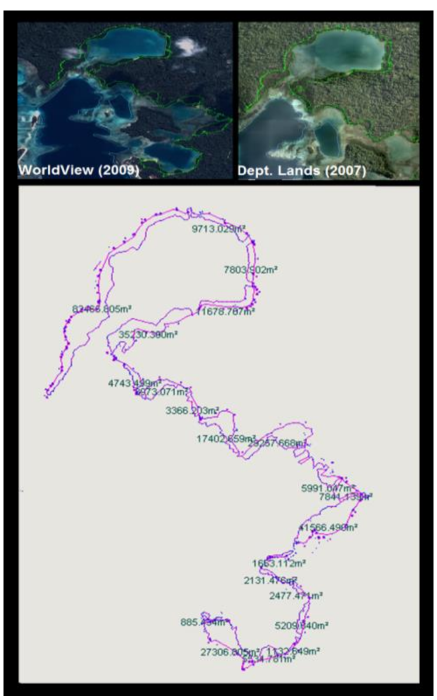


Figure 21: Outcome of using overlays and Liscad package. 21 mangrove Polygons (31.2 ha of mangrove vegetation)

Activity 8 Overlay of Existing Vegetation Maps

The vegetation map produced by the department of forestry in 2011 shows that light blue colored areas are mangrove vegetation areas. The overlay of Mangrove our Vegetation Boundary survey at Amal site and Crab bay site clearly shows that the vegetation map is too general in terms of mangrove vegetation and highlights the necessity of proper ground Surveys for Mangrove Baseline boundaries.

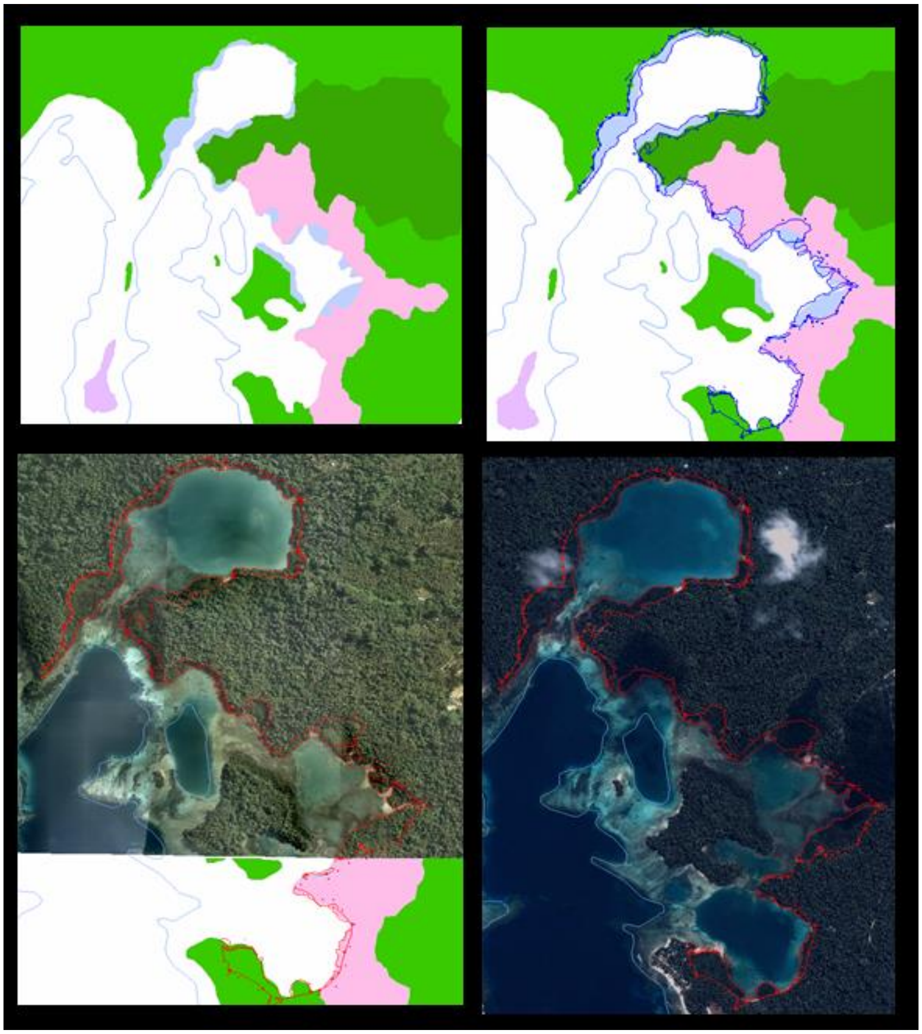


Figure 22: The Red lined polygons are Amal and Crab bay major mangrove vegetation Boundaries.

Benefits of Survey

HWM baseline for cadastral purposes

The Leases Section within the Lands, Surveying and Registry Department requires such detail information as included in this report when undertaking a plan examination on official titled plans. These plans are submitted by private surveying companies for approval towards creating Leases. The High Water Mark boundary is crucial during these checks when we are trying to protect Mangrove areas from being leased to individuals or companies.

Future potential to monitor sea level rise and coastal erosion

The Established Geodetic control Network for the three pilot sites, comprised of permanent geodetic marks and survey traverse marks, allows for future determination of High Water Mark boundary.

Reduced cost in Future Monitoring of Mangrove vegetation growth or erosion.

With the establishment of the Geodetic Control Network at the three pilot sites, the future determination of Mangrove vegetation change in growth can be easily done with reduced cost on the ground by Total Station detail survey.

Conclusion

In conclusion, major mangrove vegetation boundaries which are, back boundary species, normal high water mark and off-shore mangrove boundary, Amal Area and Crab bay on Malekula and Eratap on Efate have been positioned and established for future monitoring purposes. Future monitoring objectives would be to determine if sea level is rising within the mangrove pilot sites and also change detection of mangrove vegetation within the three pilot sites. Methodology and Techniques used to do the baseline surveys was due to the availability of limited surveying equipment that exists within the Ministry of Lands and Natural Resources.

Recommendation

It is recommended that monitoring surveys for the three pilot sites of Amal Area, Crab Bay and Eratap be done on an annual period to determine regrowth or deterioration of mangrove vegetation, in Vanuatu, as well as the changes in H.W.M boundaries for each site.

Section 2. MESCAL Project Mangrove Forestry Surveys of Amal/Crab Bay (Malekula) and Eratap (Efate), Vanuatu.

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Acknowledgements

The forestry survey team would like to acknowledge the great assistance provided by a small group of people who helped make this survey a success. Firstly we would like to acknowledge the assistance from the local communities in Amal/Crab Bay and in the Eratap site by sending in guides and volunteers and also letting us camp on their land. We would like to thank Dr. Duke and his team from JCU for helping out in setting the method and also the analysis of the forestry data. We also like to acknowledge the assistance of the MESCAL PMU team for the field assistance during our survey. Lastly but certainly not the least, the hard working staff of the Department of Forestry who had to squeeze into their very busy schedule this 4 week survey allowing the MESCAL Vanuatu project to complete one of its important outcomes.

Introduction

Mangroves have the distinction of forming unique marine habitats that are both forests and wetlands and are grouped across a number of international conventions that recognize their immense value and benefit to both coastal and marine environments, and mankind in general. It is important to have a standardized and practical way of characterizing structure and condition of these unique wetland forests (Duke, 2012). Mangrove habitats in Vanuatu have been facing many threats recently mainly due to human pressures such as clearance for (formal/informal) housing, development for resorts and cutting for timber. Therefore there was a need for the development of a baseline study on this critical ecosystem to survey 2 sites in Vanuatu under the MESCAL project to determine what is the current status of mangroves in the 2 sites. It is hoped that activities will be expanded into other sites around the country by building on the lessons learnt from this activity.

The basic field assessment unit for this methodology, the 'long plot', is relatively new in concept which was developed by Duke et al. (2012). It is delineated specifically, to accommodate mangrove forest characteristics and the method was proposed to facilitate and speed up forest biomass sampling. This method can be extended further for estimations of biomass and carbon sequestered by mangrove forests. The method is: easy and practical, requiring a minimum of skill levels and special equipment – useful to rural communities; accurate and reproducible – as well as being recognised and useful to scientists and managers.

Method

Long plots are essentially narrow, 2-4 metre wide, forest plots laid out approximately parallel to the shoreline (Fig. 23). Their great benefit is that plot length depends on tree density. This has been achieved by fixing the number of trees sampled within each plot. In this way, where there are many closely spaced trees, plots will be shorter in length than where trees are large and far apart. This method has a number of important advantages, including: standardisation of sampling effort; and, removal of guess work in making sure a representative number of trees have been sampled. There is considerably less effort, compared with laying out a square plot, as long plots are effectively laid out as work progresses. It is easier to keep track of completed trees and, it is easier to locate, establish and tag plots for future reference and re-assessment. The number of trees sampled is considered best around 30, but this number can be verified in this method using data collected. Long plots are sampled so comparisons between accumulative variances in stem diameter can be made for progressively larger plots, and larger numbers of trees.

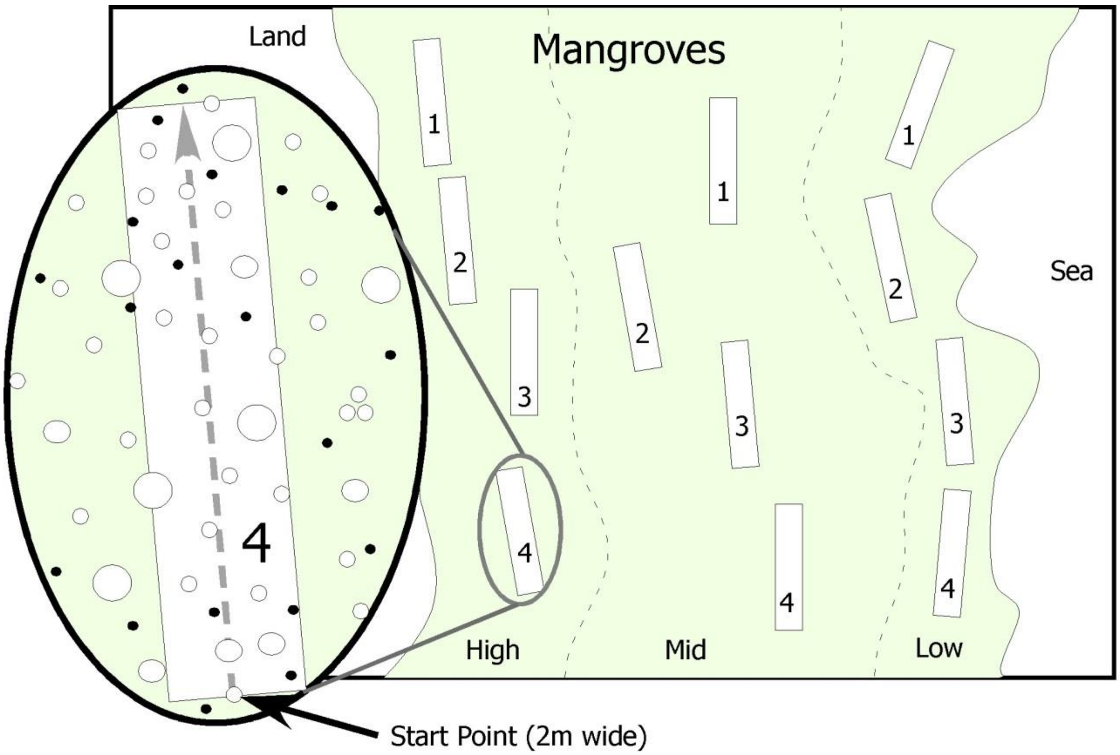

Figure 23: Layout and site characteristics of long plots (2m wide) for a replicated sampling design comparing three mangrove forest zones at low (sea edge), mid (intermediate) and high (upland margin) intertidal positions between sea and land. (Source: Duke, 2012)

Once data were collected from the field, they were then input into a dedicated, preformatted Excel spreadsheet with fields and columns matching the field data sheet. These fields have all the necessary information for determination of plot area (A), plus stem diameter (D) and tree height (H) as well as details of the location markers, like GPS coordinates, plus places to add comments about tree condition, like live or dead condition, whether they are unhealthy, and how trees died. All data was prepared in this way by the country team with assistance from the MESCAL PMU. This data was then submitted to Dr Duke for this analysis and synthesis of results.

Prior to the calculation of the biomass of individual trees (above and below ground), it was essential to first review available allometric equations. This was considered essential in the absence of local country equations for the dominant species present. There are a number of equations from studies elsewhere (Komiyama *et al*. 2008). These quantify the relationship between simple structural measures (like stem diameter of trees) and dry weight of above and below ground biomass (AGB and BGB, respectively). Equations vary between species. By summing the amounts of biomass for respective species and individual plants present, this amount equates directly to amounts of carbon stored in various mangrove plots and zones. Importantly, because there are a number of species to consider, there are common equations that apply to multiple species (Komiyama *et al*. 2005; Chave *et al*. 2005). These become specific-specific with the input of cited measures of specific wood density for particular species (Komiyama, 2005; Saenger, 2002.). The choice therefore is to either use an equation for each species (these preferably are developed locally), or to use the common equation that uses these species-specific values of wood density (*p*). The current approach is to use a common equation, but the actual choice requires additional justification and validation.

The common equations for biomass estimates of mangrove forests include:

$\mathbf{W_{AGB\ 1}} = 0.251p\text{D\^{}}2.46$ (Komiyama *et al*. 2005)
$\mathbf{W_{AGB\ 2}} = 0.168p\text{D\^{}}2.47$ (Chave *et al*. 2005)
$\mathbf{W_{AGB/H}} = 0.0509p\text{D\^{}}2.\text{H}$ (Chave *et al*. 2005)
$\mathbf{W_{BGB}} = 0.199p\text{\^{}}0.899\text{D\^{}}2.22$ (Komiyama *et al*. 2005)

Note:*Explanation of equation parameters - where* $\mathbf{W_{AGB}}$ *is above ground dry weight in kg,* $\mathbf{W_{BGB}}$ *is below ground dry weight in kg,* ***D*** *is stem diameter in cm, and* ***p*** *is wood density for individual species in* t/m^3*. Wood densities* $\boldsymbol{\rho}$ *have been calculated from the ratio of* ***WS/VS****, where* ***WS*** *is trunk (stem) dry weight in t (=tonnes =kg/1000), and* ***VS*** *is trunk (stem) wet wood volume in* m^3*.* ***Height (H)*** *is included in one equation, and this is considered more realistic across a variety of climatic zones. There is uncertainty in the literature as to whether* $\mathbf{W_{AGB}}$ *should include Rhizophora prop roots, or not. While it may seem logical that prop roots would be part of* $\mathbf{W_{BGB}}$ *often this is either not stated or inconsistent. For this treatment, it is assumed that* W_{AGB} *does not include prop roots, and* $\mathbf{W_{BGB}}$ *does. Hence, the ratio of* $\mathbf{W_{AGB}}$ *to* $\mathbf{W_{BGB}}$ *will represent the Stem to Root ratio often used in forest descriptions.*

After estimating the biomass (W in kg) for each individual tree in both above and below ground components, the sum these was taken for each sample plot. Calculation was then made of the total biomass per unit area, dividing the biomass by the plot area (A in m2). Make comparable estimates for each set of plots in each vegetation unit, in each study area. Calculation of the mean carbon stock for above and below ground biomass of each component is made by converting plant dry weight estimates to amounts of carbon. This is a primary goal - to determine the amount of carbon accumulated in a mangrove stand. For this calculation, the volume of carbon as dry biomass is quantified for the various forest components, including: woody stems, branches, leaves – using the conversion coefficients 0.4535, 0.4800, 0.5025, respectively (note that these coefficients vary and require local confirmation for particular species). Carbon accumulation is calculated by multiplying the dry weight biomass estimates (W) by the carbon coefficients. The total carbon accumulation of trees is the total of all the component parts. For overall calculation of carbon amounts in total biomass, the carbon coefficient is usually roughly averaged at 0.5. However, this calculation would benefit from using a more accurate coefficient for the particular stand. A subsequent step might also be to calculate the absorption of carbon dioxide by forests by converting carbon estimates to carbon dioxide equivalents. This is calculated by the method of NIRI (Institute Nissho Iwai-Japan) where the CO_2 absorbed equals the carbon accumulation times 44/12, where 1 ton of carbon is equal to 3.67 tons of CO_2.

The flora survey (mangrove species identification and taxonomy) will be restricted to representative sub-forest types identified from reviewing recent aerial photographs of the two areas that are relatively accessible. Where visible on the aerial photographs, a standard belt transect of (50m X 4m) in the different Mangroves species will be used to assess the spatial distribution of plants and this will allow for recording of all plants in the transects. Part of the flora work will focus on collecting herbarium quality specimens with emphasis on those groups that are relatively not well known like the cryptogams (fern allies) and epiphytes on the mangrove tree species. The same will also apply to the distribution and abundance of the rare and endangered species, and potential and currently recognized invasive species. The validation of preliminary identification carried out in the field will be later carried out at the National Herbarium at DOF in Port Vila and a preliminary annotated checklist compiled that will also include local name(s) and uses of plants recorded. The team will use a field guide to the mangroves of Australia as a guide while in the field to carry out this activity.

Figure 24: Field teams conducting long plots in the different major vegetation zones at the demonstration sites.

For all the fieldwork, three to five assistants were employed. This included a local guide, an ethnobotanical expert, and a technical assistant. Mr. Sam Chanel took the lead in this activity and was assisted by Assistant Botanist Mr. Philimon Ala of the Vanuatu Forestry Department.

Results

Floristic Surveys

Upon completing the floristic surveys it was found that Crab Bay had approximately 113.0 Ha mangrove cover (from the mapping work), 11 mangrove species were found at the site, with 5 major vegetation types and where *Ceriops tagal* was the dominant species which was found mostly in the 'Mid Zone' between the sea and back-of-mangrove zone. In Amal it was found that there was approximately 23.5 Ha mangrove cover, 11 mangrove species, 3 dominant vegetation types and *Xylocarpus granatum* was the dominant species. In Eratap it was found that there are 312 Ha of mangrove cover, 12 mangrove species, 3 major vegetation types and where *Rhizophora stylosa* is the dominant species (seaward zone). It was observed that there is a high risk of conversion in the Eratap site.

As a result of this survey we now have 8 new species records for Vanuatu which now increase our mangrove species inventory from 16 species (Spalding *et al.*, 2010) to 23 mangrove species (please refer to Table 4 below). However, these results are a culmination of work conducted by the MESCAL team nationally.

New Species Records of Vanuatu	Confirmed	Area sited
Acanthus ilicifolius (Linnaeus, 1753)	Duke, 2012	Santo
Acrostichum speciosum (Wild, 1810)	Duke, 2012	Malekula
Acrostichum aureum (Linnaeus, 1758)	Duke, 2013	Santo
Lumnitzera racemosa (Wild, 1803)	Duke, 2013	Aniwa
Pemphis acidula (J.R. Forst & G. Forst, 1775)	Duke, 2012	Eratap
Rhizophora X selala (Duke)	Duke, 2012	Eratap
Dolichandrone spathacea (Schumann)	Chanel, 2012	Crab Bay
Barringtonia racemosa (Spreng., 1826)	Duke, 2012	Santo

Table 4: New species records for mangrove species in Vanuatu

The species were confirmed by mangrove specialists and botanists Dr. Norman Duke and Mr. Sam Chanel. Four of the eight new species records were found at the MESCAL project demonstration sites. An endemic gecko not previously known to occur in Malekula (*Lepidodactylus vanuatuenis*) was also found in the Crab Bay as result of this survey.

Longplot/Biomass Surveys

Mangrove biomass data were collected from 27 long plots in the 2 demonstration areas – with 14 in Amal/Crab Bay, and 13 in Eratap. Data sheets were processed and the Excel spreadsheets for Vanuatu are available as a separate file for further reference. These data show biomass estimates for five dominant vegetation types (number of long plots) in the two demonstration site areas – *Avicennia marina* (5), *Bruguiera gymnorhiza* (2), *Rhizophora* species (10) and *Ceriops tagal* (8) and *Xylocarpus granatum* (2). These estimates can now be used with the areas derived from the mapping for development of local and national estimates of biomass and carbon bound up in living mangrove forest vegetation units (Table 25). There were issues with data checking, missing data, and possible errors that have been mostly resolved. It is advisable to check the Excel spreadsheets to validate or correct the respective data elements.

Dominant Veg. Types	Biomass & Structure	Vanuatu Average	SE X1
Bruguiera gymnorhiza	AGB Komiyama	401.9	
	AGB/H Chave	231.5	
	AGB Chave	278.7	
	BGB Komiyama	141.8	
	Hgt (m)	11.7	
	CanWHgt (m)	14.6	
	BA (m^2/ha)	69.5	
Rhizophora sp.	AGB Komiyama	85.5	12.1
	AGB/H Chave	39.8	4.7
	AGB Chave	58.6	8.3
	BGB Komiyama	37.8	4.9
	Hgt (m)	6.4	0.5
	CanWHgt (m)	7.4	0.6
	BA (m^2/ha)	20.7	2.6
Xylocarpus granatum	AGB Komiyama	254.7	
	AGB/H Chave	96.5	
	AGB Chave	176.5	
	BGB Komiyama	93.3	
	Hgt (m)	7.6	
	CanWHgt (m)	9.8	
	BA (m^2/ha)	52.7	
Ceriops tagal	AGB Komiyama	154.3	19.0
	AGB/H Chave	74.4	10.4
	AGB Chave	106.1	13.1
	BGB Komiyama	66.7	8.1
	Hgt (m)	6.3	0.4
	CanWHgt (m)	7.3	0.4
	BA (m^2/ha)	32.4	4.6
Avicennia marina	AGB Komiyama	422.0	40.9
	AGB/H Chave	94.7	17.7
	AGB Chave	292.7	28.4
	BGB Komiyama	147.0	14.7
	Hgt (m)	5.4	0.4
	CanWHgt (m)	5.4	0.4
	BA (m^2/ha)	68.3	7.0

Table 5: Vanuatu mangrove vegetation unit data, showing derived estimates of carbon (t.ha-1) in living above ground biomass (AGB) and below ground biomass (BGB). Estimates were made from the allometric common equations by Komiyama (2005) and Chave (2005) based.

For the 27 plots from the 5 dominant mangrove vegetation assemblages, *Bruguiera gymnorhiza*, *Rhizophora* species, *Ceriops tagal*, *Xylocarpus granatum* and *Avicennia marina*. Standheights ranged from 4-19 m with a total living mangrove biomass of 155-747t.ha^{-1}.

Discussion

MESCAL Vanuatu is the first project in the country to solely investigate the major facets of mangrove biodiversity and its management. Outcomes of this survey have been immense in increasing the knowledge and inventory of mangrove species in the country, even though data was mostly gathered from the 2 demonstration sites. The increase of species records from 16 to 23 of the 73 true mangrove species globally (approximately 32 %) highlights the immense biodiversity in the country. Time and budget permitting it would be a great incentive to continue this work onto the northern islands of Vanuatu (Banks Group) to investigate the species located in this region. Perhaps it can be postulated that diversity might increase upon moving north as species diversity is high in our northern neighbors of Solomon Islands, once again, this will need ground-truthing, time and money. The long plot surveys of 5 dominant mangrove vegetation assemblages have been evaluated for Vanuatu. This has been achieved by people with previously limited knowledge of mangrove ecosystems and for making assessments of biomass structure, before receiving specific training and instruction – starting with the field component. The intention with this project has been to develop both local capacity and personal skill levels for the conduct of scientific investigations with implications for major environmental management outcomes. This effort has been an outstanding success and the mangrove specialists Dr. Norman Duke need to be acknowledged and congratulated for this successful preliminary study of this scope in the Vanuatu.

Conclusion

In conclusion, the MESCAL Vanuatu project can deem that this project activity was a success. There are a few issues that still need to be addressed such as ground truthing of old mangrove maps to address discrepancies in current mapping data, more work on species diversity and distribution required in Vanuatu, carbon sequestration work as a possible activity to be carried out in Vanuatu as it was by MESCAL Fiji and more awareness raising activities to communities on the importance of conserving mangroves, its resources and associated ecosystems.

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Section 3. MESCAL Project Mangrove Faunal Surveys of Amal/Crab Bay (Malekula) and Eratap (Efate), Vanuatu.

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Introduction

The rapid fauna assessment was carried out as part of the action research of the Mangroves Ecosystems for Climate Change Adaptation and Livelihoods (MESCAL). The project aims to assist in climate-proofing coastal communities and sustaining livelihoods by promoting investments in mangrove and associated coastal ecosystems in Vanuatu. To further work on mangrove management strategy and action on ground for better management of the mangrove ecosystems at Crab Bay it is important that the ecological baseline information is known. The information will serve as a basis for the national government and the local communities concern to base their management decision in particular the associated terrestrial and aquatic fauna that live in the mangrove ecosystems. The assessment was carried along the same time with the Long Plots assessments done by the Department of Forests.

Methodology

The fauna were observed through a rapid assessment method. Data sheets were developed to use at the same area that the Department of Forest field team laid their long plots. This was not utilized due to the long plot site selection and also a lot of noise that were generated during the long plot assessment. This led the faunal team carrying out rapid assessment through general observation and collection of fauna in accessible areas of the mangroves throughout the entire period of the research.

Mangrove Ecosystem Observation

In general the mangrove of Amal-Crab Bay is still intact and in found to be in a very good health. The Amal-Crab Bay tabu area is under traditional resource management system ‘tabu’ and is managed by the Amal-Krab Bay Eria (AKTE) management committee as the local management authority. The management committee is composed of the representative from the sixteen (16) villages that surround the Amal-Crab Bay Area. This also includes the offshore islands of Uri and Uripiv. The Tabu Eria was initiated through the International Waters Programme (IWP) implemented by SPREP through the Department of Environmental Protection and Conservation with Fisheries Department that began in year 2003 and ended in year 2007. The AKTE is managed by the AKTE management Committee. The dominated *Avicenna marina* and few stands of *Ceriops tagal* located at the southern part of the Crab Bay mangrove ecosystems are slowly dying. Esrom, 1998 stated that the dead mangroves in this this particular area was affected by the tectonic plate uplift. This is the very spot that the first record of the Vanuatu endemic gecko, *Lepidodatylus vanuatuensis* on Malekula is found during this assessment period. The healthy mangroves of the Amal-Crab Bay area certainly harbors a lot of fauna as observed during this research period. These include reptiles, crustaceans, avifauna, gastropods and flying foxes. Flying foxes are found at the back zone of the mangrove forests. There is an access area that the villagers use every Tuesday of each week for collecting crab species of *cardisoma carnifex* for food and sale at the Lakatoro market. People are not permitted to use the area on other days of the week.

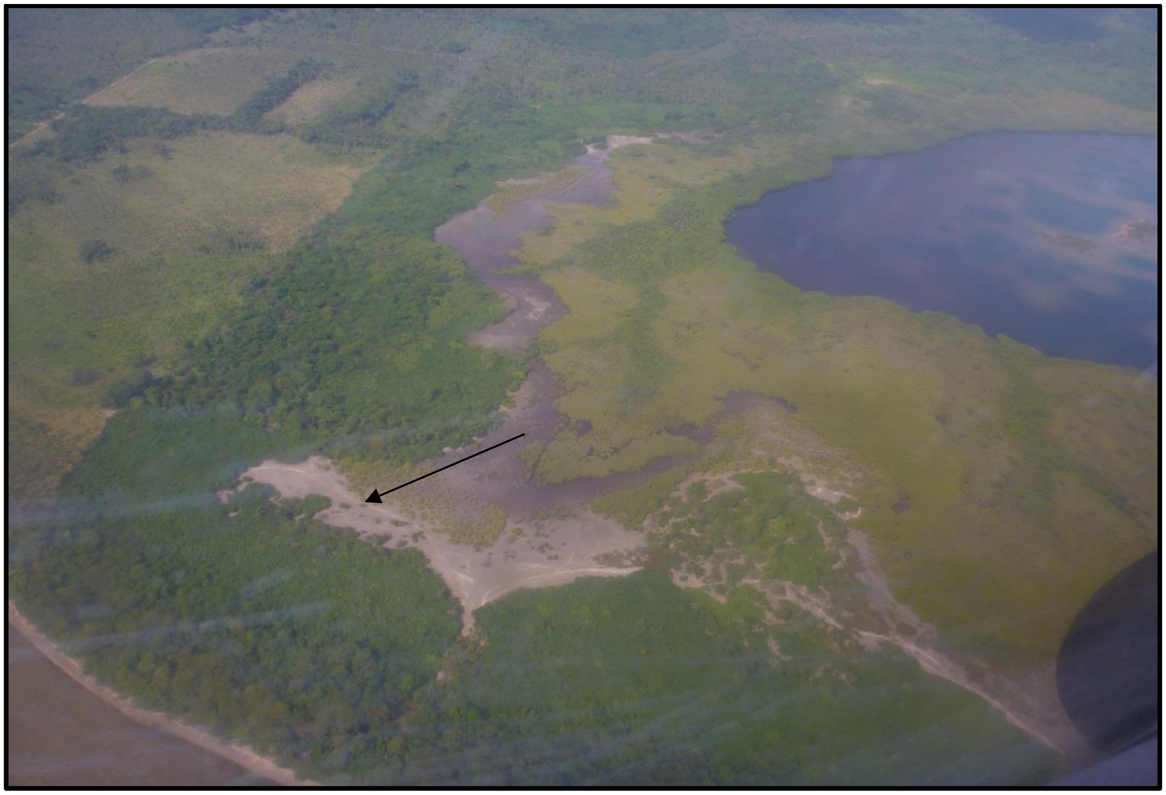


Figure 25: Uplifted area of the Avicenna marina that is affected.. © Donna Kalfatak.

The Eratap mangrove ecosystem on Efate Island is not very dense and is smaller in size (33ha) compare to Amal-Crab Bay mangrove area on Malekula Island. Thirteen (13) species of mangroves are found in this demonstration site. Eratap mangroves have been disturbed and reclaimed as a result of land lease arrangements, tourism development and larger passage as boat landing area though some scattered areas of the mangroves are still in good health. Two resorts have been built within the mangrove areas; the Eratap Beach Resort is built on the most southern end of the mangrove area, an environment friendly tourism business where it leaves the mangroves in good health along its shoreline. This resort provided co-finances to the MESCAL Project through the use of its boat for the purpose of their mangrove species identification and the video assessment. The Aquana Resort is built on reclaimed mangrove area situated on the eastern side of the mangrove areas.

Figure 26: Eratap Resort Beach with mangrove vegetation

There is evidence of mangrove tree harvesting for building traditional houses and shelters. Mangrove tree species of *Ceriops tagal* are regul arly cut within the spring water spot (Epakor) vicinity for traditional house materials. However, there is healthy natural regeneration taking place in the exploitation areas. The Eratap mangrove areas and resources are not only utilized by the native Eratap community but also by immigrants living around or close to Eratap village as well as those living in Port Vila town. It is difficult for the Eratap chiefs to control and manage mangroves and its other associated resources. Unlike Amal-Crab Bay on Malekula, there is no traditional resource management system in place for managing the mangrove resources. Due to the size and disturbance of the mangrove areas of Eratap small numbers of fauna were observed during the study however, a couple of significant species are also found during the assessment.

Figure 27: Long plots area of Ceriops tagal, north of Epakor spring water. Some ceriops tagal is being cut for traditional house. ©MESCAL Vanuatu

During the assessment, other problems were identified such as regular cutting of mangrove tree species especially *Ceriops tagal* for traditional houses and animal fencing; clearing some mangrove areas for boat and canoe passages; leasing of land area right into the mangrove areas which does not follow the land lease Act and overharvesting and harvesting of smaller size *Terebralia palustris* and improper disposal of foreign waste materials by those living close to the mangrove areas.

Observed Fauna (Amal/Crab Bay)

Scientific Name	English or Common Name	Bislama Name	Vernacular Name	Field Notes
Avifauna				
Andrea sacra	Eastern Reef Heron (White & Grey)	Long Nek blong Natontong	Merikalo	Two grey ones seen feeding on the eastern side of Tabu Eria. White one observed feeding on outer islet north of Crab Bay
Butorides striatus	Little Mangrove Heron	Long Nek	Merikalo	Calling. Confirmed by local assistants. One was in flight above the *Rhizophora stylosa forest* south of Crab Bay point.
Chalcophaps indica	Green-winged Ground Dove	Sot Leg	Umere	In flight through mangrove trees Saw one walking on pathways behind 3rd plot of day 1 assessment. Nest found on 3rd plot.
Cirus approximans	Swamp Harrier	Pijin blong Faol	Nampel	In flight above the mangrove area
Ducula pacifica	Pacific Imperial Pigeon	Nawimba	*Nimp*	Calling
Halycon chloris	Chestnut Kingfisher	Waet Nasiko	Nasi	Calling
Macrophygia mackinlayi	Rufous-brown Pheasant Dove	Long Tel		In flight
Myzomela cardinalis	Cardinal Honey eater	Smol Red Hed	*Wila Ri*	Calling
Numenius phaeopus	Whimbrel	Pijin blong Solwota	Nempere	Many were seen in the Amal Point pond
Pluvialis fulva	Pacific Golden Plover	Pijin blong Solwota	Nempere	Seen on the eastern reef of Crab Bay
Ptilinopus greyii	Red-bellied Fruit Dove	Grin Pijin		Calling
Rhipidura fuliginosa	Grey Fantail	Najikjik		In flight
Trichoglossus haematodus	Rainbow Lorikeet	Nasiviru	Sivir	Calling
*Zosterops flavirons**	Vanuatu White-eye	Yelo Nalaklak	*Wila*	In flight
Zosterops lichemas	Grey-backed Honey eater	Nalaklak	*Wila Jumperiu*	Foraging among mangrove trees
Mammal				
*Pteropus aneitianus**	Vanuatu Flying Fox	Waet Flaen Foks	*Keri*	Roosting on fig species at High Water Mark at Amal Point
Gastropods				
Terebralia palustris		Sel	Serwok	Abundant throughout the Amal-Crab Bay Tabu Eria

				even throughout the Port Stanley Mangrove areas including Uri Island. Bigger sizes found in this mangrove area compared to Eratap and Aniwa Mangrove areas.
Littoria sp.	Winkles	Nasisa	Nakou	Are found in some parts of the mangrove areas (*Rhizophora* and *Ceriops tagal* spp) trunks especially at Amal Point and some parts of Crab Bay.
Nerita grayana	Neritid Snail	Nasisa	Nase	Observed at the Amal point and Louni passage. Found on the roots of Rhizophora species roots.
Cassostrea sp.	Oyster	Oesta	Osta	Plenty found on the roots of mangrove *Rhizophora species*
Geloina sp.	Common Geloina	Grin Sel Kokias	Nar nurempuris	Many found in the *ceriops tagal* mud flats south of Crab Bay point. Plenty are also found on the south end of the Amal Point pond.
Dosinia sp.	Heart Dosinia	Waet Kokias	Banu	Found in mud of Louni passage especially at Low water mark areas.
Gafrarium sp.	Comb Venus clam	Kokias	Narmen	Are commonly found in mangrove areas between high water mark and low water mark.
Crustacean				
Cardiosma carnifex	Mud flat Cardiosma Crab	Waet Natongtong Krab		Abundant throughout the mangrove areas.
Cardiosma sp.		Blak Krab		Abundant at the back zone of the mangrove areas.
Syclla serrata	Mud crab or Mangrove Crab	Kaledoni Krab		
Grapsidae spp.		Smol Pepol Natontong Krab		Few found on branches and roots of Rhizophora species.
Gecarcinidae spp		Smol Pepol Krab		Abundant within the Amal pond area.
Ulca lacteal	Yellow Claw Fiddler Crab	Smol Red natongtong krab		Specimens collected from Uri Island.
Ulca annulipes	Red Claw Fiddler Crab	Smol yelo natongtong krab		Abundant throughout the mangrove areas.
Reptiles				
*Emoia sandfordi**	Green Tree Skink	Grin Liset	Negel	Found on Rhizophora spp. roots toward south of Crab

				Bay Point.
Emoia impar	Blue-tailed Stripe Skink	Blu Tel Liset	Wejui	Found at the back zone of *Ceriops tagal* vegetation north of the uplifted *Avicennia marina* area.
Lipinia noctua	Moth Skink	Liset	Wejui	Observed at mean water mark about 200m southwest of the Crab Bay point.
Cryptoblepharus novohebridicus	Small Skink	Liset	Wejui	Found at mean high water mark close to the *Rhiphora stylosa* vegetation at Crab Bay point.
Gehyra oceanica	Oceanic gecko	Big Ae	Momp	Two were observed under dried barks of Ceriops tagal in the uplifted area.
Gehyra spp.		Big Ae	Momp	Found in the hollows of Ceriops tagal
*Lepidodactylus vanuatuensis**	Vanuatu Gecko	Keko	Momp	Found in the hollows of *Ceriops tagal* and *Avicennia marina* at both Crab Bay and Amal point.
Lepidodactylus lugubris	Mourning gecko	Keko	Momp	Very common species found throughout the mangrove area.

**Endemic species – Please find pictures of the the observed fauna at the end of this report.*

Observed Fauna (Eratap)

Scientific Name	English /Common Name	Bislama Name	Vernacular Name	Field Notes
Avifauna				
Chalcophaps indica	Green-winged Ground Dove	Sot Leg	Tokape	Two were observed at the back zone of the mangroves areas toward Eratap Beach Resort. One observed close to mangroves near Epakor Spring water
Halycon chloris	Chestnut Kingfisher	Waet Nasiko	Sik	Calling
Myzomela cardinalis	Cardinal Honey eater	Smol Red Hed	*Alak Poumiel*	In flight through mangroves area
Rhipidura fuliginosa	Grey Fantail	Najikjik	Pistakel	Calling and a nest was found
Trichoglossus haematodus	Rainbow Lorikeet	Nasiviru	Sivir	Calling
*Zosterops flavirons**	Vanuatu White-eye	Yelo Nalaklak	Topi	Calling and a few were found in flight
Zosterops lichemas	Grey-backed Honey eater	Nalaklak	*Alak*	Calling. A young one was observed by Rolenas and her mapping team.

Gastropods				
Terebralia palustris		Sel	Ses pangpram	Some are found but commonly observed to be smaller in size compared to Amal-Crab Bay
Littoria sp.	Winkles	Nasisa	Popkas	Few are found on *Ceriops tagal* trunks close to Eratap Resort jetty and *Rhizophora sp*. leaves close to Epakor 'Spring Wota'.
Nerita grayana	Neritid Snail	Nasisa	Ses	Some are found on leaves of *Rhizophora stylosa* and *R. lamarki.*
Cassostrea sp1.	Oyster	Oesta	Rumg	Some are found on the roots of mangrove (*Rhizophora species)*
Gafrarium sp.	Comb Venus clam	Kokias	Kai Par	Found between high water and low water mark. Smaller in size compare to Amal-Crab Bay.
Crustacean				
Syclla serrata	Mud crab or Mangrove Crab	Kaledoni Krab	Rakum tas	One juvenile found
Cardiosma carnifex	Land Crab	Krab	Rakum	Reported by villagers that it exists at the back zone of mangroves north of Aquana resort. Population is decreasing.
Thalassina squamifera	Mangrove Lobster	Lobsta Krab	Pakormat	Found one dead. Their mounts found throughout the mangrove areas.
Grapsidae sp.		Smol Pepol Natontong Krab	Kav ni Natong	Few found on branches and roots of Rhizophora species.
Gecarcinidae sp.		Smol Pepol Krab	Nitamen	Found on Mangrove branches close to Epakor 'Spring wota'
Gecarcinidae sp.		Smol Blak Krab	Kav ni Natong	Few found in mangrove areas close to the Epakor 'Spring wota'
Ulca annulipes	Red Claw Fiddler Crab	Smol Red Natongtong Krab	Pialoal	Abundant throughout the mangrove areas.
Reptiles				
*Emoia sandfordi**	Green Tree Skink	Grin Liset	Plakes	Three found on Rhizophora spp. roots toward eastern side of the mangrove area.
Emoia impar	Blue-tailed Stripe Skink	Blu Tel Liset	Plakes	Three were found climbing on *Rhizophora stylosa trees* on the eastern mangrove area close to Epakor Spring wota.
Lepidodactylus lugubris	Mourning gecko	Keko	Ofang	Reported by local field assistant that it exists in the

				area
Fish				
Gobiidae sp	Mud Skipper	Los blong Natongtong	Lala	Found on inter-tidal zones and on mangrove roots
Muraenidae sp.	Moray Eel	Namarae	Mra Tar	Four found among roots of *Rhizophora* species
Echinoderms				
Protoreaster sp.	Knobbly Sea Star	Stafis	Msei ni Ntas	Found in shallow waters within the mangrove areas
Opheodesoma sp.	Synaptid Sea Cucumber	Si Kukumba	Nakplai	Found in shallow waters with the *Rhizophora* mangrove species.
Holothuria sp.?	Tiger Tail Cucumber	Si Kukumba	Nakplai pran	Found in shallow waters with *Rhizophora* mangrove species.

**Endemic species.* Vernacular names of species were provided by Jerry Kalere, Kalan Kalo and Kalowi Kaltong of Eratap Village.

Discussion of Findings

The rapid assessment was only focused at Amal-Crab Bay Tabu Eria excluding the Port Stanley Mangrove areas. Both Amal-Crab Bay and Port Stanley Area covers the 2100ha of the mangroves found on Northeast Malekula. The first day of the assessment was focused on the first two forestry long plots but did not continue on this manner due the noise generated during the long plot assessments. The rapid assessment was randomly carried out at selected sites of the mangrove areas throughout the remaining days of the survey period. The rapid assessment confirmed 15 species of birds found in the conservation area compared to the 122 species of the Vanuatu avifauna (all seabirds, land and freshwater). Bregulla H.L 1992 recorded 121 species and in year 2002 a new sea bird that is not recorded in Bregulla was observed by John Seymour from Australia. This has brought the total number to 122. Out of the 14 species observed one of them is a resident sea bird, the Grey Eastern Reef Heron (*Ardea sacra*).Two grey Reef Herons were found feeding on the eastern side of the Crab Bay area and one white one was found feeding on the reef of a mangrove islet between Amal point and Crab Bay point. *Butorides striatus*, the Little Mangrove Heron was reported by the local assistants that they are also found. This was confirmed toward end of the survey when one was seen in flight over the *Rhizophora stylosa* forest south of Crab Bay point. *Numenius phaeopus*, a whimbrel species, many were observed feeding in the Amal Point pond. The *Pluvialis fulva,* Pacific Golden Plover, were found feeding on the eastern reef of the Crab Bay. The assessment confirmed the aforementioned four sea birds species. In Vanuatu 32 species of sea birds are found, few are resident and 15 species are shorebirds (Bregulla H. L. 1992). *Ducula pacifica*, the most common Pacific imperial pigeon and the Red-bellied Fruit Dove, *Ptilinopus greyii*, were observed sitting on top of a tall *Rhizohophora* tree, about 1.5km south of Crab Bay point. The endemic Vanuatu Fruit Dove often found among the Red-bellied Fruit Dove when feeding off the fig species during their fruiting seasons were not seen. *Zosterops flavifrons* belongs to the two common species represented in Vanuatu (White-eye and the Gre-backed white-eye). *Z. flavifrons* is a common endemic species abundantly found throughout the archipelago. Both species were abundant and common in the managrove area. Some *Z. lichemas* were found feeding on the nectars of *Ceriops tagal* flowers. Other bird species found include Green-winged Ground Dove, *Chalcophaps indica*, White-collard Kingfisher, *Halycon choris*, Rufous-brown Pheasant Dove ,*Macrophygia mackinlayi*, Cardinal Honeyeater, *Myzomela cardinalis,* Rainbow Lorikeet, Grey Fantail, *Trichoglossus haematodus* and Swamp Harrier, *Cirus approximans*. Two nests of *C. indica* were found on the *Ceriops tagal* about 500 metres north of the uplifted mangrove area and a nest of *H. choris* was found on the *Rhizophora stylosa* trunk at Louni boat passage area. Both species of flying foxes observed, *Pteropus tonganus* and the endemic *Pteropus aneitianus* are found roosting on Banyan tree at the high water mark behind *Rhizophora* mangrove trees at the northwestern side of the Tabu Eria. The roosting place is located at around 300m south of Louni boat passage. Local assistants, Masing W. from Uri Island and Sael from Hatbol village informed the researcher s that there is a certain time every year that flying foxes are abundantly found in the mangrove forests of both Amal-Crab Bay and Port Stanley. Some are found on very low mangrove trees especially the *Ceriops tagal*. The local field assistants also reported a smaller white flying fox that are also abundant at the same time as mentioned above. It is likely that the species reported resemble the description of the endemic Banks Flying Fox (*Pteropus fandatus*). However, this information can only be confirmed if a specimen is collected. The local people do not know why the flying foxes descended lower to *Ceriops tagal* species each year especially those that are matured at 1.5 metres and 2 metres in height. Generally there are abundant mangrove resources in particular the molluscs and crustaceans. The *Terebralia palustris* (called 'Serwok' in Uripiv Island vernacular) are very abundant and common throughout the entire Tabu Eria. The size is larger compare to Eratap Mangroves area on Efate Island, the second pilot site for MESCAL Vanuatu and Aniwa mangrove area south of Vanuatu. *T. palustris* are sold at the Lakatoro Market. Malekula. *Nerita grayana* is also observed at the 6 assessed sites. The Oyster, *Cassostrea sp. is* also common and abundant only at some sites. The size is observed bigger than the oysters found on Eratap, Efate. *Littoria sp.*is also found in the mangrove area though it is not observed as common or abundant in the sites assessed. The other bivalve species found in the area include *Geloina sp., Dosinia sp.* and *Gafrarium sp.* The *Geloina sp. and Gafrarium sp. are* generally found in the Tabu Eria. The *Dosinia sp*. is found in the thick soft mud area at Louni boat passage which is the northern part of the Tabu Eria. These three species of bivalves are also collected in the access area for food and are sold at the Lakatoro market. Serwok, *Terebralia palustris* collected at the access areas is also sold at the market. Winkles are also observed at Amal point. *Cardiosma carnifex, Cardiosma spp*. and *Ulca annulipes* are the most common and abundant of the crustacean found in the Tabu Eria. *Ulca lacteal* is commonly found on Uri Island. The mangrove mud crab, *Scylla sp.* is also observed. *Cardiosma* and *Scylla* species are harvested in the access area once in a week for food and sale at the Lakatoro market. The rapid assessment confirmed four gecko species such as the Oceanic gecko, *Gehyra oceanica,* Gehyra spp., *Lepidodactylus lugubris* and the endemic *Lepidodactylus vanuatuensis*. *L.vanuatuensis* is known only from the islands of Santo, Efate and Aneityum and this is the first record for Malekula Island. The skink species found during the assessment include the Blue-tailed Skink, *Emoia impar*, the Vanuatu Green Tree Skink, *Emoia sanfordi*, the Moth Skink, *Lipinia noctua* and the Small Skink, *Cryptoblepharus novohebridicus.* The assessment recorded three endemic species of the Flying Fox, *Pteropus aneitianus,* the bird species of *Zosterops flavifrons* and the Vanuatu Gecko*, Lepidoctylus vanuatuensis*. The local field assistants reported that the Vanuatu Green Tree Skink*, Emoia sanfori,* also exists which makes the number of endemic species in the mangrove areas up to four.

The rapid assessment confirmed 8 species of birds compared to 15 species being observed on Amal-Crab Bay on Malekula. Vanuatu avifauna (all seabirds, land and freshwater) according to Bregulla H. L 1992, 121 species were recorded for Vanuatu and in year 2002 a new sea bird that is not recorded in Bregulla was observed by John Seymour from Australia. This has brought the total number to 122. Out of the 8 species observed no seabirds were found. A couple of Red-bellied Fruit Dove, *Ptiliopus greyii* was calling on tall trees behind the back-zone of the mangroves. The common Pacific Imperial Pigeon, *Ducula pacifica* was not observed during the assessment period compare to Amal-Crab where it is common. *Zosterops flavifrons* belongs to the two common species represented in Vanuatu (White-eye and the Gre-backed white-eye). *Z. flavifrons* is a common endemic species abundantly found throughout the archipelago. Both species were found in the mangrove area. An immature Z. *lichemas* was found by the Land survey mapping team. The Grey Fantail, *Rhipidura fuliginosa* was heard calling and a nest was found on a Rhizophora sp., about 1km south of Aquana Resort. On this particular area where the nest is found, are mostly of the mangrove species Ceriops tagal towards the back zone. Rainbow Lorikeet, *Trichoglossus haematodus* was also observed including Green-winged Ground Dove, *Chalcophaps indica*, White-collard Kingfisher, *Halycon choris* and Cardinal Honeyeater, *Myzomela cardinalis*. The *Terebralia palustris* (called Ses Pangpram in Eratap vernacular) are commonly found but not abundant and in larger size compare to Malekula. The local field assistant confirmed that it used to be abundant but has decreased due to overharvesting for food and sale at the Port Vila market over the last decade. *T. palustris* dead broken shells were found in piles along the eastern side of the mangrove area close to Epakor 'spring wota'. Gafrarium sp. was the only mangrove mud bivalve species found at Eratap mangrove area during the assessment period. Other species may be present but were not observed. Oyster, *Cassostrea s.* was observed common and abundant though they are smaller in size compare to Amal-Crab Bay on Malekula Island. Healthy clusters of oyster are found in the Rhizophora sp. vegetation toward the eastern side of Eratap resort. *Cardiosma sp*. and *Ulca annulipes* were also observed. It was reported by the local field assistant anda couple of women at Eratap village that *Cardiosma sp*. used to be common and abundant in over the last decade but it has been overexploited for food and earing cash at the Port Vila market. Ulca annulipes were found to be common but not as abundantly found on Amal-Crab Bay, Malekula. Barnacles, *Chthamalus* species belong to the crustaceans. They were also found in the Eratap mangroves. At some sites they were found by attached to the roots and trunks of mangrove trees and at some sites they were found living in association with oyster especially on the roots of mangroves. The rapid assessment confirmed two skinks, the Blue-tailed Skink, *Emoia impa* and the Vanuatu Green Tree Skink, *Emoia sanfordi.* Few were observed climbing and resting on *Rhizophora sp.* branches and stems found on the south of Epakor 'spring wota'. *E. sanfordi* is endemic to Vanuatu. Other faunal species observed within the mangrove areas include two species of bech de mer, a starfish, mud skipper and moray eel. The assessment recorded two endemic species, the *Emoia sanfordi,* Vanuatu Green Tree Skink and *Zosterops flavifrons,* the Vanuatu White-eye.

Recommendations

- Due to the richness and endemism of the fauna observed in the Amal-Crab Bay Tabu Eria it is important the Amal-Crab Bay conservation initiative resources (Cardiosma species and fish) under the current traditional tabu system extends to also include other fauna species as well as the mangroves.
- The Amal-Crab Bay Tabu Eria should be further considered for legal registration under the Environmental Protection and Conservation Act. This will give national legal recognition to the traditional management as well as giving legal power to the AKTE management committee to manage AKTE.
- This assessment did not include insect fauna therefore any project coming to Amal-Crab Bay should focus on the insects in order to understand the insect diversity using this mangrove ecosystem.

- Due to over exploitation of some resources especially the *Cardiosma* species and *Terebralia palustri,* it is important the current traditional resource management system (tabu) placed by the Eratap chiefs this year 2013 on marine fishes extends to cover other mangrove resources as well as the mangrove species. .
- The appropriate Eratap village authority should ensure that the Eratap mangrove area is agreed by all seven tribes to work towards setting up the area as a Community Conservation area through legal registration under the Environmental Protection and Conservation Act. This will give national legal recognition to the traditional management as well as giving legal power to the locally set up management committee to manage Eratap mangroves.

Conclusion

The assessment result indicates that the Amal-Crab Bay area harbours high number of terrestrial fauna and mangrove mud gastropods. Comparing to the second MESCAL Vanuatu project site, Eratap, the Amal-Crab Bay fauna is observed to have a high diversity and are abundant. The *Terebralia palustris* are abundant and are bigger in sizes than Eratap. This is the same case with *Cassostrea sp.* Since the assessment did not include the insect groups and other fauna that are not yet recorded it is important that future project funds for Amal-Crab Bay also look at this assessment. The assessment also showed that though some of the resources have been over exploited especially the cardiosma and *Tereblarlia palustri*, the area still harbours a healthy population of oyster species though the size is smaller compare to Amal-Crab Bay. Many bird species were not found. This may be the result of mangrove area is smaller and as well the mangrove area is encroached with coconut plantations and gardening activities including increase of settlements going closer to the mangrove areas. The mangrove vegetation of the area close to Eratap Resort as well as the mangrove islets are well intact compare to other areas close adjacent to the village and immigrant settlers. However, it is not too late for the Eratap community leaders to put their efforts together to revive the exploited resources including the whole mangrove ecosystems.

Observed Fauna Photos (Amal/Crab Bay)

Terebralia palustris, southwest of Crab Bay Point. ©D. Kalfatak

Terebralia palustris on sale at Lakatoro Market. ©D. Kalfatak

Terebralia palustris, south of Crab Bay Point. ©D. Kalfatak

Winkles found on the Amal Point

Nerita grayana. ©D. Kalfatak

Nerita grayana on root of *Rhizophora stylosa*. ©D. Kalfatak

Tiger Cowrie Shell, *Cypraea tigris*. ©D. Kalfatak

Cypraea tigris found within R. Stylosa roots. ©D. Kalfatak

Oyster, *Cassostrea sp*. ©D. Kalfatak

Oyster, *Cassostrea sp* on ,mangrove roots.
©D. Kalfatak

Geloina sp. ©D. Kalfatak

'Geloina sp. on Sale at Lakatoro Market. ©D. Kalfatak

Dosinia sp. ©D. Kalfatak

Dosinia sp. on Sale at the Lakatoro Market.
©D. Kalfatak

Gafrarium sp. ©D. Kalfatak

Gafrarium sp. ©D. Kalfatak

Marine slug?.. found on bare area behind *Ceriops tagal forest.* ©D. Kalfatak

Marine slug? ©D. Kalfatak

Mangrove crab, Cardisoma carnifex. ©D. Kalfatak

Cardisoma carnifex (algae growing around its eyes). ©D. Kalfatak

Cardiosma spp. found at the back zone of the *Rhizophora* species. ©D. Kalfatak

Cardiosma carnifex on sale at Lakatoro market. ©MESCAL Vanuatu

Mangrove mud crab. ©D. Kalfatak

On Sale at Lakatoro Market (2000vt each). ©D. Kalfatak

Ulca annulipes (Female and Male in same barrow).
©D. Kalfatak

Ulca annulipes(Male). ©D. Kalfatak

Fiddler Crab, *Ulca lacteal.(Photo taken at Uri Island)*
© D. Kalfatak

Porcelain Fiddler Crab, *Ulca annulipes* . Female (left) and Male (right). ©D. Kalfatak

Ulca annulipes (Female and Male in same barrow).
© D. Kalfatak

Ulca annulipes covering a bare mangrove area (Amal Point)
© D. Kalfatak

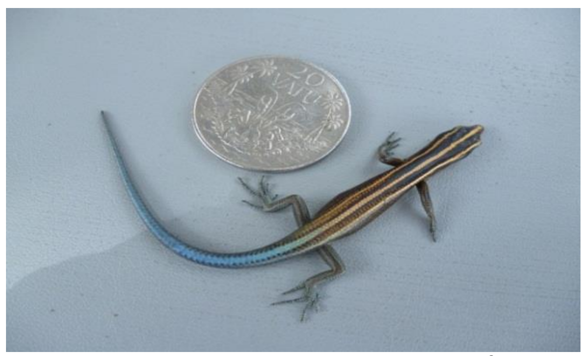
Gecaranidae spp. ©D. Kalfatak

Grapsidae spp.

Hermit Crabs, *Coenbita spp.*

Hermit Crabs, *Coenbita spp.*

Small Skink, *Cryptoblepharus novohebridicus.*
©MESCAL Vanuatu



Blue-tailed striped Skink, *Emoia impar. © D. Kalfatak*

Moth skink, *Lipinia noctu.* © D. Kalfatak

Vanuatu Green Tree Skink, Emoia sanfordi. © D. Kalfatak

Genhyra oceanic on the dried trunk of *C. Tagal.* ©D. Kalfatak

Genhyra sp. © D. Kalfatak

Lepidodactylus vanuatuensis. Avicennia maring vegetation ©D. Kalfatak

Lepidodactylus vanuatensis. Ceriops tagal vegetation. ©MESCAL Vanuatu

Lepidodactylus lugubris on trunk of *A.marina.* ©D. Kalfatak

Lepidodactylus lugubris on the branch of *R. Lamarcki. ©D. Kalfatak*

Green-winged Ground Dove, *Chalcophaps indica*. ©Llyod Davis

Nest of Green-winged Ground Dove on *Ceriops tagal.* ©D.Kalfatak

White-collared Kingfisher, *Halycon chloris* ©Llyod Davis

Red-bellied Fruit Dove, *Ptilinopus greyii.* ©Llyod Davis

Rainbow Lorikeet, *Trichoglossus haematodus.* ©Llyod Davis

Cardinal Honeyeater, *Myzomela cardinalis*. ©Llyod Davis

Observed Fauna Photos (Eratap)

Terebralia palustri, D. Kalfatak

Pile of dead *T. palustri shells found south of Epakor spring*
©D. Kalfatak

Winkles on leaf of *Rhizophora sp* ©D. Kalfatak

Winkles on leave of *Rhizophora sp. found north of Epakor spring water.* ©D. Kalfatak

Popkas

Winkles on stem on *Avecinnia marina* at Eratap Resort Jetty

Winkles found on stems on *Ceriops tagal* close to Eratap Resort

Nerita grayana. ©D. Kalfatak

Nerita grayana on Rhizophora sp branch. ©D. Kalfatak

Barnacles, *Chthamalus sp*. on trunk of Ceriops tagal, close to Eratap resort jetty. ©D. Kalfatak (Tor)

Winkles, oyster and barnacles on roots of Rhizophora stylosa. Found on the northeastern side of Eratap resort. ©D. Kalfatak

Oyster, *Cassostrea sp***.** on mangrove roots close to Eratap Resort ©D. Kalfatak

Oyster, *Cassostrea sp* on ,mangrove (*R. stylosa*) roots**.** ©D. Kalfatak

Gafrarium sp. ©D. Kalfatak

Gafrarium sp. Smaller in size compare to Crab Bay ©D. Kalfatak

Cardiosma spp. found at the back zone of the *Rhizophora* sp..
©D. Kalfatak

Cardiosma spp. ©Llyod Davis

Juvenile Mangrove mud crab, ©D. Kalfata (Rakum
ntas)

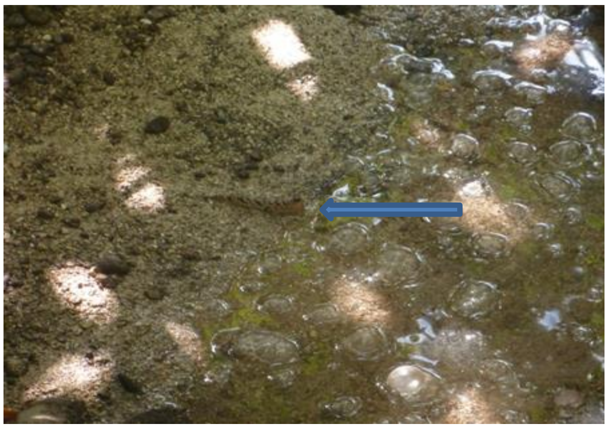
Grapsidae spp. ©D. Kalfatak

Grapsidae spp. ©D. Kalfatak

Grapsidae spp. ©D. Kalfatak

Grapsidae spp. ©D. Kalfatak

Thalassina squamifera © MESCAL Vanuatu



Mud Skipper found on the muddy sand of *Rhizophora sp.* close to Eratap resort . ©D. Kalfatak

Four moray eels found among roots of *Rhziphora sp.* ©MESCAL Vanuatu

Knobbly Sea Star, *Protoreaster sp.* among the *Rhizophora sp.* Roots. © MESCAL Vanuatu

Synaptid Sea Cucumber, *Opheodesoma sp*. among the *Rhizophora sp.* © MESCAL Vanuatu

Holothuria sp.? among the *Rhizophora sp.*
© MESCAL Vanuatu (Litot pram)

Tiger Tail Cucumber among the *Rhizophora sp.* © MESCAL Vanuatu (Nakplai pran)

Vanuatu Green Tree Skink, Emoia sanfordi. © D. Kalfatak

Emoia sanfordi on *R. stylosa* tree ©D. Kalfatak

Green-winged Ground Dove, *Chalcophaps indica*. ©Llyod Davis

White-collared Kingfisher, *Halycon chloris* ©Llyod Davis

Red-bellied Fruit Dove, *Ptilinopus greyii.* ©Llyod Davis (Suntra)

Rhipidura fuliginosa. © Llyod Davis (Pistakel)

Rhipidura fuliginosa nest on *Rhizophora sp*. ©D.Kalfatak

Vanuatu White-eye, *Zosterops flavifrons.* ©Llyod Davis (Topi)

Grey-backed Honey eater, *Zosterops lichemas.* ©Llyod Davis (Alak)

Zosterops lichemas (Immature) sitting on *R.stylosa* branch. ©MESCAL Vanuatu

Cardinal Honeyeater, *Myzomela cardinalis*. ©Llyod Davis

Rainbow Lorikeet, *Trichoglossus haematodus.* ©Llyod Davis

Section 4. MESCAL Project Shoreline Video Assessment (S-VAM) Surveys of Amal/Crab Bay (Malekula) and Eratap (Efate), Vanuatu.

Jock Mackenzie, Norman C. Duke, Apanie Wood

Centre for Tropical Water& Aquatic Ecosystem Research (TropWATER), James Cook University, Townsville.

EXECUTIVE SUMMARY

1) This report documents findings from the program of works for 2012-2013 directed by Dr Norm Duke with the Vanuatu MESCAL country teams involving their training, support and consultation, prescription of methodology and approach, as well as the compilation and preliminary assessment of data received.

2) This report details data generated from recent 2012 shoreline video assessment MangroveWatch surveys undertaken by MESCAL Vanuatu staff and associates. The data in this report has been analysed and compiled by the MangroveWatch science hub at the Australian Centre for Tropical Freshwater Research (TropWATER), James Cook University, Townsville, Australia.

3) The information in this report is designed to serve as a baseline for future mangrove monitoring along targeted coastlines, enabling future fringing mangrove health to be monitored effectively and providing a means to compare mangroves along the target shoreline with nearby areas in Vanuatu and elsewhere in the Pacific

4) The information presented here is designed to assist natural resource managers to identify and target specific issues that threaten mangroves in Crab Bay and Eratap, Vanuatu

5) A key outcome of these initial MangroveWatch surveys is a long-term visual baseline of mangrove extent, structure and condition along 14 km of Crab Bay and Eratap Bay shorelines that will provide an accurate means of assessing future change in years to come.

6) The results of this survey demonstrate the effectiveness of engaging local staff and community members to assess mangrove shoreline habitats using the MangroveWatch shoreline video assessment method (SVAM) with assistance from external experts to identify local threats and monitor habitat condition.

7) The results of this survey show the fringing mangroves of Crab Bay, Malekula to be in relatively good condition, with high ecosystem service value. Comparatively, fringing mangroves of Eratap Lagoon, Efate, are damaged by coastal development and are in poorer condition, with ecosystem service values compromised by cutting and clearing of some mangrove areas and habitat fragmentation. The very high condition and natural recovery documented in Crab Bay indicate these mangroves have high climate change adaptation and resilience capacity. Mangroves of Eratap exhibit very low rates of natural recovery from disturbances, making them particularly susceptible to climate change impacts.

8) Information regarding the extent to which fragmentation and disturbance of fringing mangroves can occur without greatly reducing habitat function and integrity is required for sustainable management. Broad scale assessments of mangrove shorelines combined with long-term monitoring will provide this information. The MESCAL project provides a first step towards achieving this goal.

Acknowledgments: We thank the five MESCAL country teams and the IUCN Oceania Office project staff in Fiji for their direction and support during this project.

Introduction

In September 2012 MESCAL Vanuatu staff and associates undertook a survey of fringing mangrove habitats in Crab Bay at the MESCAL demonstration site using the MangroveWatch Shoreline Video Assessment Method (SVAM). This report details the results of this survey, with assessment provided by the MangroveWatch hub at JCU. This report adds to previous progress reports summarizing new findings and observations about biodiversity, structure and condition of mangrove ecosystems in the five MESCAL countries, Fiji, Samoa, Tonga, Vanuatu and Solomon Islands. This data within this report specifically focuses on the structure and condition of fringing mangroves in the surveyed area and details natural and anthropogenic threats that affect mangrove function and resilience. This component of the MESCAL project has 4 key activities in each of the five countries – mapping and verification (A), floristics and biodiversity (B), biomass and carbon evaluation (C), and shoreline health monitoring (D). This combination of activities makes up an important part of this Coastal Health Archive and Monitoring Program for the region. This shoreline assessment work has only been possible after receipt of sufficient information collected by participants, with significant primary data received up to April 2013. These data have now been carefully assessed and processed with considerable effort made in checking data quality and its veracity, as far as practical.

What is MangroveWatch?

MangroveWatch is a community-science partnership and monitoring program aimed at addressing the urgent need to protect mangroves and shoreline habitat worldwide. The MangroveWatch program began in 2008 in the Burnett-Mary region of Australia with support from Caring for Our Country; an Australian Government Initiative. MangroveWatch is now currently operating in Australia and 5 Pacific Island Nations; Fiji, Samoa, Solomon Islands, Tonga and Vanuatu. In Australia, MangroveWatch monitoring is occurring in the Torres Strait, Daintree River, estuaries in the Port Curtis and Coral Coast region, the Burnett, Elliott and Burrum rivers, Tin Can Bay, Noosa River, Pumicestone Passage, Brisbane River and Moreton Bay. There are currently over 300 registered MangroveWatch volunteers from 20 different corporate, non-government and government organizations. The MangroveWatch scientific hub is based at the Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER), James Cook University, Townsville.

MangroveWatch Mission Statement

To provide coastal stakeholders with a tool to assess and monitor local shoreline habitats that;
- *is scientifically valid*
- *engages and empowers local people*
- *promotes effective natural resource management*
- *provides a visual baseline from which to assess future change.*

For more information on MangroveWatch visit: www.mangrovewatch.org.au

Figure 28: Vanuatu MESCAL MangroveWatching in Crab Bay, Malekula

Why monitor shoreline mangroves – the importance of mangrovewatch

Mangroves provide important goods and services to coastal environments that support and protect local economies, and social, cultural and heritage values of coastal communities.

These values are commonly referred to as 'ecosystem services'. Mangroves provide 7 key ecosystem services to Pacific Island communities;

- **Providing fish habitat & supporting nearshore fisheries** (Manson et al. 2005, Meynecke et al. 2008)
- **Shoreline protection** (Alongi 2008, McLeod et al. 2008, McIvor et al. 2012a, McIvor et al. 2012b)
- **Providing timber and non-timber forest resources** (Prescott 1989, Rohorua and Lim 2006, Walters et al. 2008, Warren-Rhodes et al. 2011)
- **Water quality improvement** (Alongi 2002, Adame et al. 2010)
- **Visual & recreational amenity** (Salem and Mercer 2012)
- **Carbon Storage** (Donato et al. 2011)
- **Supporting local biodiversity** (Traill et al. 2011, Wilson et al. 2011)

For further information on mangrove ecosystem services refer to Barbier et al. (2011) and Warren-Rhodes et al. (2011). Despite their importance, mangroves continue to be directly destroyed and degraded by poor catchment and coastal zone management. Globally, 30% of the world's mangroves have been lost in the past 30 years (Duke et al. 2007, Polidoro et al. 2010). Mangroves are increasingly threatened in the Pacific by anthropogenic pressures such as over exploitation of resources, coastal development, pollutants and altered hydrology in the coastal zone (Ellison 2009). These factors may not reduce mangrove extent, but they do influence habitat quality, reducing the capacity of mangroves to provide ecosystem services (Gilman et al. 2006, Alongi 2008). Mangrove habitat degradation greatly reduces the capacity of mangroves to respond to the impact of future climate change (Gilman et al. 2008). The location of mangroves at the shoreline edge places them in the direct line of climate change impacts; sea level rise, more severe and frequent storms and more frequent drought and floods (Alongi 2008, Hoegh-Guldberg and Bruno 2010, Knutson et al. 2010) (Lovelock and Ellison 2007). Reduced habitat condition, reduced biodiversity and habitat complexity and altered ecosystem processes reduce the capacity of mangroves to withstand climate impacts and their capacity of mangroves to buffer these impacts and protect adjacent coastal areas (McLeod and Salm 2006). While it is not possible to prevent climate change at the local scale, it is possible to reduce direct human related impacts that are likely to reduce capacity of mangroves to resist and recover from climate change impacts. The capacity of mangroves to respond to climate change impacts depends directly on improving local mangrove management (Gilman et al. 2008).To effectively manage anthropogenic impacts on mangroves, it is important to identify the location of impacts and the extent to which they threaten high value habitat. This can only be achieved through systematic assessment of mangrove extent, structure and condition in relation to identified threats, and through long-term monitoring.

The importance of fringing mangroves

Fringing shoreline mangroves are extremely important components of mangrove ecosystems. The shoreline edge is where the greatest interaction and tidal exchange between the marine and mangrove habitats occurs, meaning that these fringe zones are sites of great material exchange (Rivera-Monroy et al. 1995), aquatic habitat value (Meager et al. 2003, Nagelkerken et al. 2008), and are highly important for shoreline protection and water quality improvement (Kieckbusch et al. 2004). As such maintaining the condition of fringing mangroves is essential to maintaining mangrove ecosystem services and protection of inner forest areas where they are present.

The MangroveWatch approach

MangroveWatch provides data on the extent, structure and condition of shoreline habitats in estuaries and along protected coastlines. The generation of this information relies on the annual collection of geo-tagged video imagery of shoreline habitats using the Shoreline Video Assessment Method (SVAM) employed by trained community members and organisations. MangroveWatch is a 5-step process (see Figure 29);

1. **Community Training and Information Session by the MangroveWatch Hub.**
   MangroveWatch participants are provided with a MangroveWatch kit, trained in data collection methods and discuss the importance of mangroves, local threats and issues.

2. **Community video monitoring**
   MangroveWatchers collect geo-tagged video of local shorelines

3. **Data Transfer**
   Video and GPS data is transferred to MangroveWatch science team at James Cook University

4. **Data assessment by mangrove scientists**
   MangroveWatch video data is analysed by scientists to determine extent, structure and condition of shoreline habitats.

5. **Data feedback to coastal stakeholders.**
   Data is presented back to the community in report form.

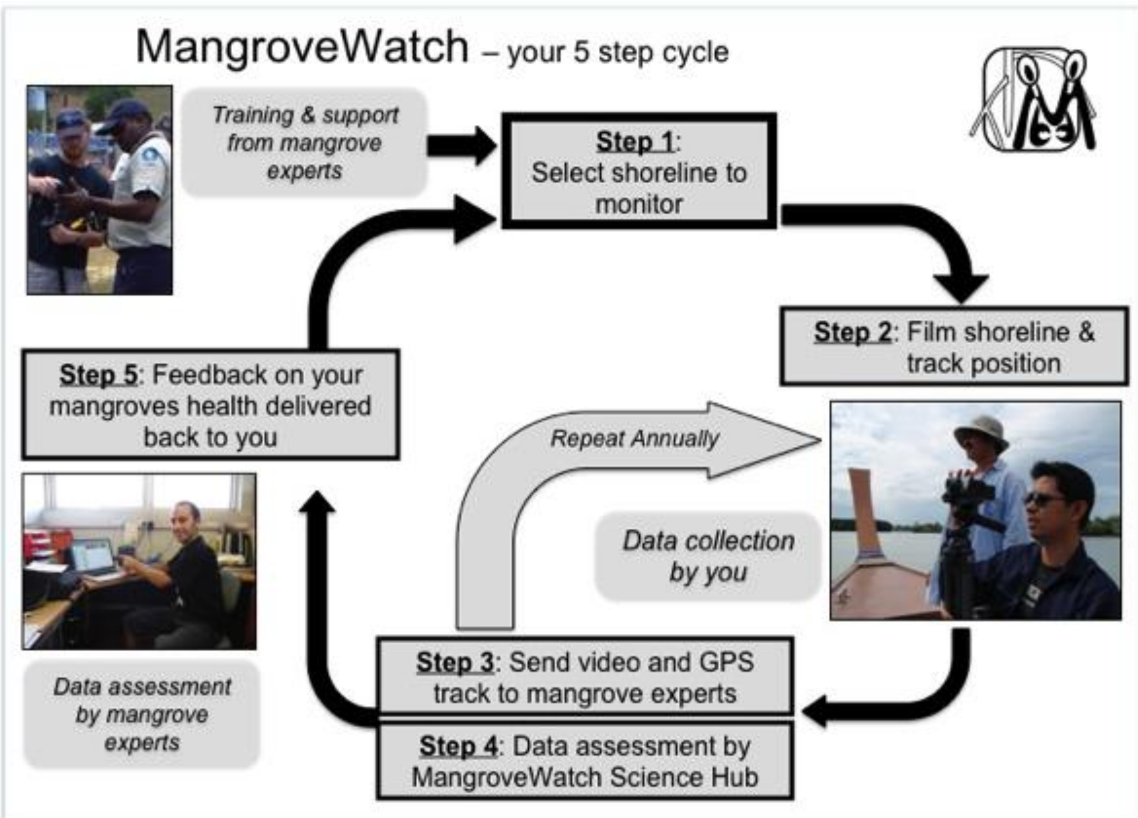


Figure 29: The MangroveWatch Approach

Advantages of the MangroveWatch Approach

The Shoreline Video Assessment Method (SVAM) used for MangroveWatch is the perfect tool for citizen science. The advantages of SVAM are that it is;

Easy to do - only limited technological skills are required to operate a video camera, handheld GPS and digital still camera

Scientifically valid - No objective decision making is required by community participants as all imagery is assessed remotely by mangrove experts.. Video data enables data quality control. The GPS track ensures repeatability. Video image assessment is backed up by groundtruthing and accuracy assessments

Rapid – Video imagery can be collected quickly allowing large areas to be assessed with minimal time commitment from MangroveWatch community participants. On average, 10km of shoreline only requires 1 hour of filming.

A permanent visual record – video imagery data provides a permanent visual record from which to assess future change and overcomes shifting baseline of environmental perception. Our intention in the near future is to make all video image data available via the MangroveWatch website.

A whole of system assessment – A continuous collection of geo-tagged shoreline images allows for the quantification of data across entire estuaries, rather than from a collection of random points along the bank or within the forest. This allows shoreline habitat features and process to be seen within the context of the whole system that better informs estuary and coastal management.

Partnering scientists with local people greatly improves our understanding of shoreline habitats and is one of the major advantages of the MangroveWatch approach.
Working with local people enables;

Local knowledge input – Local people provide locally relevant information that enhances scientific assessment and provides local context to shoreline habitat assessment. Local observations of change, historical information and knowledge of local values are highly valuable insights.

Large spatial coverage – there are very few mangrove scientists and many keen local mangrove enthusiasts. Working with local people means that more information can be gathered from more places to improve our understanding of shoreline habitats.

Community education, empowerment and environmental stewardship– When local communities are informed they are empowered. By working with scientists, local people can gain more information on the value of their local mangroves and the issues that affect them, empowering them to take action at the local scale.

Report Format

There are two MESCAL demonstration sites in Vanuatu; Crab Bay, Makekula, and Eratap, Efate. Due to the geographic isolation of these sites and differences in ecosystem condition and pressures upon mangrove forests, the results of the shoreline assessments are presented separately in the report. The methods, however, apply to both sites.

Methods

Shoreline Video Assessment Method (SVAM)

Mangroves have the distinction of forming a unique marine habitat that is both forest and wetland. As such, they form an important component of a number of international conventions that recognize their uniqueness and immense value to both coastal and marine communities, and mankind in general (eg.(Duke et al. 2007)). It is essential that the assessment of such a valuable resource be conducted in a rigorous and practical way. The MangroveWatch SVAM approach enables a whole-of-system assessment of shoreline mangrove forest structure and condition using georeferenced continuous digital video recording of shoreline. Video imagery is collected using a Sony Handycam from a shallow-draft boat travelling parallel to the shoreline at a distance of ~25 m, at a speed between 4 and 6 kts. The video camera is positioned to record directly perpendicular to the direction of travel at all times. Shoreline video imagery is collected with a concurrent time-synchronised 2-second interval GPS track to provide spatial reference to the imagery. Voice recording of observations on mangrove species composition, structure, condition and threats are made during recording with local observations and context provided by a local MangroveWatchers.

4.2 Shoreline Video Assessment Method (SVAM) survey locations

4.2.1 Demonstration site one: Crab Bay, Malekula

The Vanuatu MESCAL team surveyed fringing mangrove habitat along Crab Bay shoreline, Malekula (Figure 30). Crab Bay is one of two MESCAL demonstration areas in Vanuatu. The site has previously been used as a demonstration area for the International Waters program, directed by the Secretariat for the Pacific Region Environment Programme (SPREP). Two tabu areas, where fishing is restricted, are in place on the Eastern and Western headlands of the bay. Local communities initiated the tabu to protect fish resources. The central bay remains open to harvesting. The Crab Bay mangrove area is considered by local communities to be important for maintaining fisheries (SPREP 2005). Mangrove products are a source of economic income to some local communities, as well as being used as fire wood and for house and fence posts (SPREP 2005).

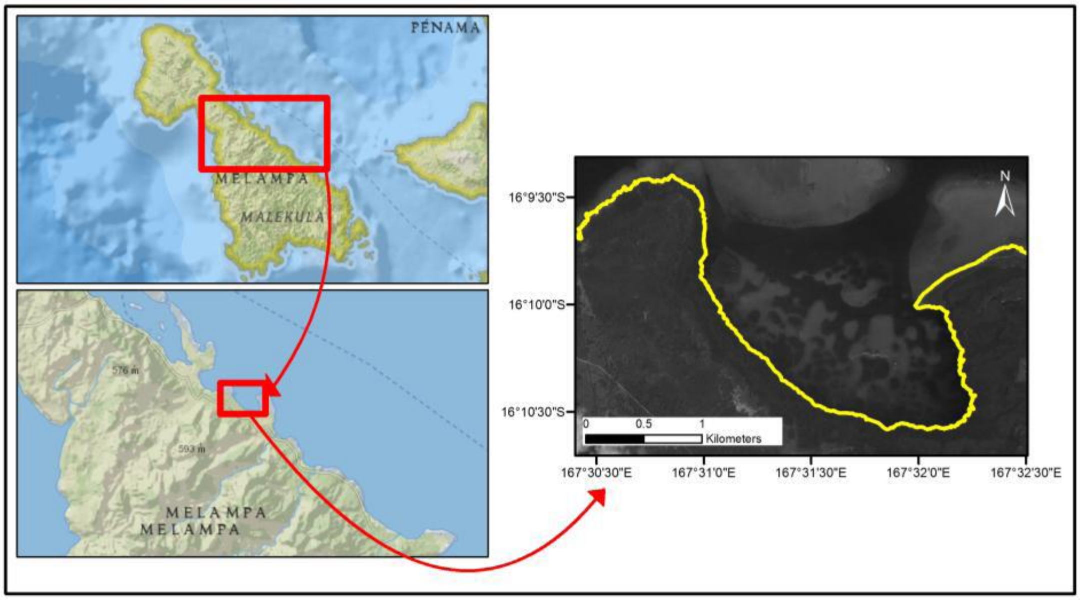


Figure 30: Location of MESCAL demonstration site at Crab Bay, Malekula.

Demonstration site two: Eratap, Efate

The second Vanuatu MESCAL demonstration site is located at Eratap, in south eastern Efate (Figure 31). Due to its close proximity to Port Vila, Eratap is subject to coastal development pressure from the tourism industry. A number of small islands provide some protection to the southern and central shoreline. An enclosed lagoon is located to the north of the site. The area has no history of environmental project activities, so limited baseline environmental data is available. The site is known to support a range of marine species including seagrass, turtles and dugong, as well as a number of commercially targeted fish species.

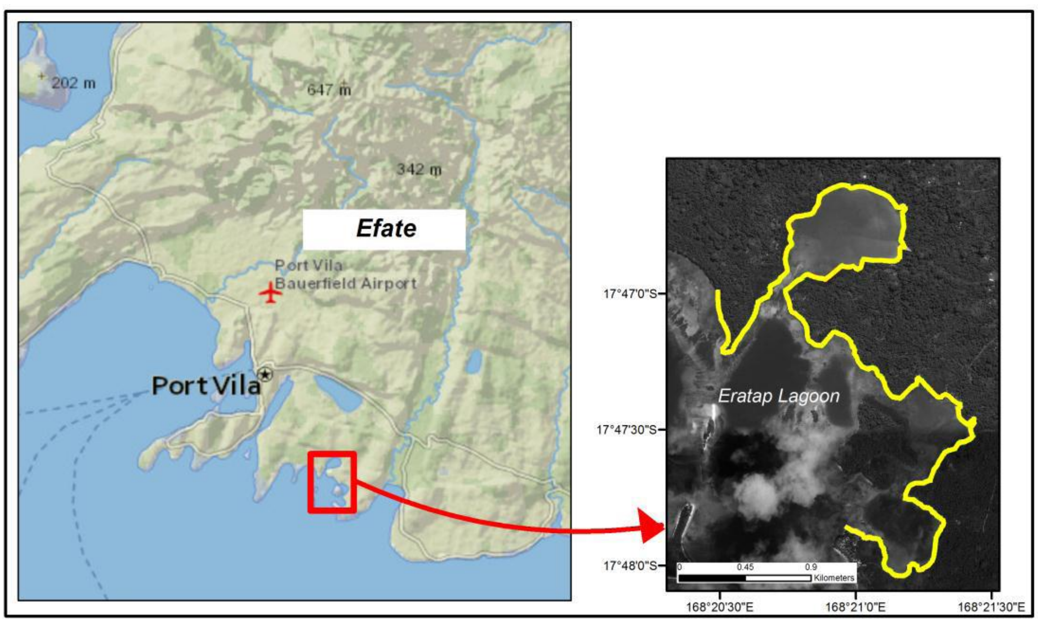


Figure 31: Location of MESCAL demonstration site at Eratap, Efate

Video imagery assessment

Shoreline mangrove forest features are recorded from the video using visual criteria-based classification. The video is first divided into 1-second jpeg frame images. The video time stamp and GPS track enable each frame to be related to a position along the shoreline (+/- 10 m). Using ArcGIS 10.0, the shoreline is divided into 10 m sections and each section related to a video frame such that the imagery seen between 2 frame locations represents 10 m of shoreline. The 10 m sections of coastline are then classified according to a set of visual criteria designed by the MangroveWatch Hub at JCU. All classification is based on the visible fringing mangroves intersecting the centre line of the video frame.

Features assessed and assessment criteria

Mangrove forest presence and biomass

Mangrove biomass describes the mass (kg/ha) of mangrove within an area. It can be used as a proxy for mangrove carbon storage and productivity and more generally relates to the overall functional value of a forest. Forest biomass is related to the size of the trees and their density. For SVAM assessment, the biomass score is a composite score of fringing mangrove *canopy height classification* and *mangrove forest structure classification*. The biomass score is a relative score that allows comparison between areas and along shorelines. Canopy height was visually estimated using height classifications based on forest biomass assessments in the region (Duke et al. 2013) and local knowledge recorded during the surveys (Table 6). Recent results comparing visual height estimates to actual heights recorded using a laser hypsometer have shown these visual estimates are accurate to within 2 m (Duke & Mackenzie, 2010). Canopy height of mangrove forests has recently been shown to be highly correlated with mangrove biomass (Duke et al. 2013). Mangrove forest structure classification describes the stem density of the forest (Table 6). The mangrove biomass score is calculated using estimated heights factored to a score out of five based on the upper height value recorded (Table 6). The factored height score represents the biomass score at maximum stem density (5 =closed-continuous forest). Where forest stem density is less than 5, the biomass score is reduced relative to the stem density as a proportion of the maximum (e.g. where stem density is 4, open-continuous forest, the biomass score equals height score * 0.8). Examples of mangrove forest assessed as of biomass scores 2 to 5 are provided in Figure 4.3.

Mangrove Biomass Score	0	1	2	3	4	5
Height classification	No Mangrove	Canopy height <2m	Canopy Height 2-4m	Canopy Height 4-6m	Canopy Height 6-8m	Canopy Height >8m
Forest structure classification	N/A	Scattered mangrove – individual trees. 1 or 2 trees	Sparse mangrove – individual trees >2m apart or small patches.	Open forest. Linear mangrove presence but spaces between canopy crowns	Open-continuous forest. Canopy crowns touching and overlapping.	Closed-continuous forest. Crown canopies intermingling

Table 6: Mangrove Biomass Assessment Criteria

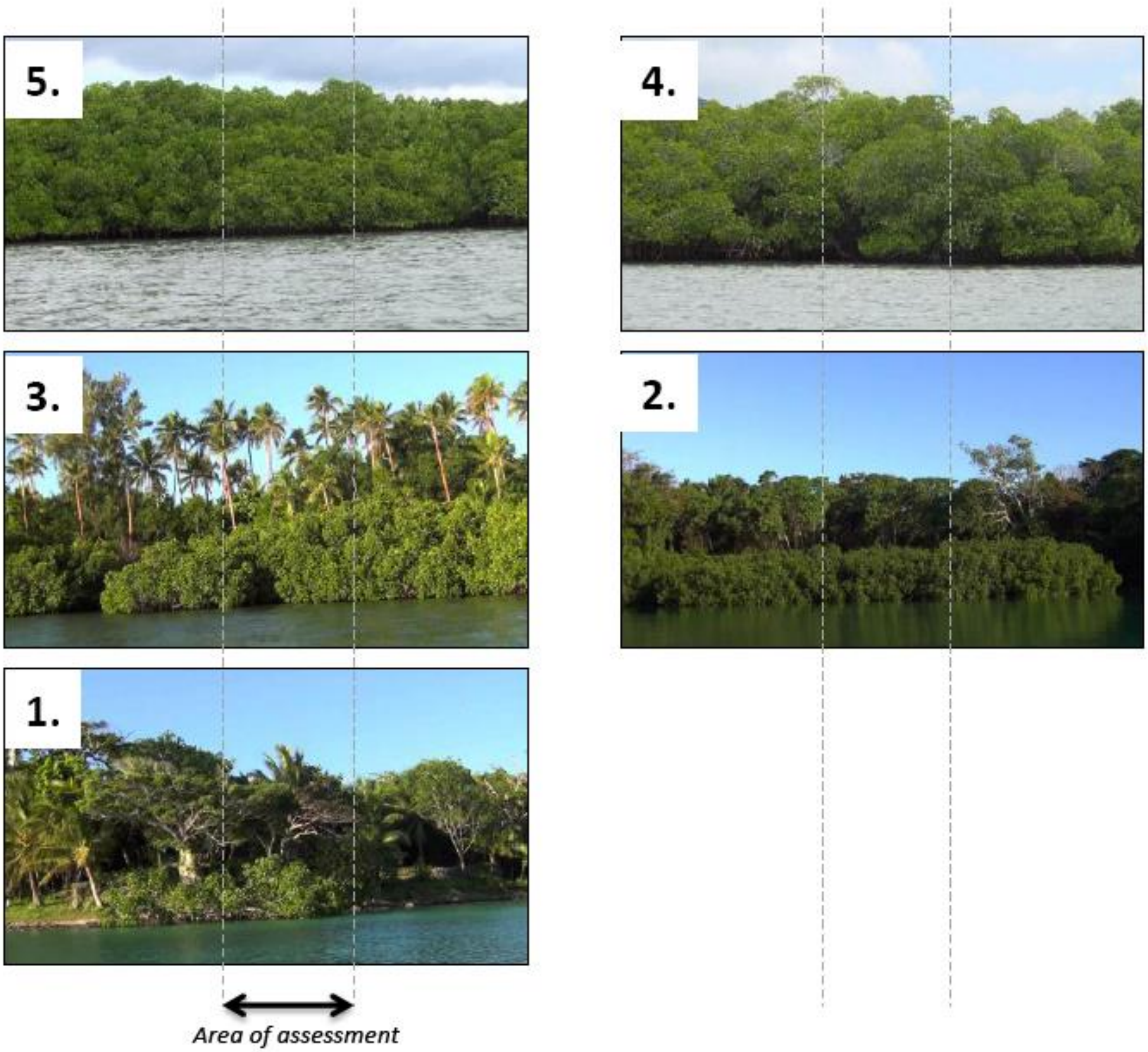


Figure 32: Example video stills of mangrove biomass assessment scores

Mangrove condition

The mangrove condition score describes the overall health of the fringing mangrove forest. Mangrove condition is visually assessed using presence of canopy dieback, dead trees and canopy density. Canopy dieback describes the presence of visible dead stems and branches ranked from 0 to 5, with 0 being the presence of dead trees. Examples of mangrove forest conditions scores are provided in Figure 32. Canopy density describes mean percentage canopy cover for fringing mangroves and the dominant canopy layer ranked from 1 to 5 as outlined in Table 7. Overall mangrove condition scores were generated by the following equation, giving a total score between 0 (unhealthy) and 5 (healthy);

Mangrove condition score = (dieback score * 2 + canopy score) / 3

Mangrove Condition	0	1	2	3	4	5
Dieback classification	Dead tree(s) present	Severe Dieback. Many dead branches. Obvious crown retreat. Bare twigs on less than 50% of the tree and ~75% of the tree affected	Moderate Dieback – Many dead twigs, canopy retreat, dead branches present. ~50% of tree affected.	Low level Dieback - Many dead twigs present. ~25% of tree affected	Very low level Dieback – a few sticks and twigs visible. ~5% of tree affected	No Dieback present
Canopy cover classification	N/A	Very low leaf cover. Majority of branches bare or near twigs, <10% estimated leaf cover.	Low leaf cover. Visible branches with 10-30% estimated cover.	Moderate leaf cover. Visible branches with 30-60% estimated cover.	Dense leaf cover. Visible branches with estimated 60-90% estimated cover.	Full lush leaf cover, Visible branches with >90% estimated cover.

Table 7: Mangrove condition assessment criteria

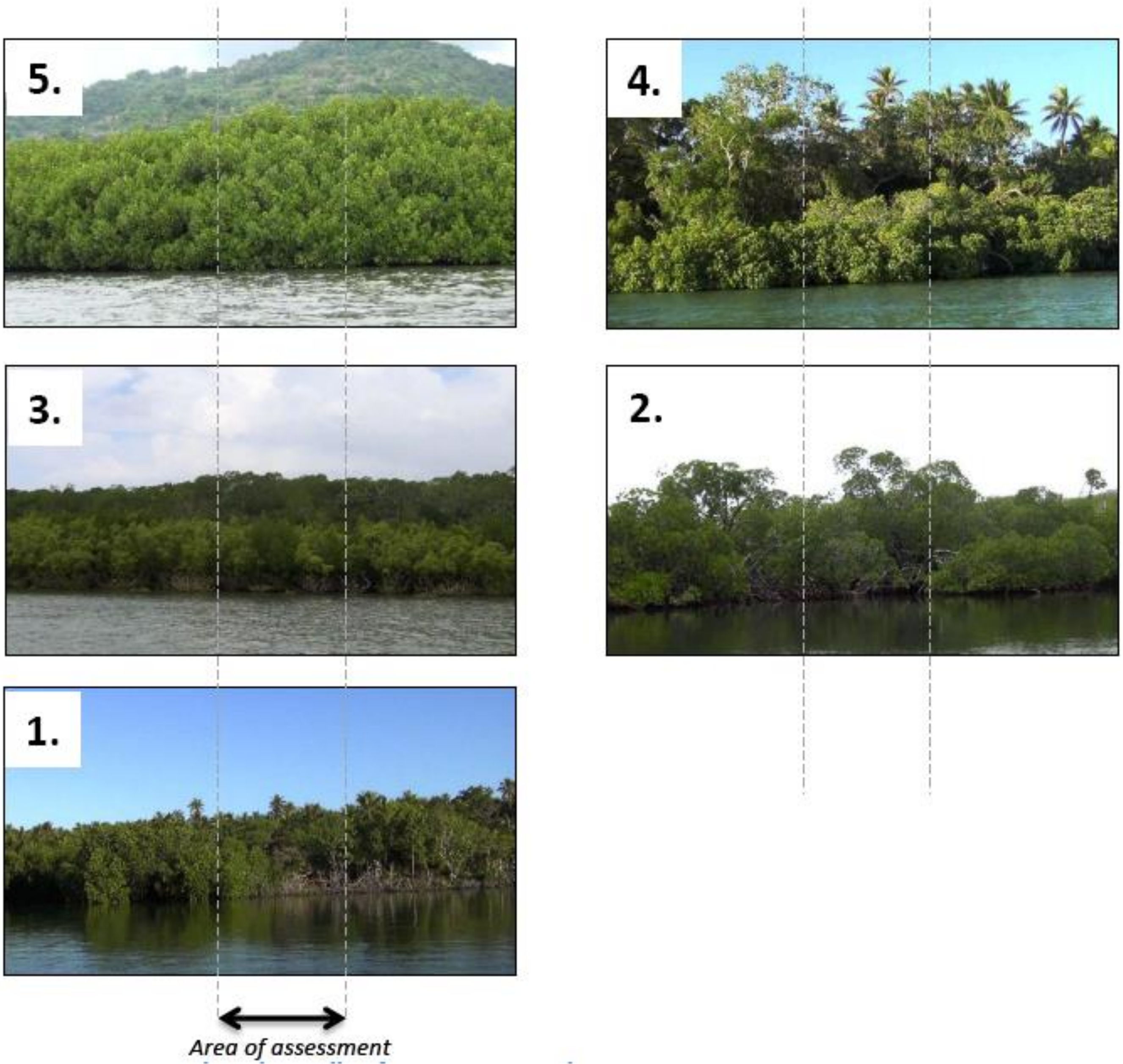


Figure 33: Example video stills of mangrove condition assessment scores

Mangrove value

Mangrove structural attributes are key factors determining the capacity of fringing mangroves to provide ecosystem services (McIvor et al. 2012a, McIvor et al. 2012b) (Alongi 2008, Nagelkerken et al. 2008). Forest structure comprised of stem density, canopy cover and species diversity relates both the physical integrity of the forest fringe and also the habitat types available. Defining forest structure provides insight into the ecosystem service capacity of mangrove forests both at specific locations and at the landscape scale. Fragmentation of fringing habitat due to human activities (cutting, clearing), or natural impacts (storm damage) have obvious effects on mangrove structural integrity, and therefore impact the physical value scores generated for this assessment. The physical value score is used as an indicator of the capacity of the fringing mangrove habitat to provide wave attenuation, shoreline stability and water quality improvement services. The physical value of mangroves used in this assessment defines the structural complexity at each shoreline location based on stem density (forest structure classification in Table 6), canopy cover (as described in Table 7), and the presence of inter-tidally submerged canopy and aerial root structures. Examples of mangrove forest assessed as of physical value scores 3 to 5 are provided in Figure 34. The habitat value of mangroves along a shoreline is dependent not so much on mangroves having high structural complexity *per se*, but is a shaped by the presence of a variety of different habitat structures across a highly interconnected landscape (Sheaves 2005). In this assessment, the habitat value score considers the richness, structural diversity and evenness of mangrove habitat structure in relation to stem density, canopy cover, inter-tidally submerged canopy, root structural diversity and forest structural diversity using Simpsons Diversity Index, where Richness (R) is the number of different structural habitat 'types', Diversity (D) is the reciprocal sum of squares of the proportion of shoreline represented by each habitat type and Evenness (E) is D/R.

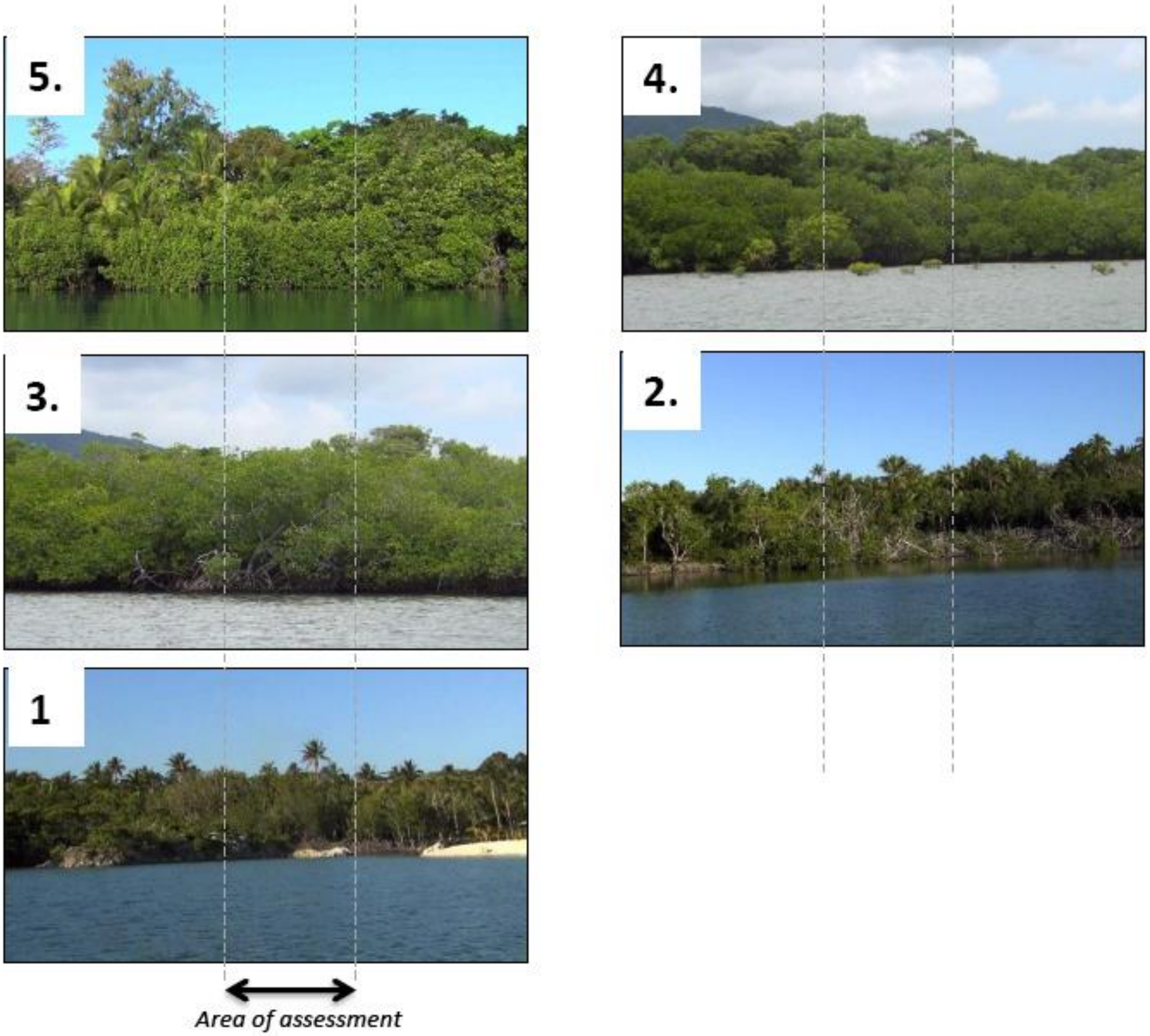


Figure 34: Example video stills of mangrove physical value assessment scores

Shoreline change and mangrove forest process

Mangrove forest process describes shoreline mangrove habitat identified as retreating, exposed, stable, growing or expanding (Table 3). Visual indicators were used to classify these conditions, as shown in Figure 35. Exposed bank is assumed to equate to high erosion potential.

Mangrove forest process	Retreating	Exposed	Stable	Growing	Expanding
Classification criteria	Undercut banks, bank slumping, fallen trees or sharp changes in bank elevation. (>45° angle)	Exposed roots and sediment visible. The absence of a mangrove fringe and obvious delineation between mangroves and shoreline with no height gradient to the shore	No visual indicators of process noted.	Emergent stems and canopy protruding above the mean canopy height. Trees have a noticeable 'pine tree' like appearance.	Dense seedlings present at the seaward mangrove edge. A noticeable height gradient decreasing to the shoreline in fringing mangroves

Table 8: Mangrove forest process assessment criteria

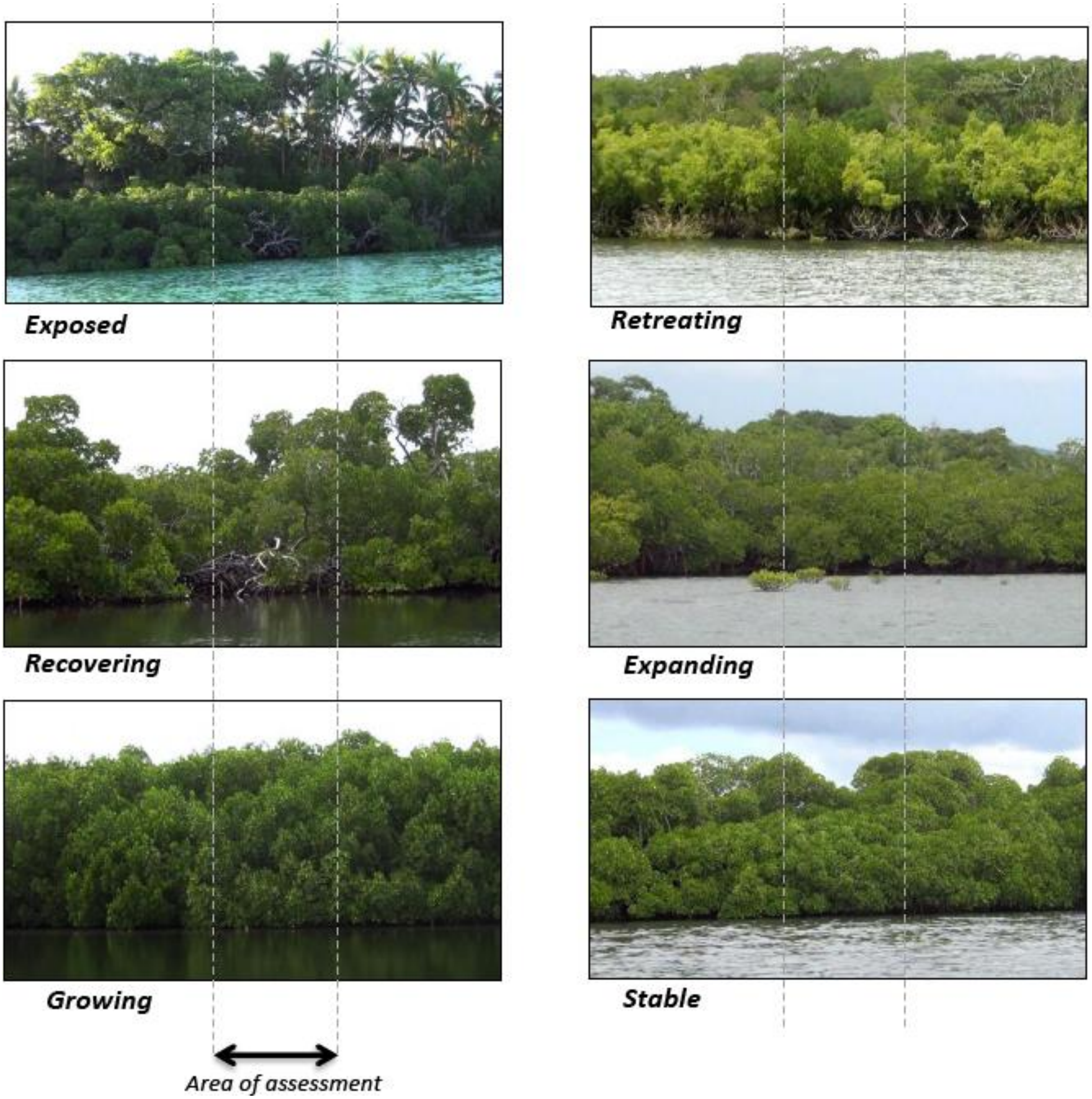


Figure 35: Example video stills of mangrove forest process assessment

Habitat fragmentation

Habitat fragmentation was assessed by identifying gaps in continuous mangrove stands. Gaps were classified as either naturally occurring or human generated. Human generated gaps were identified as areas where mangroves had been likely cleared for shoreline structures, shoreline access or wood harvesting. The habitat continuity score is the number of total gaps per kilometer of shoreline, as described in Table 9. The percentage of shoreline with gaps made by human activities determines the human modification score, as described in Table 9.

Score	0	1	2	3	4	5
Habitat continuity classification	>50 gaps/km	20-50 gaps/km	10-20 gaps/km	5-10 gaps/km	2-5 gaps/km	<2 gaps/km
Human modification classification	>40% mangrove shoreline modified	30-40% mangrove shoreline modified	20-30% mangrove shoreline modified	10-20% mangrove shoreline modified	0-10% mangrove shoreline modified	0% mangrove shoreline modified

Table 9: Habitat fragmentation score classification

Drivers of Change

Mangrove forests are impacted by both natural and anthropogenic drivers of change. Natural drivers include impacts from wind, waves and lightning strikes, as well as dieback associated with extended periods of low rainfall. Lightning is one of main natural drivers of mangrove forest turnover (Amir 2012), and can be easily identified by the presence of circular 'light-gaps' in the mangrove canopy. Dead trees radiate from the point of lightning contact. Here, the presence of light-gaps and canopy dieback in the fringing mangrove forest were quantified. Natural causes of mangrove canopy dieback include drought conditions (Lovelock et al. 2009, Eslami-Andargoli et al. 2010) and storm damage which can defoliate and snap mangroves, or can lead to more indirect tree mortality through changes in sediment elevation, compaction or chemistry (Smith et al. 1994, Gilman et al. 2008). Anthropogenic disturbance can also cause mangrove dieback, as well as often being the source of mangrove clearing and removal in populated areas. Alterations to natural hydrological regimes, for example through the creation of walls, barriers or roads in intertidal zone, can significantly alter the tidal regime of an area and cause widespread mangrove loss (Turner and Lewis III 1996). Harvesting of mangroves for timber products is common throughout the Pacific region (Warren-Rhodes et al. 2011). Root burial from sediment deposited during construction or from land-based runoff can cause loss of mangrove condition and eventually death (Ellison 1999). This assessment quantifies human impacts on fringing mangroves of Vanuatu's MESCAL demonstration areas, such as the presence of access paths, cutting, mangrove removal for coastal development and root burial.

Crab Bay Results

Survey area covered

The MESCAL team surveyed 7.22 km of the shoreline of Crab Bay on 21st September 2012. Figure 36 provides detail of the GPS track of survey travel and adjacent surveyed shoreline.

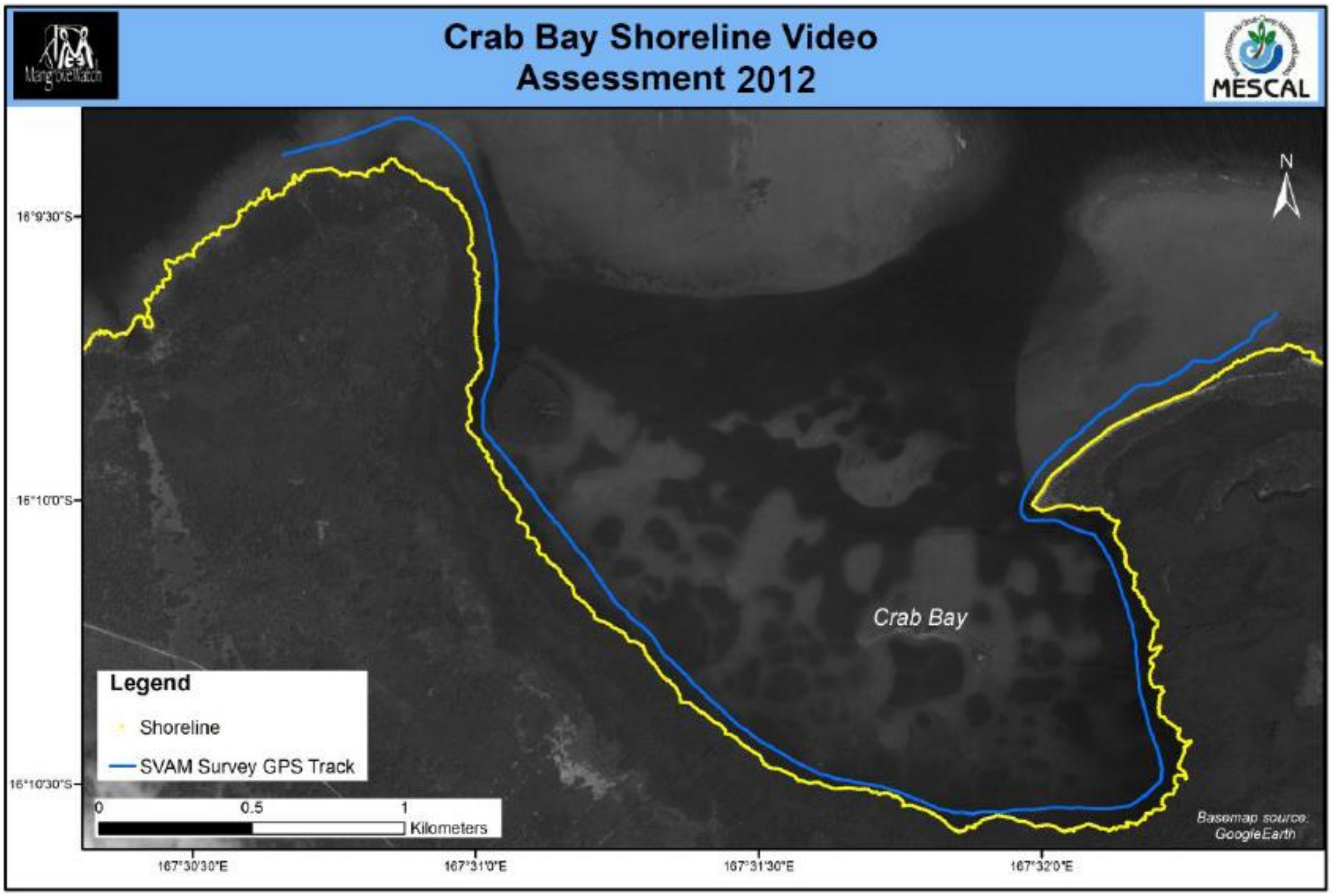


Figure 36: Shoreline video assessment, Crab Bay

Forest presence, biomass, physical value and habitat diversity

Mangroves were observed to occupy 6.37 km out of the total 7.72 km representing 88.2% of 10 m shoreline segments assessed. Forest height was relatively moderate across the surveyed shoreline, being estimated as 5 meters. The fringing forest is mostly of moderate to high relative biomass (86%), with mangroves inside the bay area having the greatest biomass (Figure 37). Forest biomass was lowest to the Eastern and Western ends of the survey area, where the survey included shoreline at the outer edge of the protective bay area. Mean mangrove forest height, structure score and biomass scores are provided in Table 10 and Table 11 provides a breakdown for the assessed forest structure, height, biomass and physical value scores. Figure 38 shows the distribution of physical value scores along the surveyed shoreline.

Mean Height (m)	Mean biomass score[1]	Mean structure score[1]	Mean canopy cover score[1]	Intertidal canopy[2]	Mean physical value score[1]
5 ± 0.03	3.3 ± 0.03	4.8 ± 0.02 *Closed-continuous*	4.7 ± 0.02 *(80-100% cover)*	72%	4.6 ± 0.02 *Very high*

Table 10: Summary of fringe mangrove forest structure and habitat diversity. [1]Relative score as described in methods. [2]Percentage of surveyed shoreline where part of the mangrove canopy becomes submerged during the tide cycle

Score	1	2	3	4	5
Height	<1%	4%	44%	49%	3%
Forest structure	<1%	<1%	2%	10%	87%
Biomass	1%	11%	46%	40%	1%
Physical value	<1%	2%	3%	22%	72%

Table 11: Percentage of surveyed shoreline classified as falling within each forest structure score

Mangroves along the Crab Bay shoreline are relatively structurally homogeneous with the majority of mangroves (87%) being closed-continuous, *Rhizophora* dominated fringe forest (Table 11; Figure 38).

The dominant species appears to be *Rhizophora stylosa* (96%), with *R. apiculata* often present (and co-dominant) along the shoreline (68%; Table 12). *R. mucronata* was also present, but in lower densities. *Avicennia marina* was present in depositional areas at both the outer limits of the survey area. *Sonneratia alba* was also infrequently present as an upper canopy species extending into the inner forest.

Species name	*A. marina*	*R. apiculata*	*R. stylosa*	*R. mucronata*	*S. alba*
% of shoreline dominated by species	8%	68%	96%	11%	4%

Table 12: Fringe mangrove species dominance. Note; percentages add to >100% where species are co-dominant

Fringing mangroves in Crab Bay have moderate structural diversity (D=3.2) and habitat type richness (r=35) owing to differences in canopy cover along the shoreline (see Table 14). The most common fringe habitat types are provided in Table 13. A very low habitat evenness score (E=0.09) reflects how the presence of remaining factors (stem density, canopy layers, intertidal canopy, aerial root structures) are relatively similar across the surveyed shoreline. The most common structural attribute association is closed continuous, *Rhizophora* dominated fringe forest with inter-tidally submerged canopy and either very high canopy cover (52%; Table 12, types 2 and 3).

Habitat 'type'	Stem density	Canopy cover	Intertidal canopy[1]	Aerial root structures	Canopy layers	% Shoreline
1	Closed-Continuous	80-100%	Yes	Prop Roots	Fringe Only	52%
2	Closed-Continuous	80-100%	Yes	Prop Roots	Fringe & Upper Canopy	14%
3	Open-Continuous	60-80%	No	Prop Roots	Fringe Only	6%
4	Closed-Continuous	60-80%	No	Prop Roots	Fringe Only	5%
5	Closed-Continuous	80-100%	No	Prop Roots	Fringe Only	4%

Table 13: Five most common fringe mangrove habitat 'types' contributing to habitat type richness. [1]Percentage of surveyed shoreline where part of the mangrove canopy becomes submerged during the tide cycle

Fringing *Rhizophora* forest generally has very high structural complexity that is beneficial to mangrove shoreline protection capacity and water quality improvement. As such the fringing mangroves surveyed have an overall very high mean physical value score (4.6 ± 0.02). The value of the fringe with respect to shoreline protection and water quality improvement capacity was diminished in some locations by poor mangrove health and fragmentation (Figure 38).

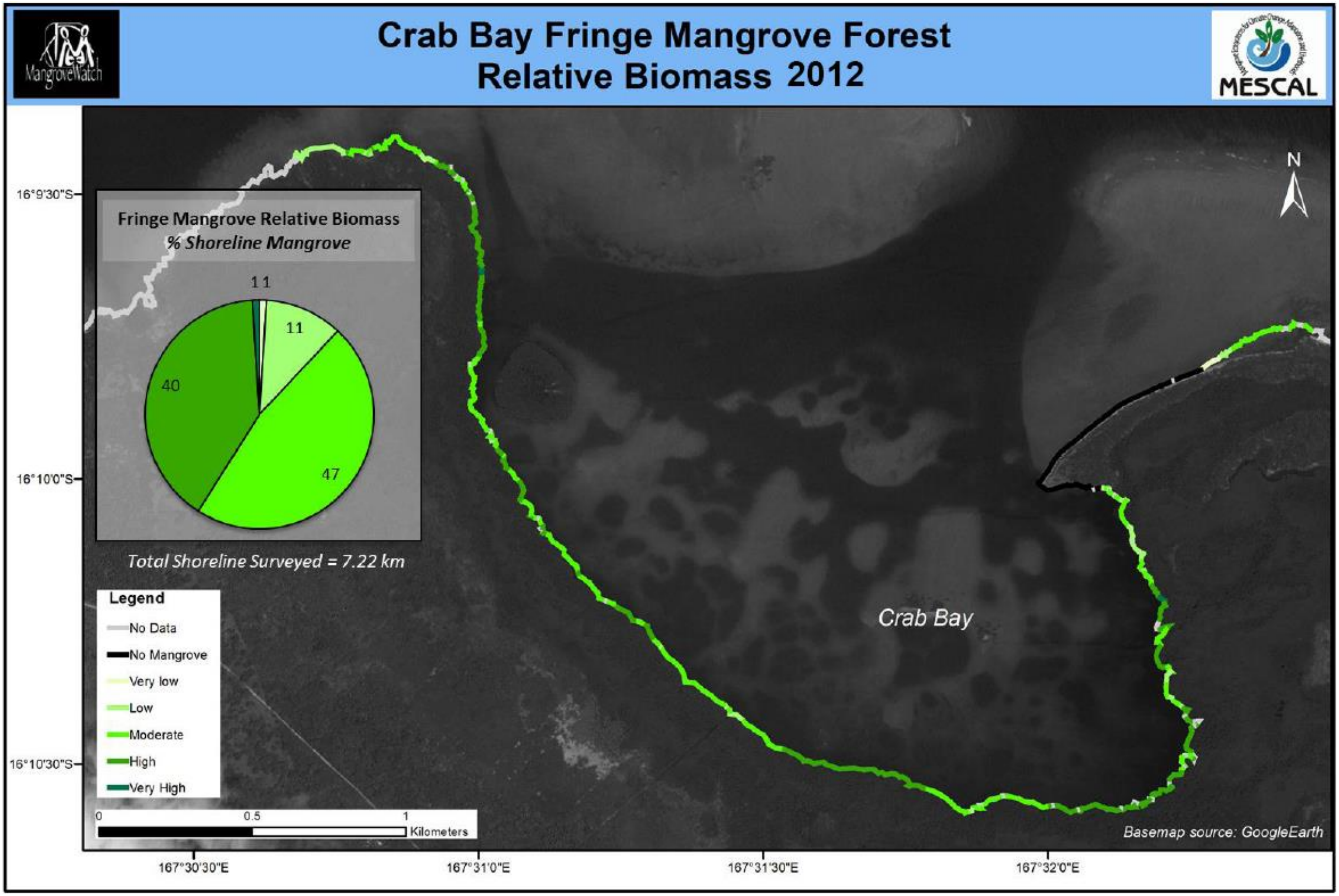


Figure 37: Forest biomass, Crab Bay fringe mangroves

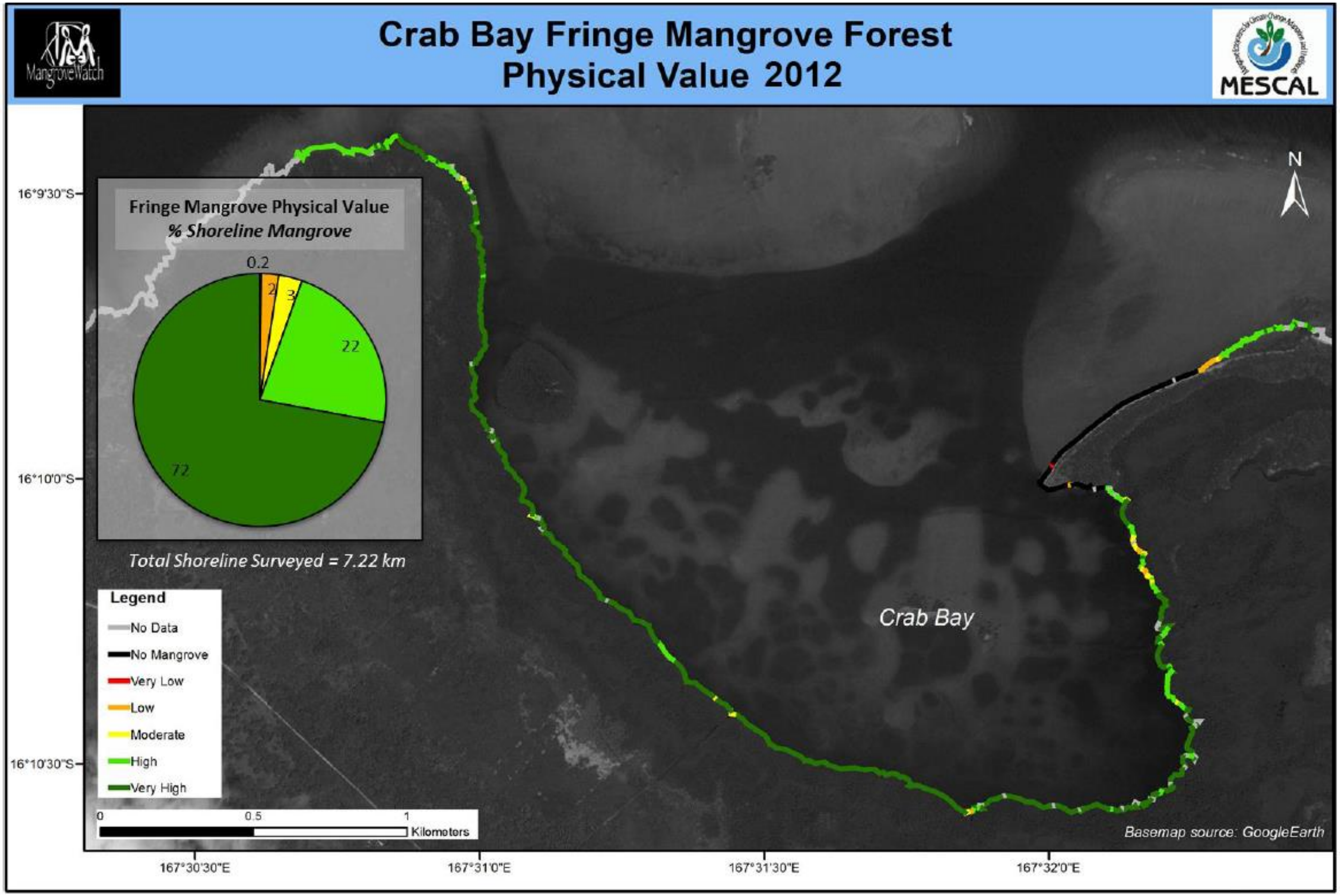


Figure 38: Physical value score, Crab Bay fringe mangroves

Condition of fringe mangrove forest

The majority of fringing mangroves along the surveyed shoreline are in very good or good health (90%) with a mean mangrove condition score of 4.6 ± 0.03. Seventy-five percent of mangroves were recorded as very healthy, having no visible signs of dieback (Table 9; Figure 5.4). Less than 2% of fringe mangroves were in poor condition. However, 12% of mangrove shoreline was observed as having noticeable or obvious dieback. Eleven individual dead trees were observed; 2.3 dead trees recorded per kilometre of shoreline. The mean canopy cover score was high; 4.2 ± 0.03 (see also Table 13).

Score	1	2	3	4	5
Dieback	<1%	5%	6%	15%	75%
Canopy cover	<1%	<1%	2%	21%	77%
Mangrove condition	<1%	1%	8%	15%	75%

Table 14: Mangrove health score distribution

Forest process

Within Crab Bay proper, fringing mangrove forest is stable, growing or expanding. Fringe mangrove forest is stable along 40% of the surveyed shoreline, and exhibits clear signs of growth along almost half of the shoreline (Figure 40). Where the survey extended beyond the bay area, mangroves become exposed to wind and wave action. This is evident at the Eastern and Western ends of the surveyed area.

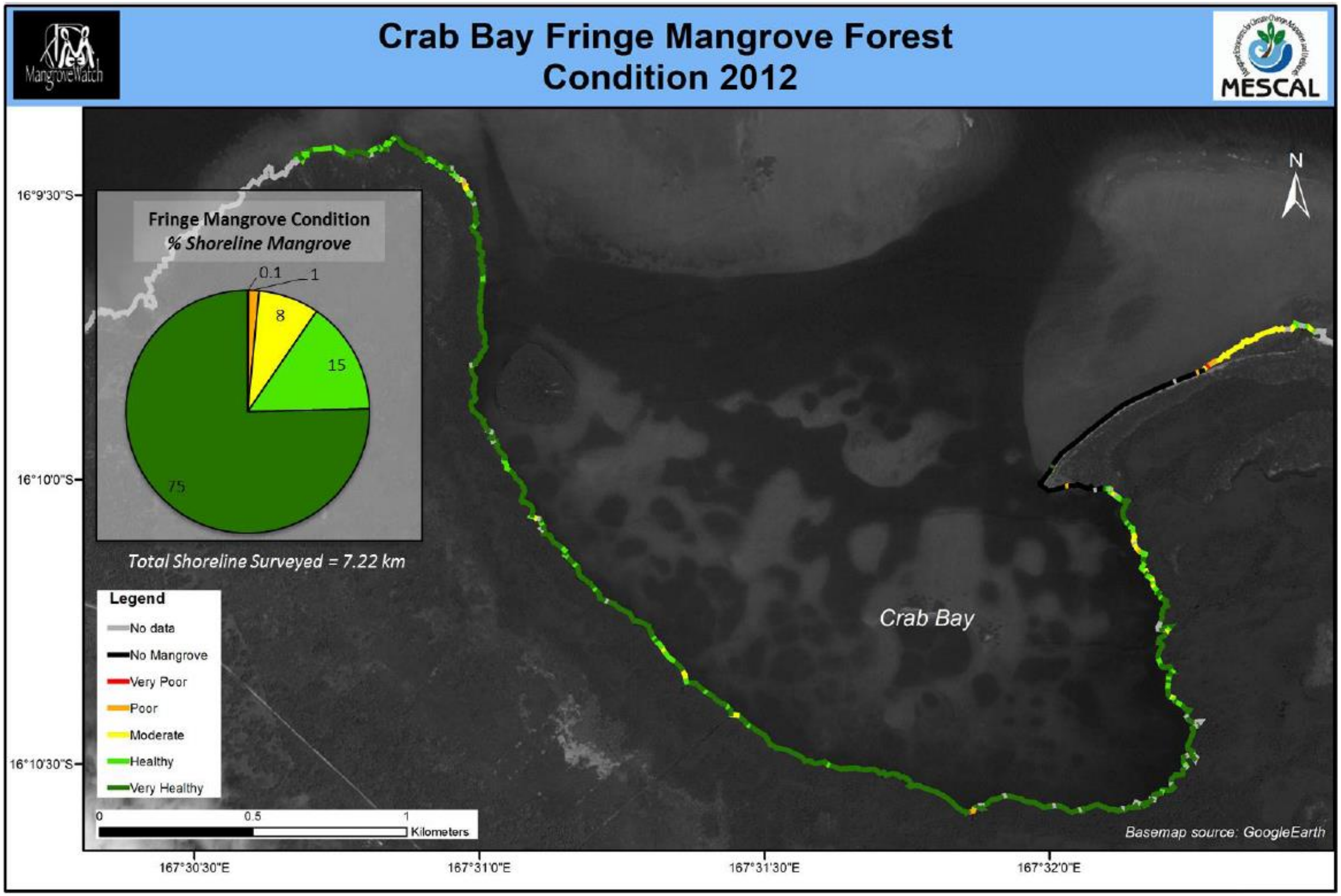


Figure 39: Forest condition, Crab Bay fringe mangroves

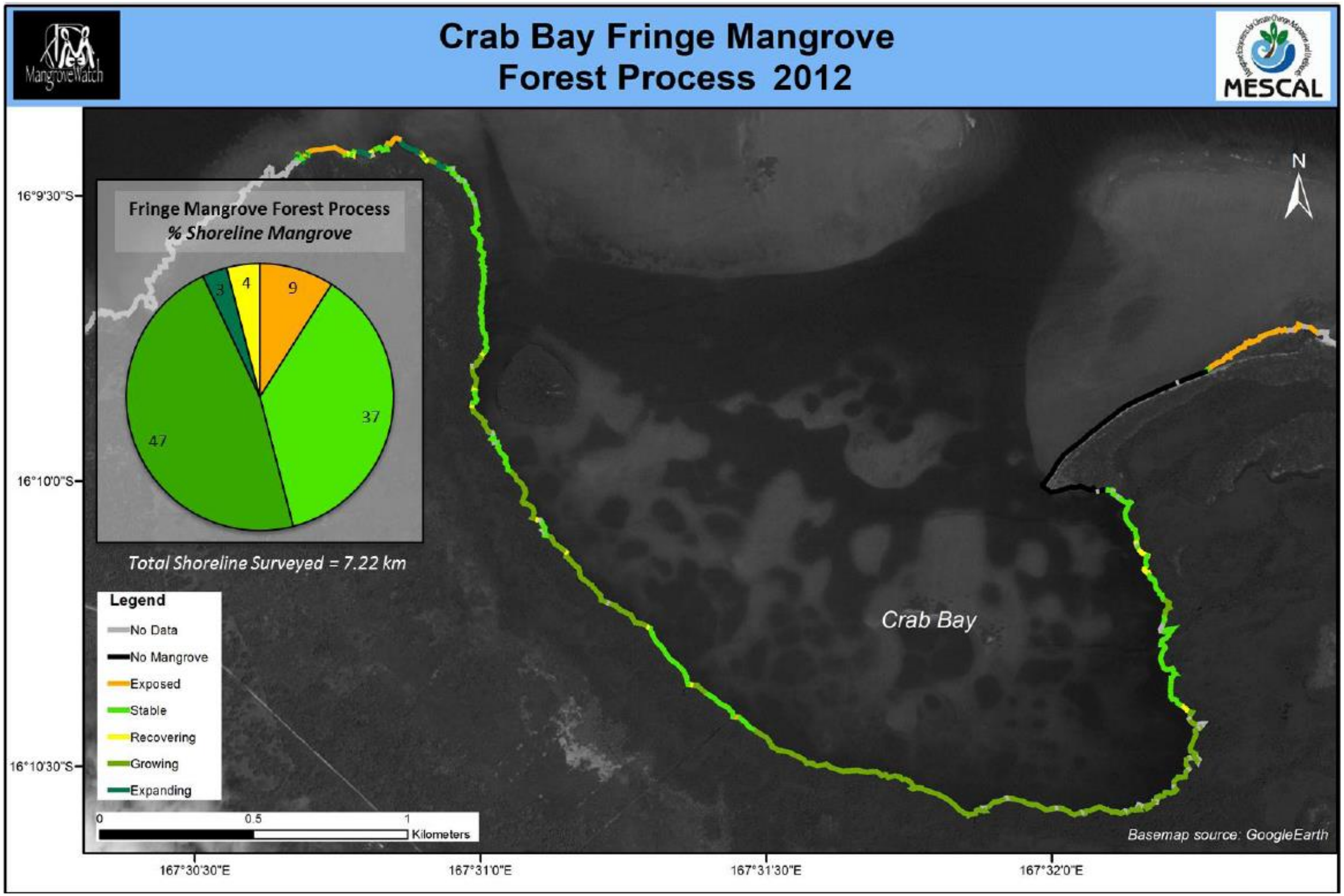


Figure 40: Forest process, Crab Bay fringe mangroves

Fragmentation of fringe mangrove forest

Fringing mangroves of Crab Bay are relatively in-tact with little obvious fragmentation. Five unnatural gaps in the fringing forest were observed (out of a total of 9 gaps), equating to 1.2 gaps per kilometre of shoreline. This is a very low rate of fragmentation. The average length of fringe forest patches was 631 m showing high connectivity and structural integrity. All unnatural gaps in the fringe were created for access to the shoreline or as a result of mangrove cutting (Figure 41).

Drivers of change

Mangroves in Crab Bay are exposed to low levels of natural and anthropogenic disturbance (Table 10; Figure 42), reflected by the general healthy condition of the fringing forest. Direct disturbances resulting in canopy dieback was identified in only 2% of fringing mangroves along the shoreline. However, unattributed disturbances are affecting mangrove condition as indicated by the level of dieback and reduced mangrove condition along an additional 8% of shoreline (Table 14; Figure 38).

Natural drivers include exposure to wind, wave and currents which are affecting a small amount of mangroves growing outside the area of Crab Bay proper. Three light gaps, most likely caused by lightning, strike are present along 50 m of shoreline.

Figure 41: Lightning strike damage (left) and a gap formed for shoreline access (right) in Crab Bay fringing mangroves

Inside the bay some cutting (80 m) and clearing (130 m) is evident, and what appear to be unnaturally formed gaps in the forest fringe are present in some areas (100 m). These are likely access trails for local communities.

Source	Driver	Shoreline affected (m)
Anthropogenic	*Unnatural gaps*	100
	Cutting	80
	Clearing	130
Natural	*Light-gap*	50
	Waves, wind, current damage	600

Table 15: Drivers of change in fringing mangrove forest

Other Observations

Shoreline erosion affecting non-mangrove shoreline habitats is present along the eastern outer bay shoreline.

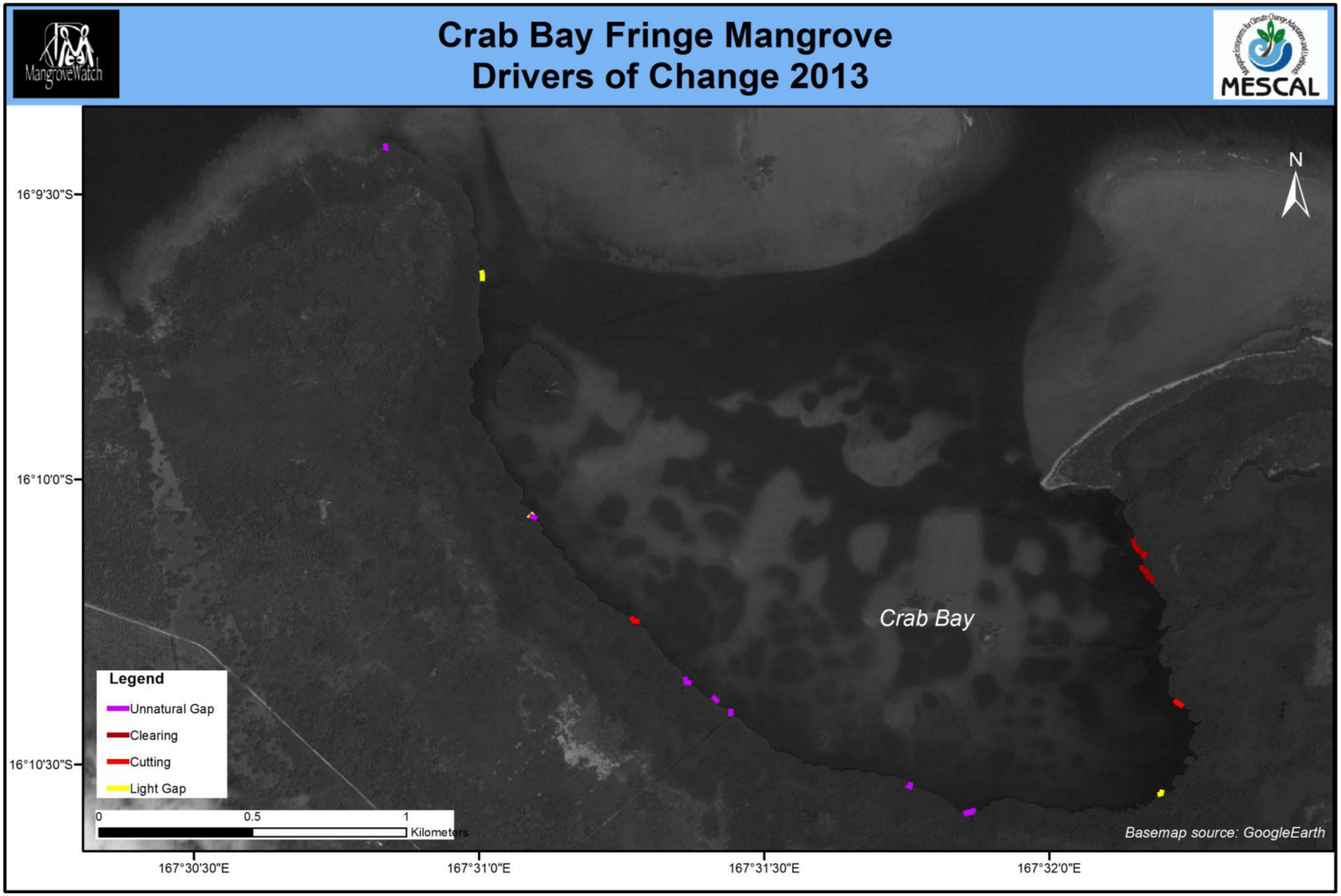


Figure 42: Drivers of change, Crab Bay fringe mangrove

Eratap Results

Survey area covered

The MESCAL team surveyed 6.65 km of the shoreline of Eratap on 27th September 2012. Figure 43 provides detail of the GPS track of survey travel and adjacent surveyed shoreline.

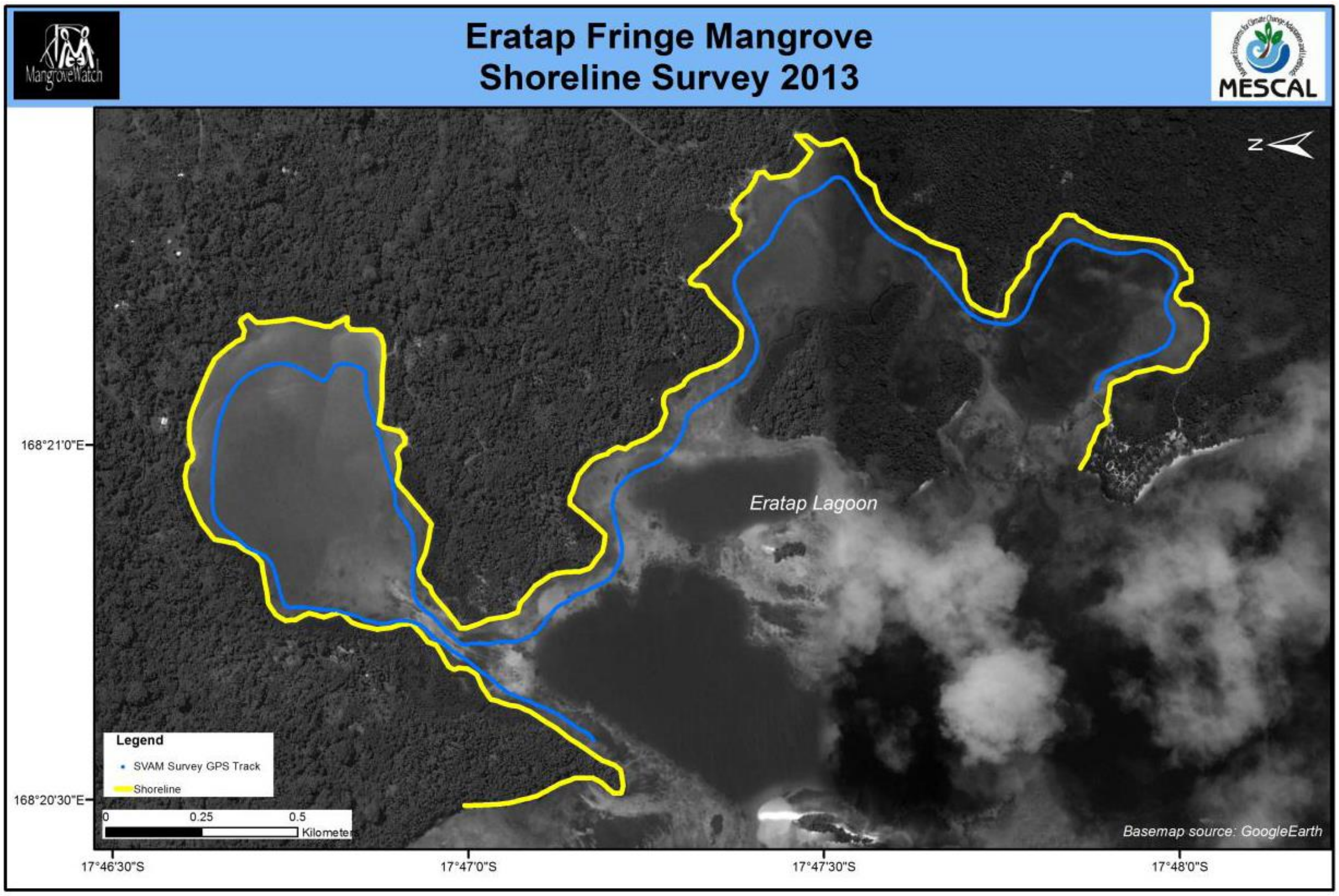


Figure 43: Shoreline video assessment, Eratap

Forest presence, biomass, physical value and habitat diversity

Mangroves were observed to occupy 5.71 km out of the total 6.85 km of shoreline representing 83% of 10 m shoreline segments assessed. Mean mangrove percent cover for shoreline segments was 79%, including non-mangrove areas. Forest height was relatively moderate across the surveyed shoreline, being estimated as approximately 5 m. The fringing forest is mostly of moderate to high biomass (67%; Figure 44). Mean mangrove forest height, structure score and biomass scores are provided in Table 16 and Table 11 provides a breakdown for the assessed forest structure, height, biomass and physical value scores. Figure 45 shows the distribution of physical value scores along the surveyed shoreline.

Mean Height (m)	Mean biomass score[1]	Mean structure score[1]	Mean canopy cover score[1]	Intertidal canopy[2]	Mean physical value score[1]
5.04 ± 0.04 *Moderate*	2.9 ± 0.04 *Moderate*	4.5 ± 0.04 *Closed-continuous*	4.4 ± 0.03 *60-80% cover*	34%	4.1 ± 0.03 *High*

Table 16: Summary of Eratap fringe mangrove forest structure and habitat diversity. [1]Relative score as described in methods. [2]Percentage of surveyed shoreline where part of the mangrove canopy becomes submerged during the tide cycle Mean Height (m) Mean biomass

Score	1	2	3	4	5
Height	4%	15%	37%	41%	3%
Forest structure	2%	3%	5%	25%	65%
Biomass	9%	23%	36%	31%	1%
Physical value	<1%	6%	12%	21%	58%

Table 17: Percentage of surveyed shoreline classified as falling within each forest structure score

Mangroves along the Eratap Lagoon shoreline are relatively structurally homogeneous. The dominant species appears to be *Rhizophora stylosa* (69%), with *R. apiculata* often present (and co-dominant) along the shoreline (43%; Table 18). *Avicennia marina* was present in more marine areas. *Sonneratia alba* was present in isolated stands within the lagoon. *Ceriops tagal* was observed where the upper inter-tidal zone was near the shoreline edge, often occurring as small shrubs.

Species name	*A. marina*	*R. apiculata*	*R. stylosa*	*S. alba*	*C. tagal*
% of shoreline dominated by species	8%	43%	69%	10%	3%

Table 18: Fringe mangrove species dominance. Note; percentages add to >100% where species are co-dominant

Fringing mangroves in Eratap Lagoon have high structural diversity (D=6.64) and habitat type richness (r=47) owing to variation in canopy cover along the shoreline related to habitat condition (see Table 20). The most common fringe habitat types are provided in Table 19. A very low habitat evenness score (E=0.14) reflects how the presence of remaining factors (stem density, canopy layers, intertidal canopy, aerial root structures) are relatively similar across the surveyed shoreline. The most common structural attribute association is closed continuous, *Rhizophora* dominated fringe forest with inter-tidally submerged canopy and either very high canopy (34%; Table 19, types 1 and 2).

Habitat 'type'	*Stem density*	*Canopy cover*	*Intertidal canopy*[1]	*Aerial root structures*	*Canopy layers*	**% Shoreline**
1	Closed-Continuous	80-100%	No	Prop Roots	Fringe Only	34%
2	Closed-Continuous	60-80%	Yes	Prop Roots	Fringe Only	10%
3	Open-Continuous	80-100%	No	Prop Roots	Fringe Only	9%
4	Closed-Continuous	60-80%	Yes	Prop Roots	Fringe Only	9%
5	Open-Continuous	60-80%	Yes	Prop Roots	Fringe Only	7%

Table 19: Five most common fringe mangrove habitat 'types' contributing to habitat type richness. 1Percentage of surveyed shoreline where part of the mangrove canopy becomes submerged during the tide cycle

Fringing *Rhizophora* forest generally has very high structural complexity that is beneficial to mangrove shoreline protection and stabilisation capacity and water quality improvement. As such the fringing mangroves surveyed have an overall high mean physical value score (4.1 ± 0.05). The value of the fringe with respect to shoreline protection and water quality improvement capacity was diminished in some locations by poor mangrove health and fragmentation.

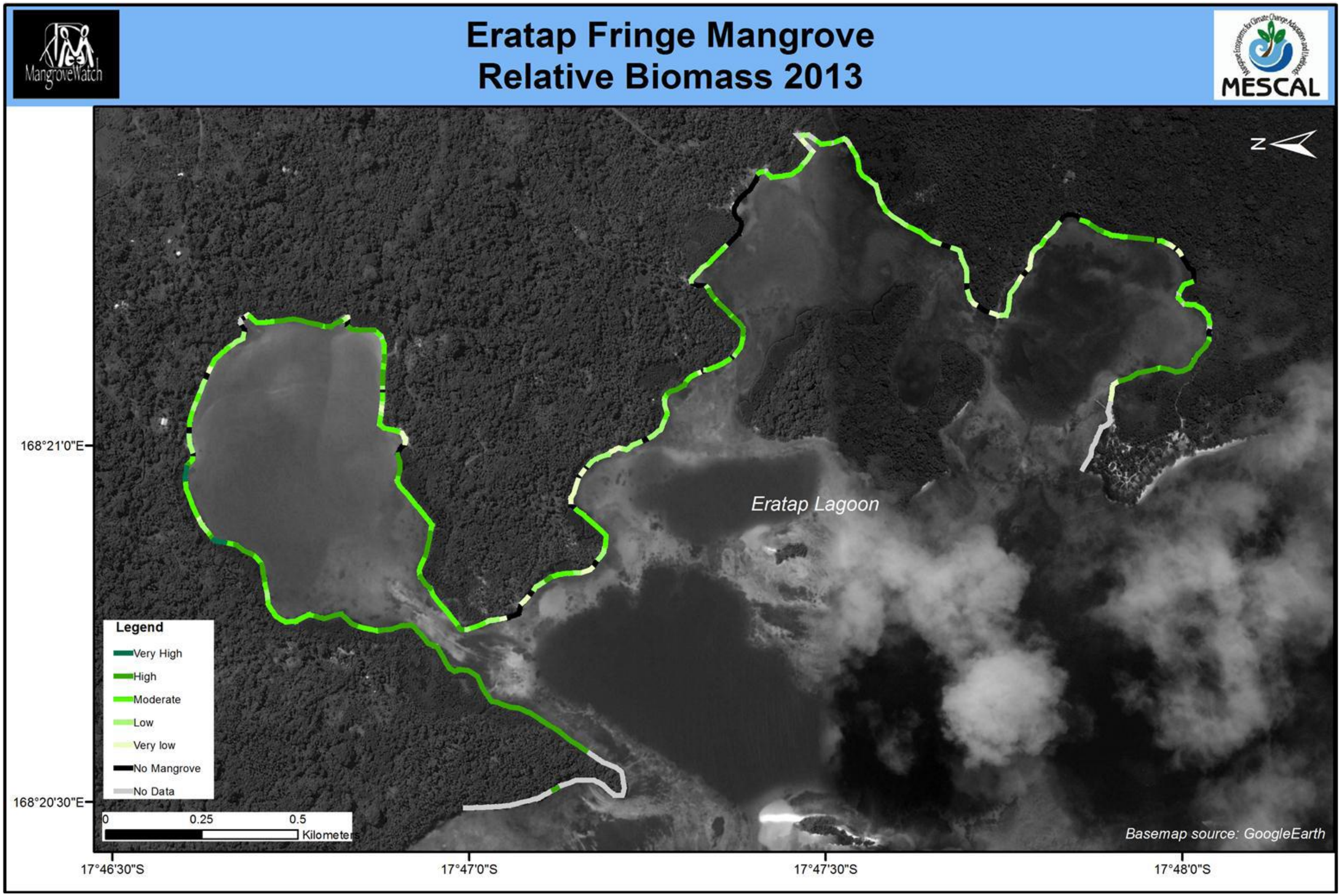


Figure 44: Forest biomass, Eratap fringe mangroves

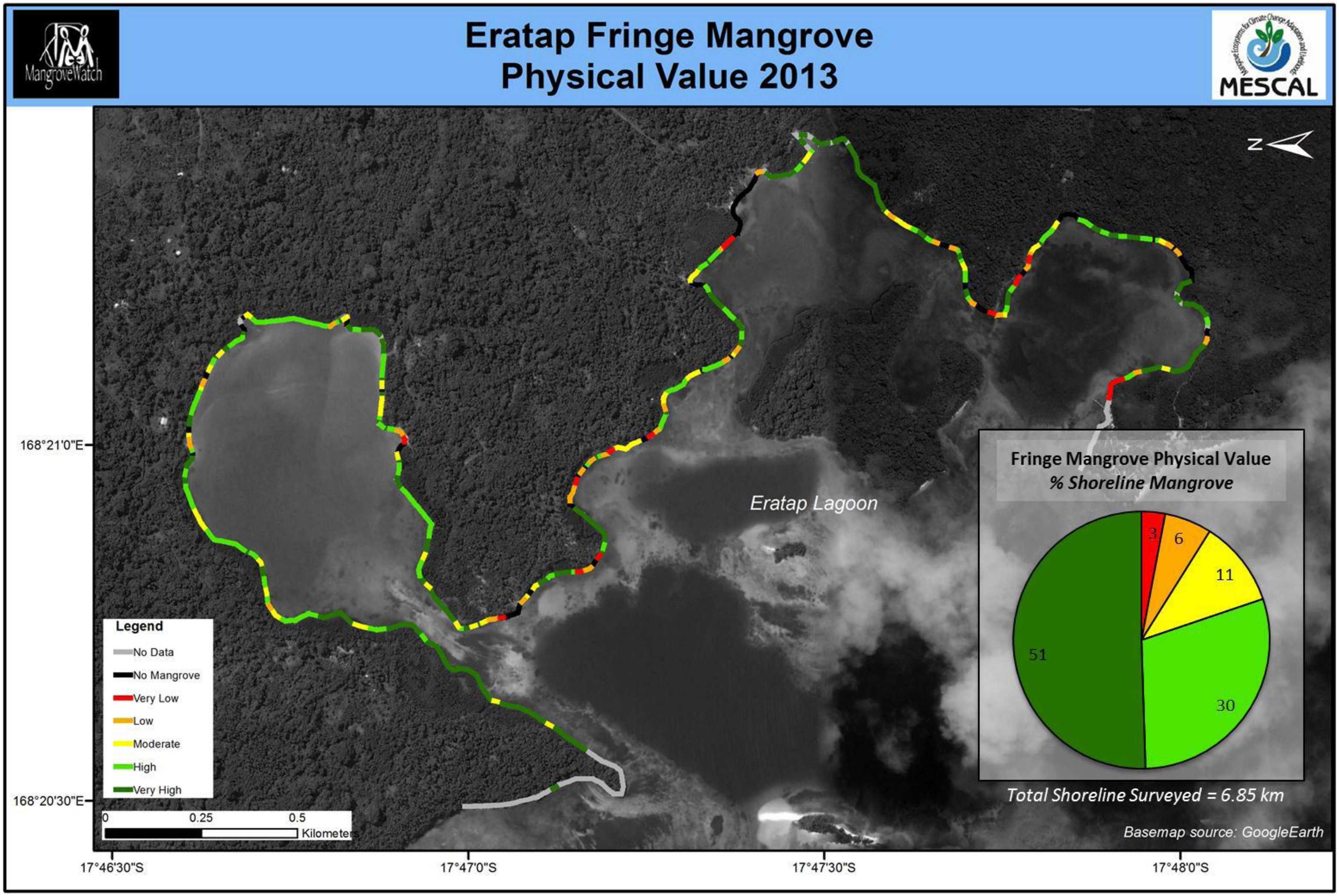


Figure 45: Forest biomass, Eratap fringe mangroves

Condition of fringe mangrove forest

The majority of fringing mangroves along the surveyed shoreline are in very good or good health (78%) with a mean mangrove condition score of 4.2 ± 0.04. Forty-eight percent of mangroves were recorded as very healthy, having no visible signs of dieback (Table 20; Figure 46). Twenty-two percent of fringe mangroves were less than healthy having either low canopy cover, dieback or experiencing cutting. Dieback was obvious in fringe mangroves along 35% of the shoreline, giving an overall low dieback mean score (4 ±0.05). Fifteen individual dead trees were observed, occupying 2.6% of the shoreline, with 2.6 dead trees per km. The mean canopy cover score was high; 4.4 ± 0.03 (60-80% cover; see also Table 20), showing that mangrove fringe forests have relatively open, yet continuous, canopies in Eratap Lagoon.

Score	1	2	3	4	5
Dieback	3%	7%	25%	19%	48%
Canopy cover	<1%	<1%	8%	39%	52%
Mangrove condition	2%	3%	17%	25%	53%

Table 20: Mangrove health score distribution

Forest process

Eratap fringing mangroves are generally stable (85%), however on just over 10% of the shoreline fringe mangroves are either exposed (5.8%) or retreating (5.4%). Expanding mangrove forest is present along 2.8% of the shoreline (Figure 6.5). Very little shoreline mangrove showed signs of new growth (0.7%). Retreating and exposed mangrove were mostly present within the small embayment at the northern end of the lagoon.

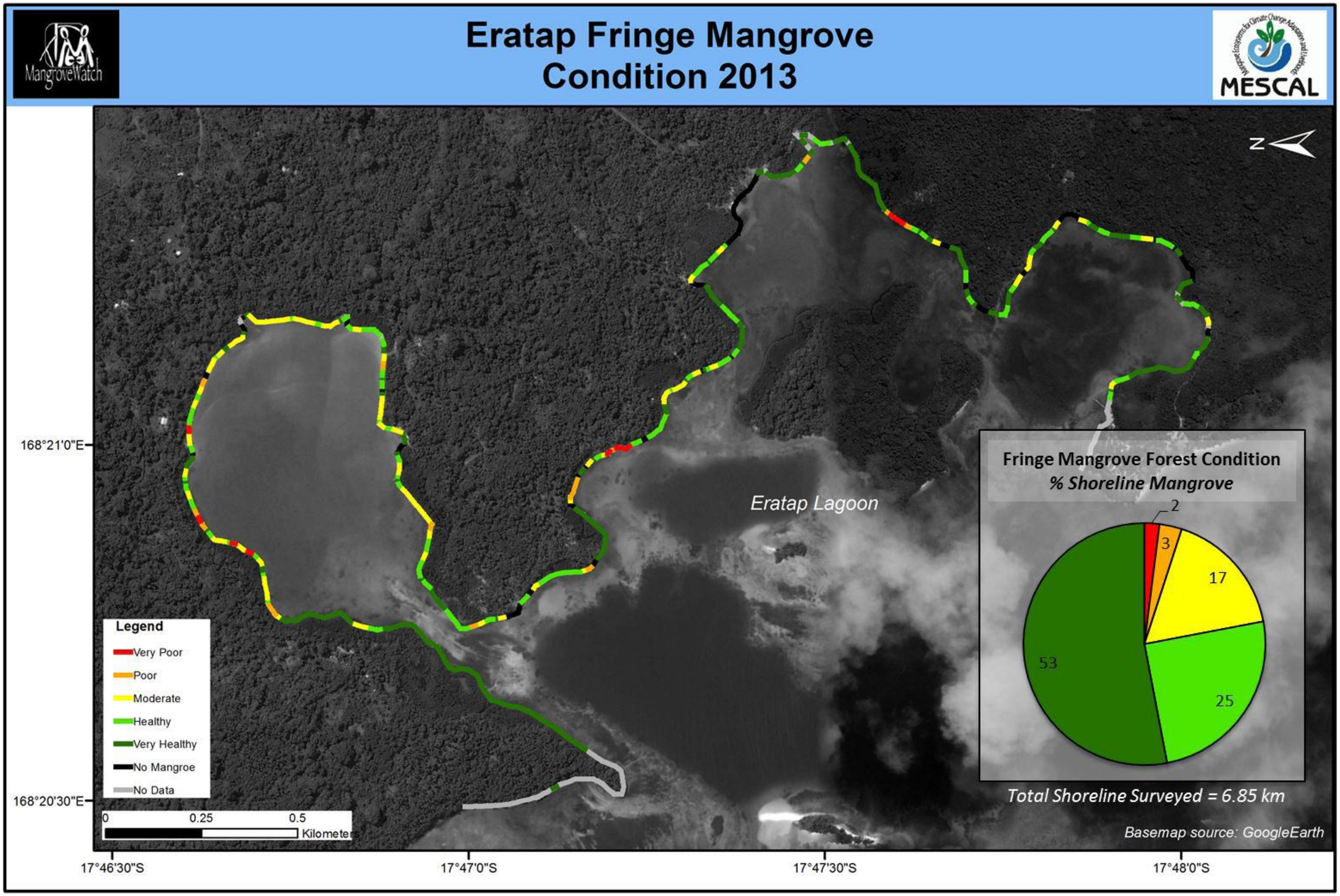


Figure 46: Forest condition, Eratap fringe mangroves

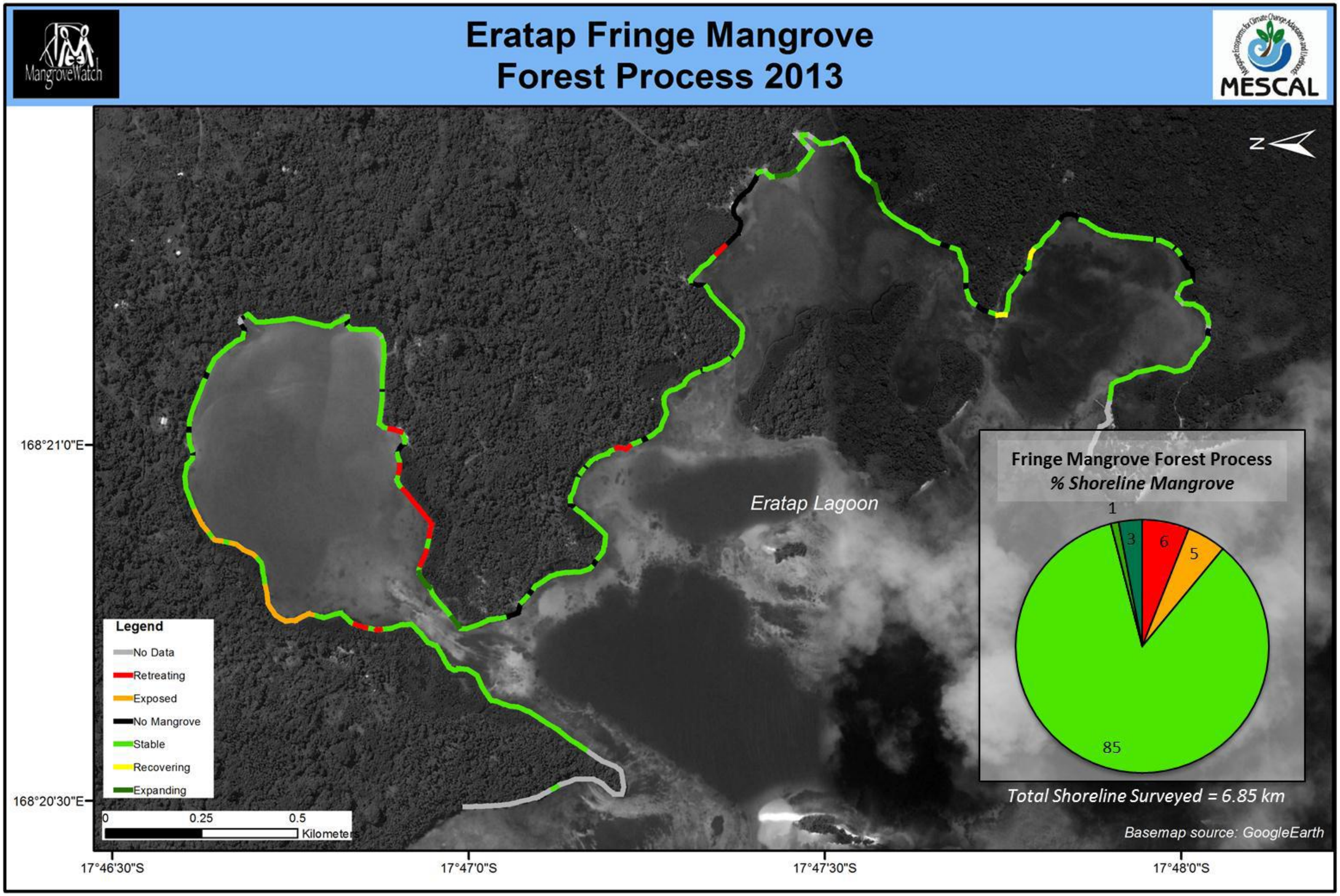


Figure 47: Forest process, Eratap fringe mangroves

Fragmentation of fringe mangrove forest

Fringing mangroves of Eratap Lagoon are fragmented with 50 gaps in the mangrove fringe observed equating to 7.3 gaps per kilometre of shoreline. Half (25) of the forest gaps can be attributed to recent or historic coastal development and mangrove clearing. The average length of fringe forest patches was 100m.

Drivers of change

Mangroves in Eratap Lagoon are exposed to high levels of anthropogenic disturbance (Table 15; Figure 49), which is reflected by the level of fragmentation and high proportion of mangroves with less than healthy condition. The primary anthropogenic driver of mangrove habitat degradation is coastal development related to recent and historical clearing (670 m) and cutting (450 m). The construction of Aquana Beach resort has resulted in the loss of approximately 220 m of mangrove. Sand deposited during construction is impacting 40 m of adjacent mangrove due to root burial (Figure 48). Natural drivers of change are also affecting Eratap Lagoon fringing mangroves. The primary natural driver appears to be wind, wave and currents, causing shoreline exposure and mangrove retreat along 640 m of shoreline (Figure 47).

Source	Driver	Shoreline affected (m)
Anthropogenic	*Unnatural gaps*	590
	Cutting	450
	Clearing	670
	Root Burial	40
Natural	*Light-gap*	10
	Waves, wind, current damage	640

Table 21: Drivers of change in fringing mangrove forest

Figure 48: Drivers of change in Eratap fringing mangroves: Cutting (top left), clearing for a new coastal development (top right), and root burial causing mangrove dieback adjacent to resort development (bottom)

Other Observations

The Eratap Lagoon is shoreline is mostly raised coral reef platform with a sharp delineation between terrestrial and intertidal habitats and limited intertidal zone width available for mangrove colonization.

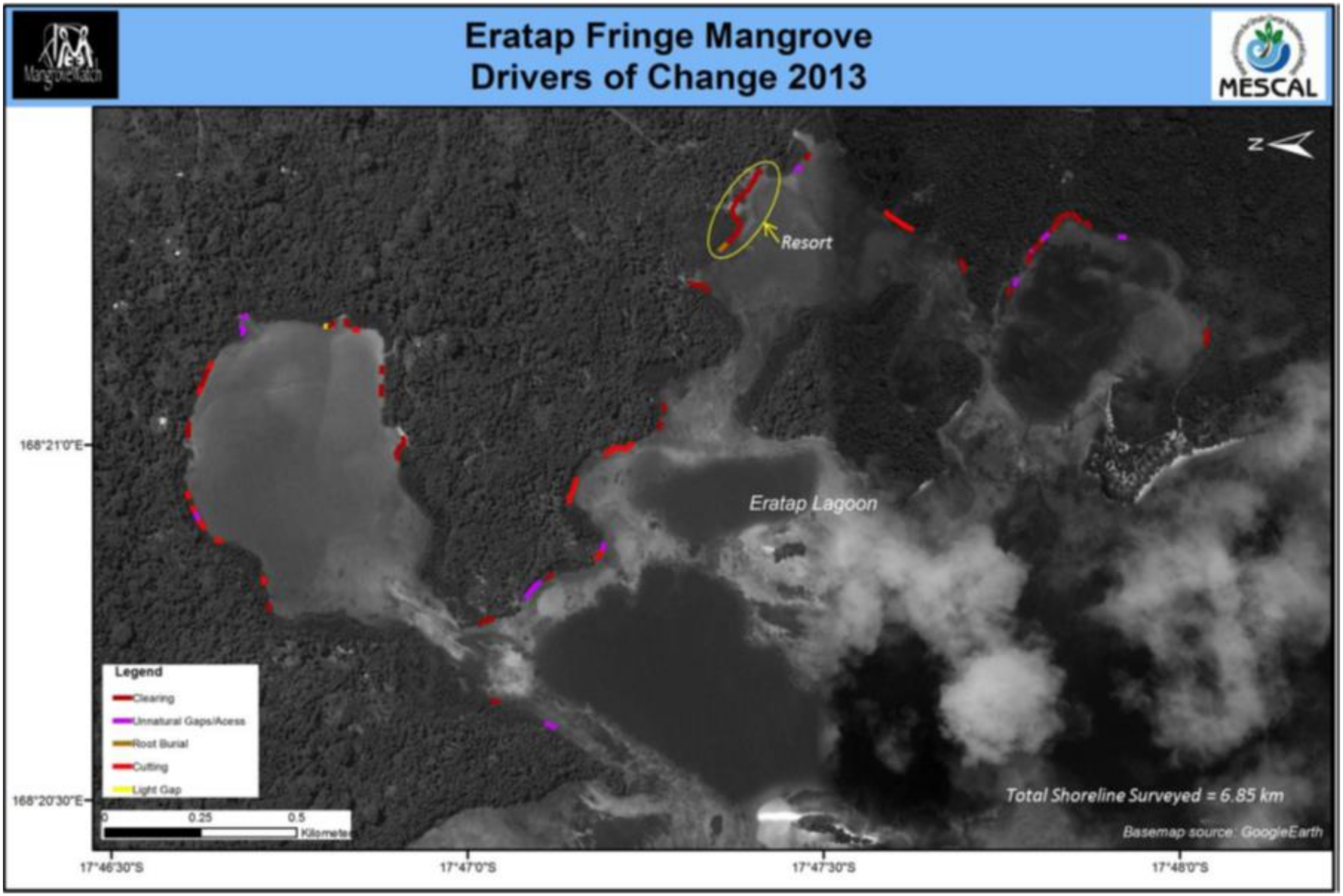


Figure 49: Drivers of change, Eratap fringe mangrove

Discussion

This report provides critical baseline information to inform future management of valuable fringing mangrove habitats in Vanuatu for the maintenance and improvement of mangrove ecosystem resilience to climate change. Pacific Island Countries and Territories (PICTs) are particularly susceptible to climate change impacts due to their often low elevation and large coastal frontage relative to landmass (SPREP 2012). Mangroves are particularly susceptible to changes in sea level and increases in storm intensity due to their location within the tidal zone at the shoreline edge (Lovelock and Ellison 2007, Alongi 2008, Hoegh-Guldberg and Bruno 2010, Knutson et al. 2010). Tropical cyclones are the most destructive force facing the coastal environments and communities of PICTs (Kuleshov et al. 2012, SPREP 2012). In the Pacific region, climate change predictions indicate tropical cyclone intensity will increase, and the frequency of cyclones will change in the over the coming decades (Kuleshov et al. 2012, Walsh et al. 2012). Shoreline vegetation can provide significant shoreline protection to coastal communities by buffering wave action and reducing the impact of storm surge upon adjacent infrastructure (McIvor et al. 2012a, McIvor et al. 2012b). Tropical cyclone induced increases to wind and wave intensity have dramatic implications for mangrove forests, defoliation or snapping trees, and changing the soil elevation profile or chemistry, all of which cause mortality (Smith et al. 1994, Gilman et al. 2008).

The capacity of coastal vegetation to adapt to sea level rise and survive storm events is affected by the health and extent of the ecosystems (Alongi 2008). Reductions in extent, structural complexity, and condition of mangrove ecosystems can lead to accelerated coastal erosion, with serious implications for coastal developments and human safety (SPREP 2012).

The management of coastal vegetation for its protective capacity is identified as a worthwhile adaptation measure already being pursued in the Pacific region (SPREP 2013). The habitat value of mangroves is also well recognised, particularly for supporting local and commercial fisheries (Nagelkerken et al. 2008). Mangroves are increasingly becoming recognised as a valuable carbon store that can help in efforts to minimise destructive climate change (Donato et al. 2011). Overexploitation, pollution, deforestation, and ill-advised infrastructure development have been identified as human induced pressures facing the mangroves and coastal vegetation of PICTs generally (Bank 2000). Management of these human pressures will help to build resilience in coastal vegetation communities (Alongi 2008), will enhance their capacity to protect coastlines and communities from erosion and storm damage (McIvor et al. 2012a, McIvor et al. 2012b) and will maintain other ecosystem service values such as habitat (Alongi 2002, Nagelkerken et al. 2008) and carbon storage (Donato et al. 2011). There remains, however, an insufficient level of understanding of the condition and extent of coastal vegetation communities throughout the region from which to make informed management decisions. Data presented in this report provides an assessment of 7.22 km of fringing mangrove forest of Crab Bay, Malekula, and 6.85 km of fringing mangrove forest of Eratap, Efate; the two MESCAL demonstration sites in Vanuatu. From this data, informed management actions can be taken to address anthropogenic pressures currently identified as negatively impacting the health and extent of mangrove forests within the surveyed area.

The assessment of two distinct areas in Vanuatu provides capacity for comparison between the demonstration sites and enables a more holistic view of mangrove forest structure, condition and threats throughout Vanuatu that can inform future mangrove management. The results presented here show that mangrove forest structure is relatively similar at Crab Bay and Eratap Lagoon. However, there are key differences in structural integrity between the two sites relating to ecosystem service provision and resilience capacity. These differences are for the most part due to adjacent human population densities, the proximity of the sites to urban centres, and coastal geomorphology. Crab Bay shoreline is of relatively low-relief with a gradual intertidal slope allowing for expansive tidal wetland areas. In comparison, much of the Eratap lagoon shoreline is raised coral reef platform, with sharp delineation between terrestrial and intertidal habitats and limited intertidal margins suitable for mangrove colonisation. Eratap Lagoon is 6 km from the capital Port Vila, an area of high population density, whereas Crab Bay is more isolated and surrounded by small villages and low-intensity land use.

Comparisons of mangrove structure between the two survey locations show that fringing mangroves within Eratap Lagoon generally have lower stem density, more open canopies and less intertidal canopy compared to fringing mangroves in Crab Bay. In Crab Bay the canopy was on average a closed continuous structure, with high canopy cover and a high proportion of intertidal canopy present. These variations in forest structure are likely a result of differences in coastal geomorphology between the sites, but may also relate to greater anthropogenic pressure experienced at Eratap.

High levels of cutting, clearing and habitat fragmentation were observed at Eratap compared to Crab Bay. In Crab Bay the average length of a continuous mangrove fringe (between gaps) was 631 m. In Eratap this distance was only 100 m. These differences in fragmentation are probably due to both greater demand for wood resources relating to proximity of the site to Port Vila, and generally elevated population density on Efate compared with Malekula. The close proximity of Eratap to Port Vila also increases coastal development pressure, e.g. for resort developments.

Fringing mangrove habitat in Eratap Lagoon was in poorer health than in Crab Bay. The hard coral platform substrate of Eratap Lagoon would very likely influence mangrove growth and condition. Additionally, Eratap mangrove condition is partly related to greater exposure to climatic variations (wind, waves and currents) of this site compared with the protected interior of Crab Bay, and the intensified effect these have on the fragmented mangrove forest at Eratap.

Habitat fragmentation is known to negatively affect ecosystem health and resilience {McLeod and Salm 2006}. The capacity of mangrove stands to provide ecosystem services are also negatively impacted by reductions in forest density and condition (Victor et al. 2004, McIvor et al. 2012a, McIvor et al. 2012b). Mangroves in Eratap Lagoon received a lower fringing mangrove physical value score compared with Crab Bay mangroves. As a result, it is likely that Eratap Lagoon mangroves have lower capacity to buffer wind, waves and storm surges and maintain good lagoon water quality. Additionally, in some circumstances habitat fragmentation may actually exacerbate damaging waves and storm surges; increasing risk of habitat loss and damage to coastal infrastructure (McIvor et al. 2012b).

Habitat fragmentation reduces connectivity, having likely negative impacts on value of the mangroves as fish habitat (Sheaves 2005). As such, despite Eratap Lagoon exhibiting higher mangrove structural complexity and habitat diversity, it is likely that the habitat value of Crab Bay mangroves is the higher of the two demonstration sites due to the low rates of fragmentation at this site. Additionally, habitat value is positively influenced by high mangrove productivity. Healthy mangroves have higher rates of productivity, which in turn influences fisheries productivity (Twilley 1988, Barbier and Strand 1998). Crab Bay mangroves are healthier than those in Eratap Lagoon; likely resulting in higher productivity and habitat value in Crab Bay mangroves.

Both Eratap Lagoon and Crab Bay are experiencing some degree of mangrove loss and exposure associated with shoreline erosion. In Crab Bay exposed mangrove areas, which represent potential loss, are offset in part by areas of mangrove expansion. In Eratap lagoon there is both greater extent of mangrove retreat and exposure, and little mangrove expansion occurring. Consequently, there is a greater net loss of mangrove fringe in Eratap Lagoon.

Whilst some areas in Crab Bay have experienced natural and anthropogenic damage, recovery and regrowth in areas previously damaged shows that Crab Bay has high resilience capacity. Mangroves in Crab Bay were observed to be increasing in biomass through forest growth, a further indicator of the health of mangroves in this area. Comparatively, in Eratap Lagoon no recovery of the fringing mangroves was observed, and little evidence of forest growth were identified. These forest processes indicate what may be a lower resilience capacity of mangroves in Eratap Lagoon compared with Crab Bay mangroves.

The coastal geomorphology of Eratap Lagoon is a limited intertidal zone abutting a sharp increase in relief (an elevated step), meaning mangroves are mostly restricted to a narrow shoreline fringe. The absence of extensive mangrove areas in Eratap Lagoon elevates the importance of the mangrove fringe for coastal defence, water quality improvement and habitat provision compared to areas that have basin forest mangroves behind the fringe such as occurs in Crab Bay. Additionally, the stepped physical profile means that mangroves of Eratap Lagoon are highly at risk of sea level rise impacts, as both accretion capacity and landward encroachment is likely to be low (Lovelock and Ellison 2007). Identification and implementation of management actions that build the resilience and adaptation capacity of Eratap mangroves are of great importance at this site, particularly given the documented low rates of natural mangrove recovery and regrowth. The current study has identified relatively high levels of anthropogenic disturbance within Eratap fringing mangroves. Actions which work to limit or reduce further anthropogenic disturbances will have likely positive outcomes for climate change adaptation capacity and resilience of mangroves in Eratap Lagoon.

Conclusions

This report highlights the importance of managing anthropogenic disturbance to maintain fringing mangrove habitat structural integrity, ecosystem function and climate change adaptation and resilience capacity. The information presented here provides a baseline from which to assess future habitat change and monitor the success of management actions. The maps presented in this report highlight areas of fringing habitat that have low structural integrity and reduced condition, with key drivers of change spatially identified. Fringing mangrove habitat with reduced structural integrity or in poor condition due to natural or anthropogenic disturbance should be considered management priorities to improve habitat value and resilience. Specifically, fringing mangroves in Eratap Lagoon require greater protection from anthropogenic fragmentation, clearing and cutting in order to maintain ecosystem values and climate change resilience capacity. Additionally, restoration of damaged areas may be required to assist timely habitat recovery, particularly given the lack of observed natural recovery in Eratap Lagoon.

The data presented here applies specifically to the demonstrations sites surveyed, but the issues reported are likely indicative of general trends in mangrove forest management issues for mangroves throughout Vanuatu and the Pacific. Presently there is little data available on the condition and structure of mangrove forests in the Pacific and presence, extent and intensity of natural and anthropogenic pressures that may reduce mangrove ecosystem function and their climate change adaptation and resilience capacity. More information is required regarding sustainable use of mangrove forests and the extent to which fragmentation and disturbance of fringing mangroves can occur without greatly reducing habitat function and integrity. This information is particularly relevant in the context of climate change and increasing population pressure in the Pacific coastal zone. Such information can only be gained through broad-scale assessment of mangrove habitats in a variety of locations and from long-term monitoring using methodologies such as SVAM. Engaging local communities in mangrove assessment, monitoring and management through a program such as MangroveWatch will strengthen efforts to maintain mangrove habitat function and value, balanced with local resource needs.

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Section 5. MESCAL Project Mangrove Fisheries Surveys of Amal/Crab Bay (Malekula) and Eratap (Efate), Vanuatu.

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Introduction

Mangrove forests represent some of the most extensive wetland vegetation in Vanuatu and its distribution is limited to only some of the islands in localized areas in sheltered coasts (Bani & Esrom, 1993). Other smaller mangrove stands are also found at the following localities Hiu, Efate, Emae, Epi, Vanua Lava, Ureparapara, Mota Lava and Aniwa. The only significant mangrove stands are two large extents along the east coast of Malekula, Port Stanley and Port Sandwich, while elsewhere mangroves occur only as small stands or narrow belts along lagoons, sea shores and estuaries (FAO, 2005). In a few sites in Vanuatu, the landward fringe has been affected by the conversion to agriculture use, such as coconut plantations, encroachment of land leases and informal housing. In other areas they have been removed for coastal development, as in the Maskelyne Islands and in the Port Vila area (FAO, 2005; Bani & Esrom, 1993). The objective of this study was to conduct a rapid but representative survey of fish and mobile crustacean assemblages of Crab Bay/Amal Area and Eratap as a first step to understanding the areas mangrove faunal biodiversity and fisheries resources. This work will only represent a single snapshot in time but is aimed at providing a strong basis in both faunal representation and methodological approaches to:

- Provide a good spatial representation of the most common species (those making up more than 20% of occurrences) present at the time of sampling;
- Detect the occurrence of at least the most commonly occurring 90% of all mobile fish and crustacean species present at the time of baseline sampling;
- Begin to define the occurrence of key life-history stages in the bay;
- Provide a strong starting point for developing a fisheries fauna guide as a standard allowing comparisons between this and future studies;
- Provide a base-line for future sampling at different times of year to allow the base-line data to be extended with temporal understanding, on-going monitoring, and more detailed habitat-specific studies.

The sampling protocol, study site sampling areas and analysis of this work was carried out by Dr. Marcus Sheaves and Mr. Ross Johnston of TropWater, James Cook University, Townsville, Australia. All fieldwork was carried out by Mr. Jayven Ham and Mr. Jeremie Kaltavara of the Department of Fisheries. This report is a combination of both field reports and the reports produced by Dr. Sheaves and Mr. Johnston.

Study Sites

Crab Bay/Amal Area, Malekula Island

Five high priority sites in Crab Bay will be sampled (Fig. 50) and a sixth, lower priority site, has been suggested to encompass a small section of coastal mangrove outside the southern headland of the bay. Sampling in site six should only be considered once sampling in the five high priority sites has been completed and only if resources to do so are available.

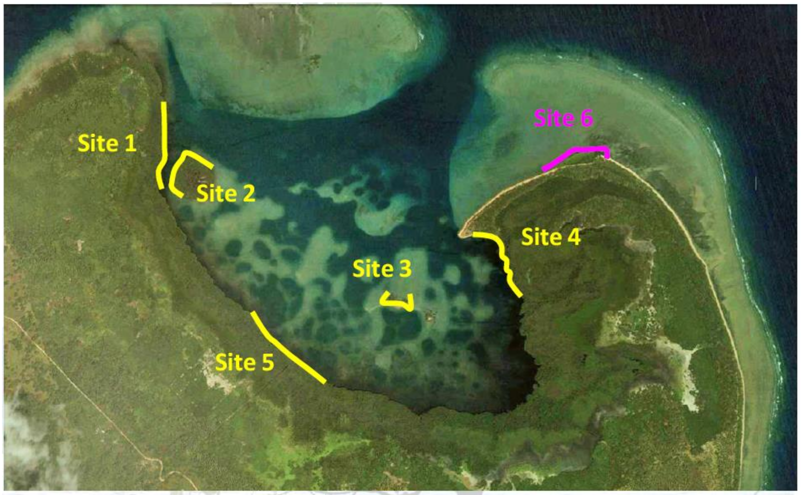

Figure 50: Approximate locations of the five (5) primary (yellow, sites 1-5) and one (1) secondary sampling site (pink, site 6) oin Crab Bay. Sites 1-5 are in the lagoonal mangrove zone. Site 6 is a coastal mangrove zone and the aerial extent is too small to allow multiple sites. Sites 1, 4 and 6 are in the "tabu" areas.

Eratap, Efate Island

Three sites in the Eratap demonstration site will be sampled (Fig. 51).

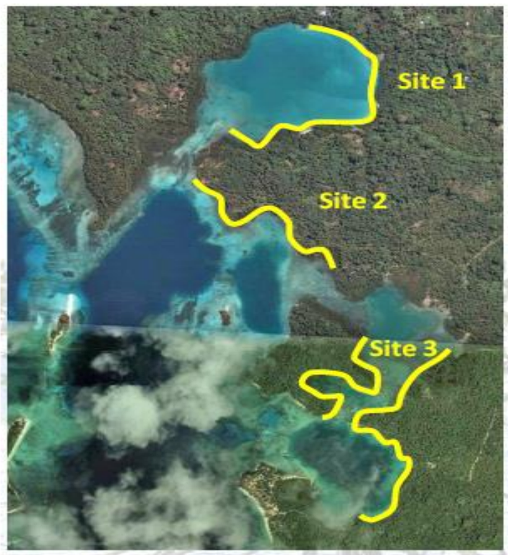

Figure 51: Approximate locations of the 3 sampling sites in the Eretap. It may be more difficult to find suitable sampling points in site 3 due to the dense seagrass meadows in this part of site so the length of this site should be determined by the distribution of accessible sampling points.

Sampling Protocol

Crab Bay/Amal Area, Malekula Island

The initial plan is to sample 1 zone (Table 22):

1. Lagoonal mangrove zone, the shoreline of Crab Bay.

Zone	Characteristics
lagoonal mangrove	The mangrove zone lining the entire bay section of the Crab Bay demonstration site. On-site validation indicates the entire bay appears to be a single, relatively homogeneous, low energy zone. Substrate type along mangrove edges varies from mud to sand and rock. Outer edges of mangrove forests are only drained at low tide in small areas so opportunities for effective fish sampling are greatly reduced because fish are able to access mangrove forests at all times in most of the bay.
coastal mangrove	Mangroves growing along the more exposed shoreline in site six (6) outside the southern headland. There may be associated sand/rock flats, sometimes with areas of seagrass or macro-algae.

Table 22: Zone Characteristics

The mangrove zones may comprise of a number of habitats. The intention is to produce a broad understanding of the fauna of those zones by sampling the dominant habitats, and concentrating sampling along edges where most fish species occur in highest abundances.

The aim is to sample multiple sites in the lagoonal mangrove zone and due to its small aerial extent a single site in the coastal mangrove zone to ensure that key baseline fisheries data are collected. Sampling locations have been prioritised to ensure that a core of key data are collected if sampling is limited due to logistic constraints. It is essential that the five high priority locations are sampled to ensure good representation of fish and crustacean faunal assemblages of Crab Bay however an additional sampling location, coastal mangrove (site 6) has been suggested (lower priority site) should time and resources permit additional sampling.

The mangrove zones will be sampled with a suite of gears suitable for the area (Table 23). Because of the possibility of different substrate conditions across the zone different gears will need to be employed in specific habitat types. One gear, cast nets, will be employed across all habitats to provide standardisation. Although the cast net data will be comparable across habitats, the full data set for each habitat will not be directly comparable on a quantitative basis because of the variety of gears used. Consequently, the primary comparisons will be based on species occurrences rather than comparative estimates of abundance.

Sampling sites within the demonstration site should be approximately 500 metres long but their exact position needs to be determined on-ground by those conducting the sampling. Approximate positions designed to provide a representative sample of fish and crustaceans across the demonstration site are provided. It is unlikely that all gear types can be deployed in all sites and access issues at low tide may require the positions of some sites to be altered.

Zone	Habitat	Gears
Lagoonal mangrove	Mangrove edges – high tide	Gill nets
	Deep banks	Gill nets, cast nets
	Shallow banks	Seine nets[1], cast nets
	Mangrove drains	Fyke nets
Coastal mangroves	Mangrove edge	Gill nets, cast nets
	Shallow banks	Seine nets, cast nets
	Drains	Fyke nets

[1] Seine nets should only be used over firm substrates lacking complex structure. If such substrates are not present in the zone then Seine nets should be omitted from the sampling plan. Complete instructions for Seine net use are provided in Appendix 2.

Table 23: Sampling Gears suitable for each zone.

Cast net sampling

Cast net sampling will target the major bank-side habitat types; low angle banks and deep banks if they are present. Cast netting will be conducted in a single zone in Crab Bay. Ten cast net samples will be collected in two habitats (low-angle bank, deep banks [if present]) at three sites (Fig.52).

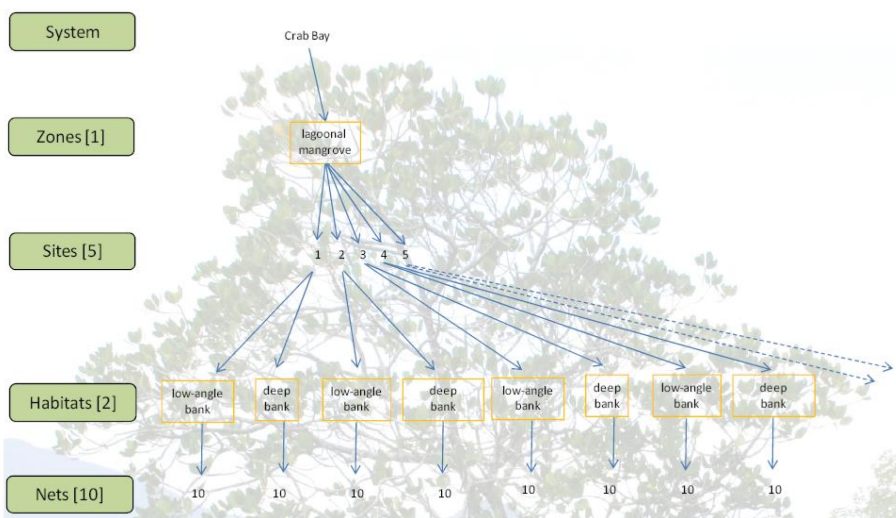

Figure 52: Cast net sampling scheme

Seine net sampling

Seine net sampling will only be conducted on shallow angle banks with firm substrates. Three seine net samples will be collected at five sites where possible (Fig. 53).

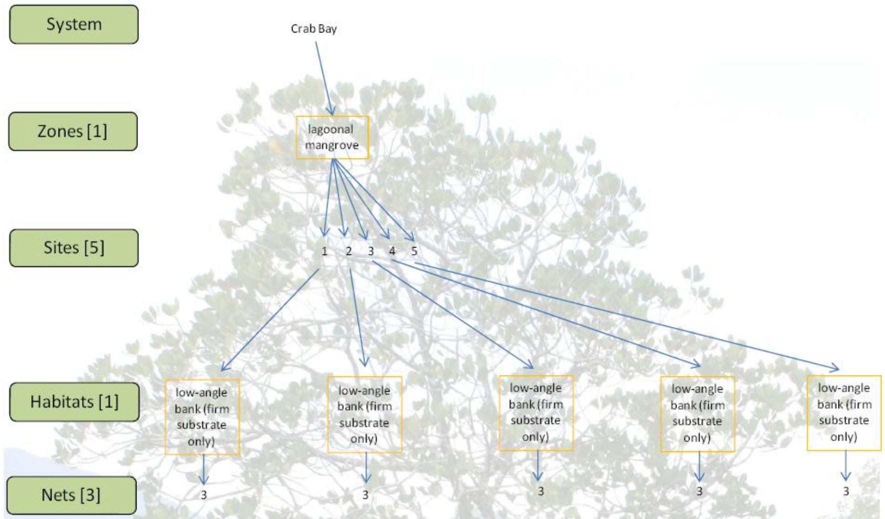

Figure 53: Seine net sampling scheme

Gill net sampling

Gill net sampling will only be conducted along mangrove edges in water deeper than 50 cm. Gill net sampling should be conducted across the top of the tide. Three gill net samples will be collected at five sites in Crab Bay (Fig. 54).

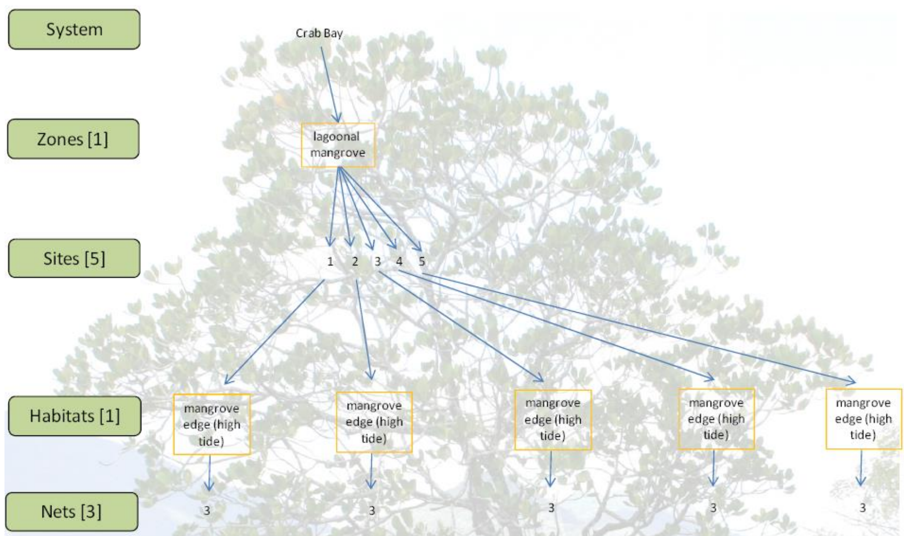

Figure 54: Gill net sampling scheme

Fyke net sampling

Fyke net sampling will only be conducted where shallow drainage channels drain the intertidal. At least one (1) fyke net sample will be collected in each site where possible (Fig. 54).

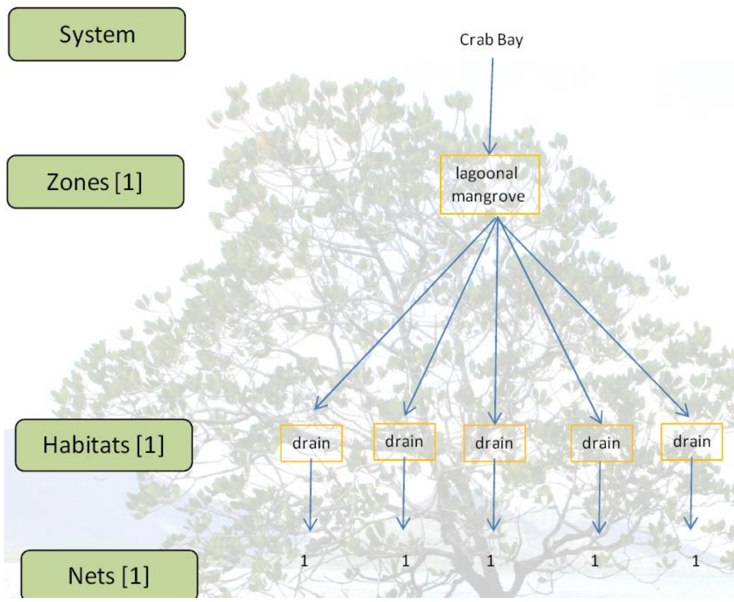

Figure 55: Fyke net sampling sheme

Physical parameter sampling

Physical measures of water quality will be recorded for all sampling sites. Two replicate samples will be recorded at each site where fauna are sampled. Physical parameter samples include pH, salinity, temperature, depth and turbidity.

Eratap, Efate Island

Cast net sampling

Cast net sampling will target the major bank-side habitat types; low angle banks and deep banks if they are present. Cast netting will be conducted in a single zone in the Eretap demonstration site. Ten cast net samples will be collected in two habitats (low-angle bank, deep banks [if present]) at three sites (Fig. 56).

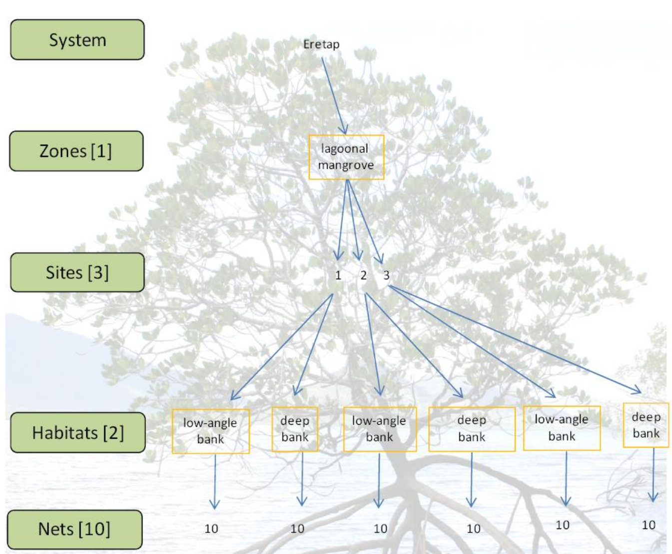

Figure 56: Cast net sampling scheme

Seine net sampling

Seine net sampling will only be conducted on shallow angle banks with firm substrates. Three seine net samples will be collected at three sites where possible (Fig. 57).

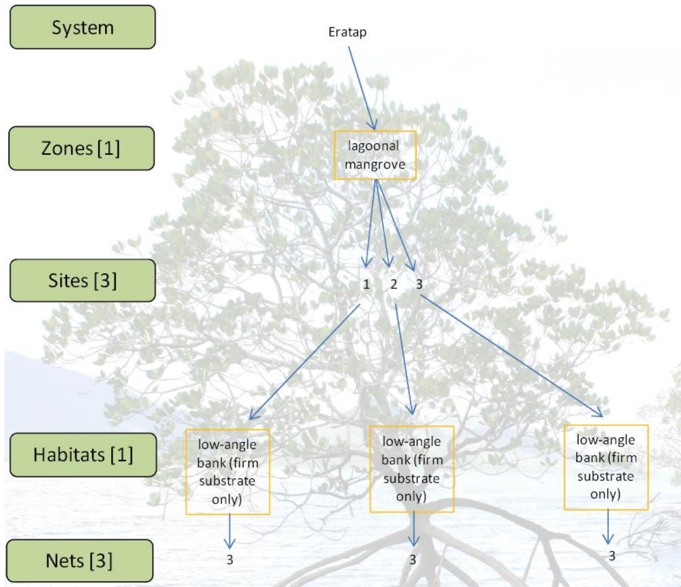

Figure 57: Seine net sampling scheme

Gill net sampling

Gill net sampling will only be conducted along mangrove edges in water deeper than 50cm. Gill net sampling should be conducted across the top of the tide. Three gill net samples will be collected at three sites in the Eretap demonstration site (Fig. 58).

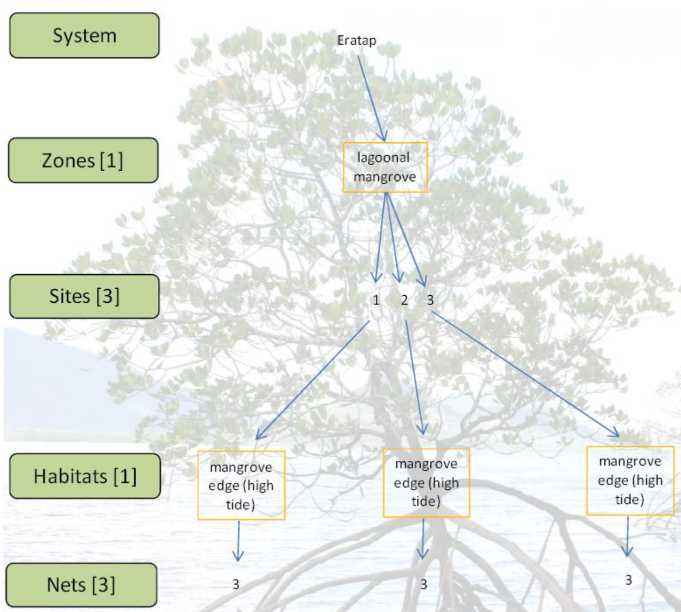

Figure 58: Gill net sampling scheme

Fyke net sampling

Fyke net sampling will only be conducted where shallow drainage channels drain the intertidal. At least one fyke net sample will be collected in each site where possible (Fig.59).

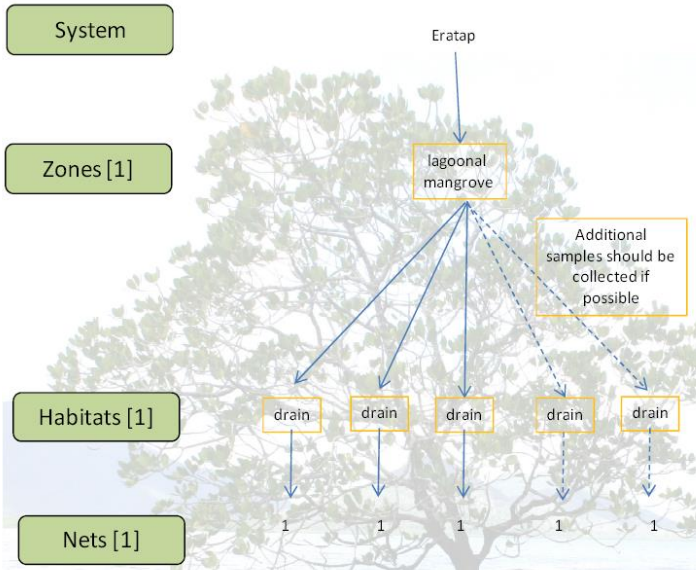

Figure 59: Fyke net sampling

As in Crab Bay/Amal Area, Physical parameters will also be recorded at each sampling station.

Results

A total of 328 fish belonging to 9 species were caught (Table 24). The cast net captured the highest number of fish (around 79 percent) and the highest species diversity in its catch (around 50 percent).

Country	Sampling Gear	Total fish Abundance	No. of taxa: scientific name[1]	Number of taxa: common name[2]
Vanuatu	Cast net	260	4	11
	Fyke net	54	2	7
	Gill net	0	0	0
	Seine net	14	3	6
	TOTAL	**328**	**9**	**19**

[1]Taxonomic identifications provided for Fiji are expected to be correct although no photographs have been provided to allow validation of identifications. Approximately 20% of taxa from the remaining countries have not had their scientific names validated because photographs have not been provided. Numbers provided here should be interpreted with caution because many incorrect scientific identifications were made in-country however where good quality photographs were provided identifications have been corrected.

[2]At present an absence of photographs means that many taxa have only local or common names provided. In the absence of photographs further identification is not possible.

Table 24: Summary catch statistics

It is difficult to be confident with identifications of taxa because there were many instances of incorrect identification among taxa for which photographs were provided to JCU. Estimates of taxonomic richness, number of taxa, is presented (Table 24) but should be interpreted cautiously.

Gear efficiency and cost effectiveness of sampling is always an important consideration but caution in interpreting effectiveness of sampling gears is important. When data are examined as catch per net (CPN), it is clear that cast nets and fyke nets caught most individuals. These rankings were based purely on abundance per 50 nets and made no allowance for time required to set and retrieve nets and samples, an important consideration in cost benefit trade-offs, so an adjusted CPUE estimate ($CPUE_{est}$) was constructed to incorporate a time function. By necessity $CPUE_{est}$ needed to be an estimate because data delivered from sampling and required to incorporate time into CPUE calculations was incomplete. Cast nets produced the most favorable $CPUE_{est}$ and were more than twice as effective as the next best gear type.

Country	**Sampling gear**	**CPN[1]**	**$CPUE_{ext}$[2]**
Vanuatu	Cast net	203.1	304.7
	Fyke net	245.5	4.9
	Gill net	0.0	0.0
	Seine net	53.8	16.2

[1] CPN: calculated as mean number of fish per 50 nets
[2] $CPUE_{est}$: CPUE once cast, seine and gill nets standardised to match with average time to collect a single fyke net sample, i.e. standardized to 5 hours sampling time. Estimates of the number of nets possible over a five hour period are conservative; cast = 75, fyke = 1, gill = 4 (based on 1 hourr soaks), seine = 15

Table 25: Catch per net (CPN) and estimated catch per unit effort (CPUEest) for the four sampling gears used in the sampling.

A lack of more definitive evidence means we have to assume that fish assemblages were reasonably well represented and use $CPUE_{est}$ as an assessment tool to link gear effectiveness to ease of use and versatility (number of habitat types they can be used to sample). A lack of on-ground expertise during sampling, and a lack of background data about local fish assemblages, means ease of use and versatility of sampling gears must become the primary criteria for determining appropriate approaches for future sampling of mangrove fish assemblages in the Pacific.

Discussion

As a result of the MESCAL fisheries surveys conducted at both demonstrations sites in Vanuatu, the project fisheries experts and advisors Dr. Marcus Sheaves and Ross Johnston came up with the various points below that will need to be considered in future fisheries surveys in Vanuatu. All four fish sampling gears used during the MESCAL project were relatively easy to use. During training sessions cast nets passed the greatest difficulties for in-country operatives, however regular practice should have rapidly negated this issue. Cast nets generally produced the best $CPUE_{est}$ suggesting that most operators were relatively proficient with the equipment by the time sampling was conducted. Levels of replication set out in country-specific sampling protocols for cast nets were achieved in all countries. This indicates that replication levels for cast nets were not too ambitious and higher levels of replication should be possible as operators become more proficient with equipment and protocols. Higher replication levels can offset a major disadvantage of cast nets (variable sampling areas), however large fish and surface-dwellers will usually be under-represented in catches. This is only a disadvantage when quantitative data is required but is not an issue when more robust presence-absence data is used. Cast nets were clearly a successful approach for collecting mangrove fish data for the MESCAL project.

Fyke nets were relatively effective at capturing fish exiting mangrove forests in the Pacific and were the only gear capable of discriminating those species entering mangroves from those using adjacent habitats.

Although net avoidance and escape can be high the ability to isolate species using mangroves is valuable. Gill nets have many problems associated with their use however their ability to sample larger individuals, an area where the other three methods are less efficient, made gill nets a useful approach for the MESCAL project.

Seine nets were less effective in many MESCAL demonstration sites because they could not be used effectively in most mangrove-associated habitats. Species captured in seine nets were often present in catches from other net types so although seine nets are easy to use and possibly less species and size selective than other approaches their effectiveness was limited to a single habitat type. This makes them less useful across the spectrum of mangrove settings encountered in the Pacific.

Assessment of the functional roles of mangroves in fisheries productivity is a difficult problem that has not been satisfactorily addressed in any country (Johnston & Sheaves, 2007) despite general understanding that mangroves play a pivotal role in many fisheries (Manson et al. 2005; Aburto-Oropeza *et al*., 2008, Hussain & Badola 2010). Arriving at estimates of the value of mangroves to fisheries, and the people that rely on mangroves, may be even more difficult, with present valuations likely to highly underestimate their worth (Barbier 2000, O'Garra 2012). Assessing functional roles of mangroves in the Pacific is made more difficult by the lack of technical expertise and scientific experience on-ground in Pacific Island countries.

The present MESCAL project recognized that a lack of experienced people on-ground meant that only basic approaches could be relied on to produce sensible outcomes. Consequently netting approaches were used to assess mangrove roles in fisheries productivity yet, as previously stated, problems related to lack of sampling and data handling experience surfaced and compromised what should have been quite robust data. Based on this outcome it would be inappropriate to suggest changes to the existing sampling approach until local operators had gained sufficient experience to deliver reliable outcomes. However we would strongly recommend that further training be implemented in the use of equipment and the recording, handling and reporting of data before additional sampling is undertaken. Further, we would recommend having an expert on-ground during initial repeats of the sampling to oversee protocols and contribute experience that can be passed on to local operators.

There are many alternative approaches that have much potential to address the question at hand, and would be suited to use in the Pacific were expertise and equipment readily available. Otolith chemistry, stable isotope analysis and acoustic tagging approaches have many advantages over conventional netting and other approaches but they can be very costly and require appropriate skills to implement. At present we don’t believe such approaches could be implemented for Pacific Island countries without considerable investment of funds and overseas expertise however we are of the opinion that much could be gained by incorporating such approaches into future planning.

Recommendations

1. There is a crucial need for more extensive training in all aspects of mangrove fish sampling approaches. Training workshops and in-field instruction is necessary to develop greater understanding equipment operation and of identification and avoidance of potential problems.
2. There is a crucial need for more extensive training in all aspects of data recording, handling and reporting. Training workshops and in-field instruction is necessary to develop greater understanding recording requirements and protocols. Further, workshops addressing issues

surrounding data handling and reporting are necessary before analytical capability for interpretion of data can be addressed.

3. Data analysis capability is at a very low level and this needs to be addressed. Workshops and/or intensive courses are required to improve this situation.
4. Fish taxonomy skills need to be developed as matter of urgency. Few operatives were capable of providing reliable species identifications and/or reliable information to allow remote identification from descriptions and photographs. Development of taxonomic skills should incorporate a photographic skills component that ensures clear images of diagnostic morphologies are produced.
5. All training programs (workshops, in-field instruction, and intensive courses) should be focused at a selection of local personnel who will become “dedicated” operators, i.e. operators earmarked to become leaders responsible for particular aspects of mangrove fish research, including in-field sampling and data analysis. Not only should dedicated personnel be developed to improve in-country capabilities, those personnel should be encouraged to pass their skills on to other operatives to build a pool of experienced personnel so skills are not lost as experienced people move away or change roles.
6. In the absence operators with substantial in-field experience, basic netting approaches should be retained for mangrove fish sampling. Additional training should be sought, and whenever possible experienced local personnel should be enlisted to assist and external experts retained to oversee operations.
7. We suggest continued use of cast nets, fyke nets and gill nets is the best way forward for the Pacific. There are too few habitats where seine nets can be effectively deployed so time previously apportioned to seine netting could be used more efficiently by collecting additional cast net samples.
8. Chemical approaches will make a valuable contribution to understanding the values of mangroves to fisheries so they warrant consideration. However the level of expertise required to undertake such studies is not present in the Pacific so any project would almost certainly have to be heavily supported and managed by external experts rather than Pacific Island nationals.

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Section 6. MESCAL Project Traditional Uses of Mangrove Surveys of Amal/Crab Bay (Malekula) and Eratap (Efate), Vanuatu.

Molu H. Bulu

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Introduction

This study was formulated and integrated into the Mangrove Ecosystems for Climate Change Adaptation and Livelihoods (MESCAL) project's action research plan that was carried out in September - October 2012 on the projects two demonstration sites, Amal/Crab Bay on the island of Malekula and Eratap on Efate. Amal/Crab bay is a conservation area that was initially co-managed by the 16 communities sharing its resources. It wasn't until the International Waters Project (IWP) used the area as a Pilot site in 2003 that it became a nationally recognized conservation area, a process that was guided by the DEPC, Department of Fisheries, Department of Forestry, Department of Lands, the 16 chiefs of Malampa province, the Cultural Centre and the communities of Amal/Crab Bay. The aim of this study was to gather as much information as possible on the lost, nearly extinct and/or still existing cultural and traditional uses of Mangroves in the two demonstration sites, and to document all this information. The research team was led by Mr.Molu H Bulu, a Resource Environmental Economic Assistant contracted by MESCAL, with help from Primrose Malosu and local assistants from Amal/Crab Bay and Eratap communities.

Methodology

The primary goal of the action research exercise was to gather information for a socio economic analysis and evaluation between the mangrove ecosystems and their contributions and interactions towards the livelihoods of the villages nearby. The secondary and integrated goal was to collect information on traditional and/or cultural uses of the mangrove tree. Information was gathered using a series of group discussions and household interviews.

Group Discussions

Group discussions were held with as many participants as possible from each village in the two sites. The villagers attending the workshop were divided into two groups based on gender. This was done with the intent of giving the women the opportunity to have their say without the men dictating their opinions. There was also two other groups, consisting of a mix of male and female assistants that were designated to help facilitate the work. Figure 60 below shows a women's discussion group and a men's discussion group at Ewentau station on Eratap.

Figure 60: Group discussions (women and men).

Interviews

There were three structured questionnaires in total, each focusing on separate yet equally important aspects, i.e. Mangroves, Crabs and reef fishes. The houses interviewed were randomly selected by the socio-economic team and any one or more adult(s) who were there and willing to cooperate was interviewed. The questionnaires focused on the uses, subsistence and/or commercial, patterns of sale, sale at what prices, sale where, details of sale process, extent of resource use, patterns of resource extraction and personal opinions on issues in relation to the mangrove ecosystem nearby.

Study Sites

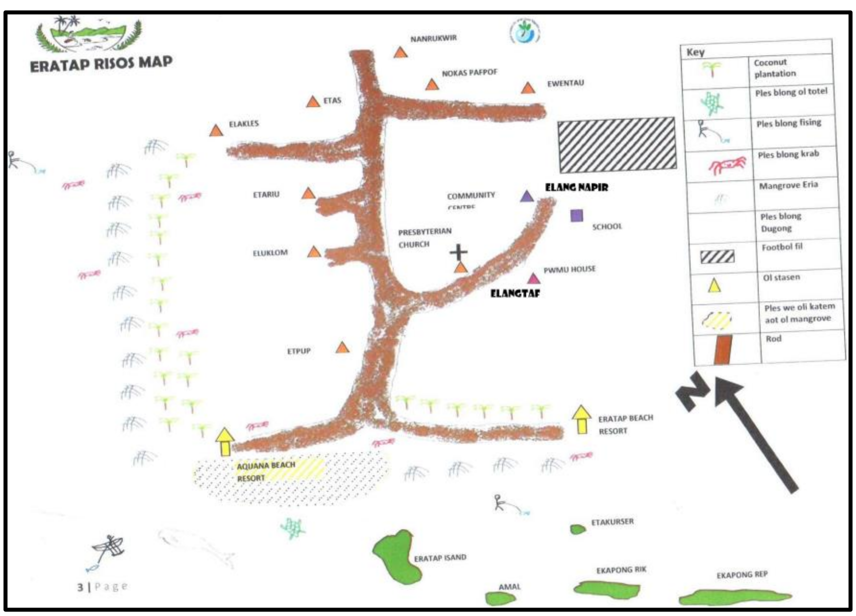

Figure 61: A resource map of the Eratap stations indicated by the triangular shapes in the map.

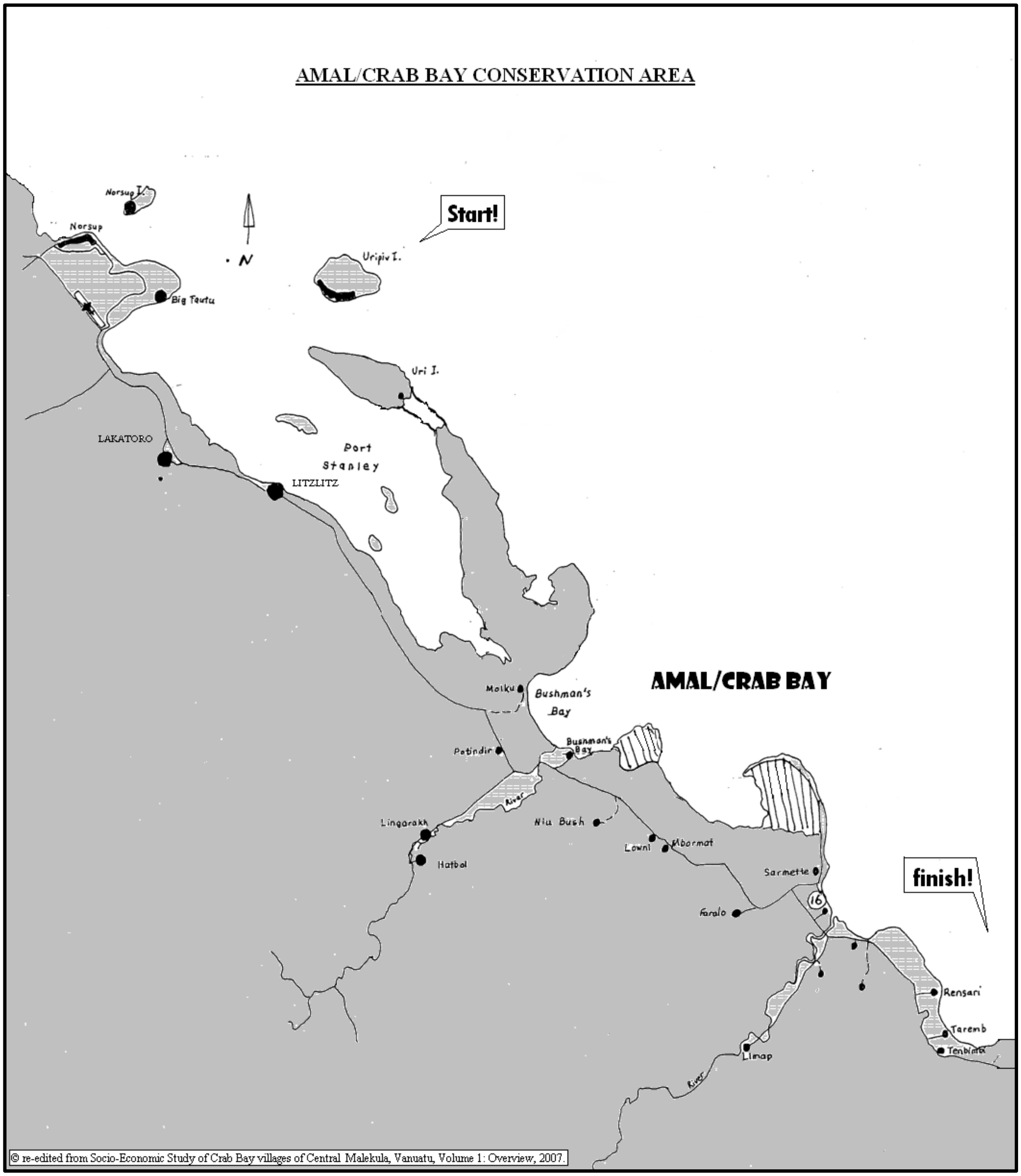

Figure 62: Amal/Crab Bay demonstration site. Marked are the start and end points of the survey.

Results

Cultural Uses

Apart from the mangrove ecosystem providing services to the environment, the mangrove tree is also very useful to mankind as it provides for resourceful but subtle ways to sustain livelihoods as is the case in our two survey sites. *Table 2* shows the different cultural uses and the specifics of the mangroves in Amal/Crab Bay and Eratap.

Part(s) of tree	Use	Species type
Leaves	Bait	Any
Bowed roots	Bow and Arrows	*Rhizophora stylosa*
Trunks	Carvings	*Ceriops tagal*
Branches , young trees	Chair/ Bench	*Ceriops tagal*
Branches , young trees	Coconut husk remover	*Ceriops tagal*
Young and mature trees	Fence posts (pigs, chicken, etc…)	*Ceriops tagal*
Any	Firewood	Any
Branches , young trees	Gardening tool	*Ceriops tagal* plus other
Trunks	House posts	*Ceriops tagal*
Branches , young trees	Rails (roofing)	*Ceriops tagal* plus other

Table 26: Cultural Uses of mangroves

The leaves of the mangrove tree are sometimes dumped in a heap and be left for up to a month to attract shells which would later be collected to eat or sell. These shells are known to the locals as *serwok* and are very common in Malekula. This practice was mentioned in a lot of the villages of Amal/Crab Bay but not in Eratap as there are no *serwok* shells on Eratap. The leaves are also useful when after crabs are caught, they are dumped in bags of collected white crabs, found in the soft mud mounds, holes and roots of the mangrove ecosystem to prevent the crabs from eating each other or the bag itself. Bow and arrows are commonly made from the bowed out roots of the *Rhizophora stylosa* species. It is fashionably crafted by the locals for sale to tourists in Port Vila, the urban capital of Vanuatu. This is the case only for the people on Eratap The Amal/Crab Bay villages have not reached that stage yet due to the ability to earn sufficient amounts of money, the idea and practice is not common to them, there are no available opportunities for them to do so. On Eratap, sale is not done every week or month, but occasionally when the people have the time and opportunity, or need the extra money. Earnings from sales are normally propelled towards helping the household with such needs as food, clothing, electricity and transport costs, school fees and bills and other pressing issues. Mangrove carving is not a common practice and only one person was found who is at current engaging this practice. He is from the station of *Ewentau* on Eratap who does carvings made from the hard trunks of the *Ceriops tagal* species. This has been and still is his profession and though it is time demanding and requires patience and hard work it's partly a hobby for him that pays fairly well. The finished carvings are taken and sold in the market in Port Vila to tourists. This he does once in a while when he wants to and not every month. Apart from that, he also goes to New Zealand in the Seasonal workers scheme every year so he only does carvings when he is back home in the village which is about half the year. The chair or bench refers to simple constructions of outdoor seating's made for resting under the shade. Being local in nature, the constructed seating caption needs not follow any architectural rules giving the builder a broad span of choices of wood to use. This can be found in Chief Johnsins island of *Uri*. Fencing posts refer to and vary between pig and chicken (small scale) farming as well as compound or yard fences. This type of fencing are normally made from young and fairly good sized (medium) trees from the *Ceriops tagal* species as posts which are then filled with other trees if needed and then completed with the wiring. The mangrove tree is good source of firewood too as it burns brighter and longer and gives less smoke when burnt. Any type species and parts of the trees are used as firewood, except the leaves, flower and fruits. Firewood is used only from dead branches found lying around or sometimes leftovers from posts or houses but they do not go cutting mangroves down and drying them specifically to use as firewood. For example, there is a house in Mapbest plantation that was built using mangrove trees as posts that has stood for more than 8 years is being used as firewood by the neighbors because it is now empty. The branches of the mangrove tree can sometimes be used as a gardening aid tool as well. The good branches or young trees are used by some villages to help with Yam planting. House posts are mostly used from the *Ceriops tagal* family. The long and straight and long lasting characteristics of the trunks make very good posts for houses because not only are they strong, but they can last up to a decade. 'Rails' as the locals call it, are simply the supports of the roofing framework consisting of less wider but equally long sized branches that hold together the top part of the house keeping the roof intact. Young *Ceriops tagal* trees are normally used for this.

Traditional Uses

There are very little to no surviving records of traditional uses of the mangrove tree in the 16 villages of Amal/Crab Bay and 10 stations of Eratap. According to the general information gathered from the different villages, majority claim to have never had any traditional uses for the mangrove tree, or they guessed they died out too long ago for anyone to have any recollections that they existed. The commonly mentioned traditional use derived from the mangrove ecosystem was the *kastom* medicine. However, acknowledging its existence in some of the villages has been the biggest advancement that the project was able to reach. The medicinal details and the practice itself is known only to a selected few inside the village and sadly it is not revealed to just any interested parties, especially outsiders. The only shared information on any traditional practice came from the small island village of *Uri*. The people of *Uri* believe that their ancestors had this special traditional tie with the mangrove ecosystem giving them this sort of custom heritage. This traditional heritage practice comes only on display in certain occasions for example, a marriage ceremony. When a girl from their village is to marry a man from another village, there is a custom ceremony that is always held before the actual wedding, the bride's family presents the bride to the bridegrooms family with gifts accompanied by some mangrove leaves (no specific type or species) at this ceremony, usually in small batches to simply show that the girl comes from the small island village of *Uri* with that particular heritage.

Summary

In summary, the mangrove ecosystem is being exploited and destroyed mostly as a result of the people's cultural needs like earning income, basic consumptions needs and betterment of their livelihoods. Traditional uses of the parts of the mangrove tree are very scarce and may cease to exist completely if the mangroves are not being carefully managed and its knowledge documented.

Section 7. Impacts of Projected Climate Change on Mangrove Ecosystems and Community Livelihoods in Vanuatu.

Linda Yuen

Introduction

The Mangrove Ecosystems for Climate Change Adaptation and Livelihoods (MESCAL) project is a four-year project (2010-2013) funded by the German Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). It is one of the projects under the umbrella of the Pacific Mangroves Initiative (PMI). MESCAL is managed by the International Union for Conservation of Nature – Oceania Regional Office (IUCN ORO) and has an overarching goal to increase the climate change resilience of Pacific Islanders as well as improve their livelihoods through selected capacity support in adaptive co-management and restoration of mangroves and associated ecosystems in five countries: Fiji, Samoa, Solomon Islands, Tonga and Vanuatu.

Rationale

The overall goal of the MESCAL project is to increase the climate change resilience and livelihoods of the five pilot countries (Solomon Islands, Vanuatu, Fiji, Tonga and Samoa) by improving knowledge and management capacity of their mangrove and associated coastal ecosystems. Much of the project's groundwork in the pilot countries centres on baseline assessment on the current status of mangrove and associated resources. While it would have ideal for the countries to also produce climate change projections at the national or even demonstration site level, limitations in time, funds and modelling skills meant that this task was beyond the current scope of the project.

The first of the overall MESCAL project's four outcomes is to produce national baseline information about climate change scenarios, use and values of mangroves and associated ecosystem. This review aims to identify recent climate change projections (particularly sea level) and assess their likely impacts on mangroves and associated ecosystems and community livelihoods for the five MESCAL pilot countries.

National-level Climate Change Projections

Climate change projection using global climate models (GCMs) for small islands in the Pacific and elsewhere in the world poses a great challenge to researchers because the resolution of the models are generally not fine enough to distinguish small land areas from the sea surface (IPCC, 2007). As a result, projections for small islands are usually associated with some degree of uncertainty. The efforts of regional climate research organisations in the Pacific have contributed to improving the way that models simulate climatic changes in small islands and thereby reducing uncertainties associated with large-scale global models.

SimCLIM Open Framework Modelling System (SimCLIM)

The SimCLIM Open Framework Modelling System (SimCLIM) is a versatile and user-friendly climate modelling software package that uses observed data with combined atmospheric-ocean general circulation models (AOGCMs) to produce climate projections. The system can be customised for individual countries to projection outputs from the scale of the whole country to specific sites (UNFCCC, 2013). This high spatial resolution feature can be particularly valuable for adaptation planning in Pacific island countries that have their islands geographically scattered and exhibiting slightly different climate regimes.

Several of the MESCAL pilot countries including Solomon Islands, Vanuatu and Tonga previously held software licences for customised versions of SimCLIM and also received training in running the model; however, the licences have since expired without any national-level projections being made. The MESCAL project had originally proposed to use SimCLIM to generate sea level projections for its demonstration sites. With the publication of projections by the Pacific Climate Change Science Program (PCCSP), which will be further discussed in the next section, there is a preference for government agencies to use this source in their decision making and reporting. The cost of maintaining the software licence is also a likely factor in discouraging countries from using SimCLIM to generate their own projections.

Pacific Climate Change Science Program (PCCSP)

The PCCSP aims to assist 14 Pacific Island Countries and East Timor in improving their decision-making capacities in adaptation planning by developing national-level climate change projections. The program is the Pacific regional component of a larger Australia-funded International Climate Change Adaptation Initiative (ICCAI) which has an overall goal of helping vulnerable countries in the Asia-Pacific region to meet their priority adaptation needs (BOM and CSIRO, 2011f).

The findings of the program were presented as an interactive online tool, the Pacific Climate Futures (http://www.pacificclimatefutures.net), which allows users to explore the projections for ten climate variables, three IPCC greenhouse gas emission scenarios and for the three time periods of 2030, 2055 and 2090 for each of the 15 countries.

Coastal ecosystems, including mangroves, are found at the interface between land and sea and are thus affected by both land and sea surface temperatures. These two temperatures, together with sea level are among the key climate variables to affect the health of mangrove ecosystems and will therefore be assessed in this review.

Pacific Sea Level Monitoring (PSLM)

The Pacific Sea Level Monitoring (PSLM) project was known as the South Pacific Sea Level and Climate Monitoring Project (SPSLCMP) until 2010 when it was absorbed under the umbrella of the Climate and Oceans Support Program in the Pacific (COSPPac). It aims to provide an accurate long-term record of sea levels in the Pacific region for scientific research purposes and to better inform decision making in national development and planning processes (SOPAC-SPC, 2013). The project uses a highly sensitive Sea Level Fine Resolution Acoustic Measuring Equipment (SEAFRAME) to record sea level and several other 'ancillary' variables including air and water temperatures, wind directions and speed and atmospheric pressure.

The map in Figure 63, below, presents the sea level trends for all of the PSLM stations, with MESCAL pilot countries labelled in yellow. The trends are calculated as the average annual change in sea level from the time the station was installed in the respective countries until the end of 2010 (BOM, 2010a).

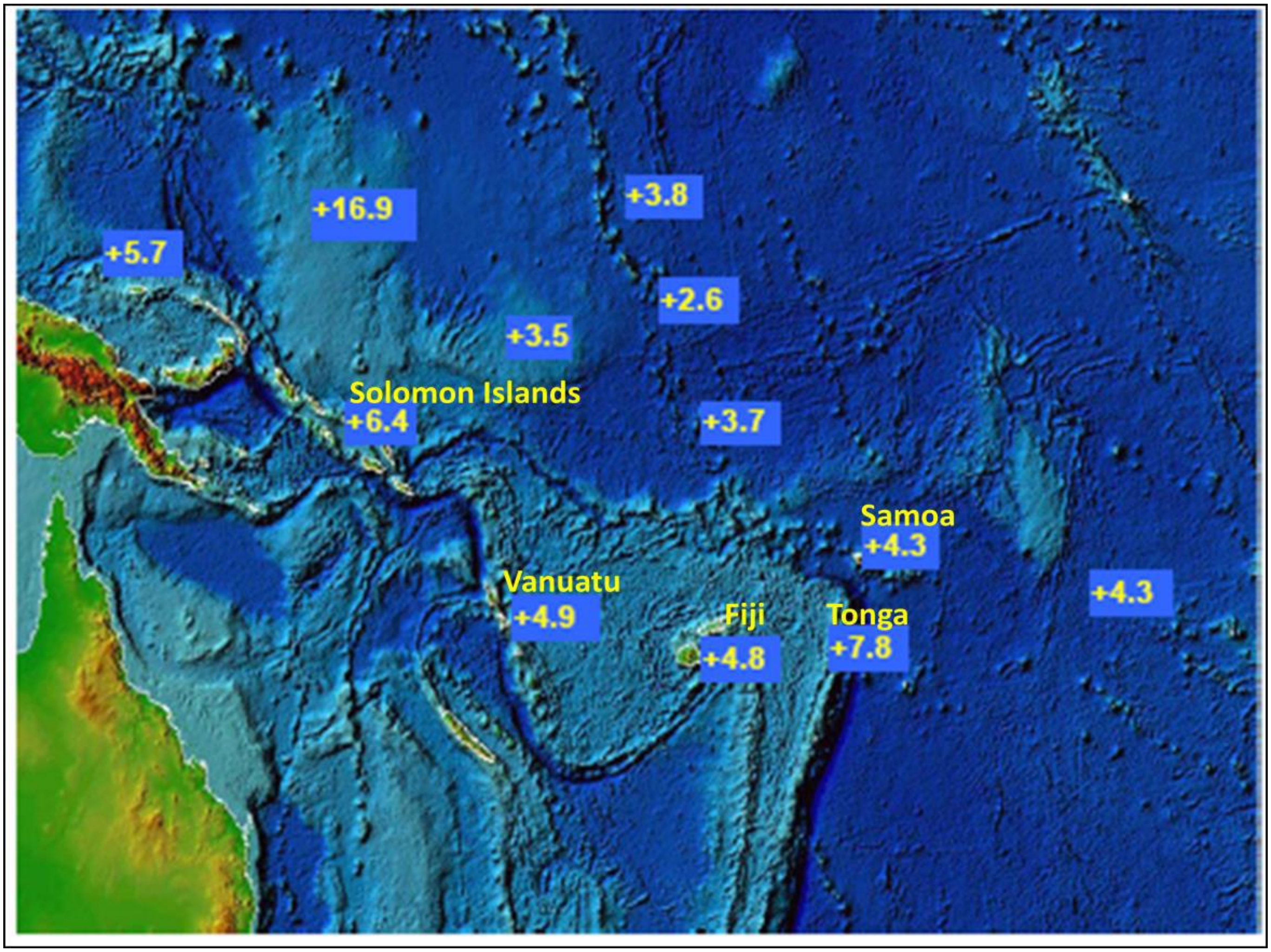

Figure 63: Map of Pacific region showing net sea level trends (in mm/year) for different countries (BOM, 2010a)

While the sea level trends recorded by PSLM are not technically 'projections' for future trends, it does provide an understanding of the current rate of sea level change for the specific countries being monitored. Furthermore, future sea levels could be estimated by way of linear extrapolation of the current observed trends. This is a simplistic method to derive future sea levels in the absence of modelled projections; however, the rate of sea level change is actually non-linear. The effect of seasonal climate variability will become smaller and reliability of long term trends will improve as the length of data record increases (BOM, 2010a). Station information, as well as the current observed sea level trends and linearly extrapolated sea levels of the five MESCAL pilot countries are shown in Table 27, below.

Country	Location	Installed	Years of data	Net sea level trend (mm/yr) as of Dec '10)	Sea level (mm) extrapolated to 2100
Vanuatu	Port Vila	15/01/1993	18	4.9	529.2

Table 27: Sea level trend in Vanuatu (BOM, 2010a)

Global Climate Projections

Global temperature is projected to rise between 1.8°C under B1 (the most conservative of the Intergovernmental Panel on Climate Change or IPCC's carbon emission scenarios) and 4.0°C under A1FI (the most extreme scenario), with an average of 2.9°C (IPCC, 2007). The trend for the Pacific would be smaller due to the high thermal capacity of the ocean acting to regulate extreme temperature changes.
The global rate of sea level rise was estimated to be around 1.7 mm/yr over most of the 20th century and under a range of carbon dioxide emission scenario assessed in IPCC's Fourth Assessment Report (AR4), the rate was projected to range between 0.18 - 0.59 m (average of 3.8 mm/yr) by the end of the 21st century (IPCC, 2007).

Subsequent studies since 2007 have found that this projection was overly conservative and that new evidence suggesting sea level rise of at least 1 m was more likely (Hansen *et al*., 2011; Vermeer and Rahmstorf, 2009; Pfeffer *et al*., 2008). One of the most recent studies even suggested a long-term rise of about 2 m for every degree of warming after 2100 (Levermann *et al*., 2013). Levermann *et al*.'s study combined paleo-climatic evidence with extensive model simulations built around the dynamics of thermal expansion, major glaciers and the Antarctic and Greenland ice sheets. These are the four main contributors to long-term global sea level rise and accurately modelling their behaviour produces projections that can closely reflect their true impact on global sea level. IPCC, themselves, noted that their assessments had not taken into account the effect of the melting ice sheets and thus produce much lower sea level rise projections (IPCC, 2007).

This further demonstrates the importance of reliable scientific information in projecting future climate, especially for the Pacific region. With the next IPCC assessment expected in 2014 and the improved climate modelling capabilities, it is anticipated that updated projections would contribute to better inform national and local decision-making processes.

Climate Change Impacts

The effects of sea level rise on the livelihoods of Pacific communities over the past 200 years have been related mostly to changes in the coastal environments. These changes brought about scarcity in marine food sources, coastal flooding and erosion and saltwater intrusion into groundwater sources (Nunn, 2013). The current changing environment and climate cause the same physical effects on today's communities; however, the impacts are multiplied due to the increased populations that these areas support.

Mangroves and associated coastal ecosystems perform numerous functions that are important to coastal communities that live close to them and for countries as a whole. These include but are not limited to the following:

- Supporting traditional practices – communities utilize mangrove ecosystems as a source of traditional medicines, fuel wood, building material and natural dyes (Gilman *et al*., 2006; SPREP, 2009).
- Food security – coastal communities are often dependent on these areas to provide food such as fish, shellfish, crustaceans, etc. (Gilman et al., 2006; SPREP, 2009).

- Coastline protection – the mangrove root system is well adapted to trapping sediment and breaking down the energy of strong winds and waves (Gilman *et al*., 2006; McIvor *et al*., 2012).
- Wildlife spawning ground, nursery and habitat – the calm and nutrient rich environment in the mangrove forests provide a safe and stable habitat for marine life (Gilman *et al*., 2006). Up to 80% of global fish catch utilises mangrove ecosystem services in one form or another (Polidoro *et al*., 2010).
- Improve coastal water quality – the roots of mangroves reduce water flow and allow suspended sediment and other pollutants to settle, effectively filtering the water before they reach the seagrass beds and coral reefs. Much of the nutrient is also retained, preventing eutrophication of coastal waters (Mumby *et al*., 2004; Ewel *et al*., 1998).
- Supporting connected coastal ecosystems including seagrass bed and coral reefs – the vegetative detritus from mangroves are transferred as nutrients to these connected ecosystems (Gilman *et al*., 2006; SPREP, 2009).
- Carbon storage – mangroves around the word, including associated soils, could sequester about 22.8 million metric tons of carbon each year (Giri *et al*., 2011) and provide at least 10% of the ocean's global organic carbon supply (Polidoro *et al*., 2010).
- Education, research and recreation – mangrove areas are easily accessible and ideal for environmental education and awareness, scientific research and also has potential to be developed into ecotourism areas (Gilman *et al*., 2006).

Impacts on ecosystems

Mangroves are found in the inter-tidal zones of the tropical and sub-tropical regions of the world and geographically distributed between 30°N and 30°S latitude, with the belt between 5°N and 5°S containing the densest systems (Giri *et al*., 2011). Temperature is the main controlling factor for mangrove distribution and limited mangrove areas can be found extending into the latitudinal limits of 32°N and 40°S (Stuart *et al*., 2007). The 20°C isotherms for both winter water and air temperatures restrict latitudinal mangrove distribution. Horizontal distribution is controlled by tidal inundation, with mangroves mostly found from mean sea level to highest spring tide mark (Alongi, 2009). Tidal inundation also dictates mangrove species zonation (Ellison, 2000). Within these broad geographical demarcations, the local diversity and extent of mangrove forests are affected by variables including temperature, rainfall and level of shelter from wind and wave action (NTG, 2002).

Temperature effect

Mangroves are found to be most productive within the temperature range of 15 - 25°C (Hutchings and Saenger, 1987). Thermal stress starts to affect the roots and seedlings at about 35°C and at 38 – 40°C, the leaves stop photosynthesizing (Clough *et al*., 1982, Andrews *et al*., 1984).

Projected increase in atmospheric temperature and carbon dioxide could increase mangrove productivity, alter their phonological patterns and expand their range into higher latitudes where low temperatures previously would not have allowed them to survive (Ellison, 2000). Mangroves are naturally well adapted to daily fluctuations in water and atmospheric temperature. In the tropical Pacific, where seasonal temperature varies little, mangroves are likely to have the capacity to adapt to temperature changes.

Increase in temperature alone seems to have an overall positive effect on mangrove trees. Unfortunately, the impact of climate change is not limited to changes in only temperature. Other associated impact has largely negative effects.

Relative sea level effect

Gilman et al. (2006) presents four generalised mangrove response scenarios to sea level change:

a. Stable sea level, where mangrove margins remain in place (Figure 5.1A)

b. Sea level fall, where the landward and seaward margins both migrate seaward (Figure 5.1B)

c. Sea level rise without landward obstruction (by artificial structures such as roads, buildings and seawalls), where landward and seaward mangrove margins both migrate landward (Figure 5.1C)

d. Sea level rise with landward obstruction, where landward migration is not possible and seaward margin continues to erode (Figure 64D). Under this scenario, the 'coastal squeeze' effect forces mangroves to get progressively narrower with severity of sea level rise (Alongi, 2009).

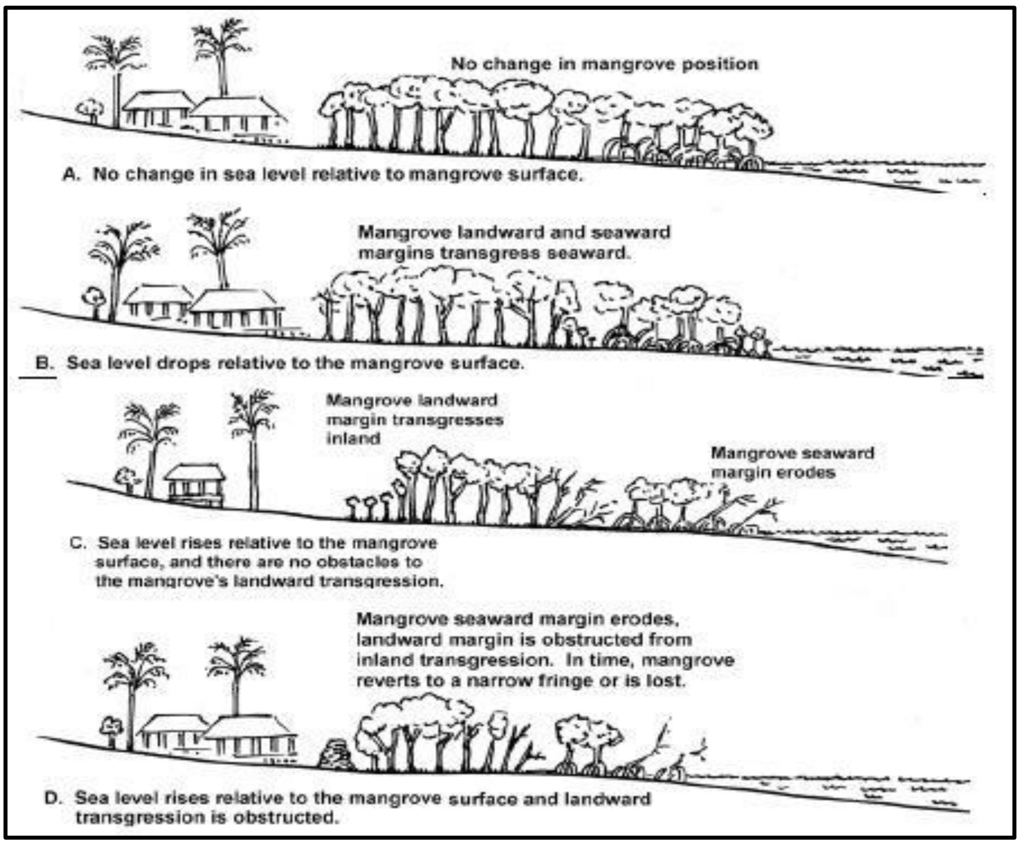

Figure 64: Generalised mangrove response to changing sea level (Gilman *et al*., 2006)

Sedimentation effect

The rate of sedimentation also has a large influence on the response of mangroves to rising sea levels. The two predominant settings where mangroves are found in the Pacific are the river deltas and estuarine areas of high volcanic islands and the bays, lagoons and reef flats most commonly found on low islands (Ellison, 2000). In addition to sediment accumulation from vegetative detritus breakdown, the delta and estuarine mangroves also receive significant sediment load from terrestrial sources. Low island mangroves, however, rely solely on detritus and naturally have a much lower rate of sedimentation. Consequently, they are also much more susceptible to sea level rise. Low island mangroves are able to keep up with and adapt to the effects of rising sea level as long as the rate of increase does not exceed 12 cm per 100 years (Ellison, 1989, Ellison, 1993) and for high island mangroves, not exceeding a rate of 45 cm per 100 years (Ellison and Stoddart, 1991).

Mangroves are known to have historically adapted to fluctuations in sea level (Alongi, 2008, Erwin, 2009, Fiu et al., 2010), however, their capacity to continue doing so, especially under the additional human-induced stresses such as urbanization, pollution and overharvesting, is less certain.

Impacts on livelihoods

Mangroves and associated coastal ecosystems provide goods and services which contribute to the welfare of local and national communities but they continue to be threatened by degradation and environmental change. More than 70% of the inhabitants of the Pacific islands live in the coastal zones (SPREP, 2012) and the impact of a changing climate is already taking a toll on many of these communities.

The most immediate impact on community livelihoods will be food security. Saltwater intrusion into coastal soils and groundwater sources could severely reduce the yield of crops and food trees. The projected rise in atmospheric and sea surface temperature could increase heat stress on mangroves and near-shore marine food supply and also reduce their yield. Depending on the severity of the event, coral reefs would also be susceptible to bleaching which could reduce the supply of reef fishes. These will all lead to local shortage of food supply. Marine food makes up a significant part of the diets of coastal communities. Nunn (2013) estimates that by the middle of the 21st century, many Pacific island coastal communities would no longer have the capacity to meet local demands for food and they would also be unlikely to have the financial means to purchase food regularly from the shops.

Subsistence farmers and fishermen in the coastal communities often supplement their household income by selling excess catch and crops. There is also likely to be a loss in income when there is reduced yield in crops and marine food supplies.

If the community affected also relies on groundwater as a primary freshwater source, then saline intrusion also has the additional impact of reducing the community’s water security by making the brackish groundwater unsuitable for human consumption. Sometimes, the communities have limited alternative drinking water options and continue to use this brackish water, which may cause sanitation and health issues (Lal *et al*., 2009).

When early settlers voyaged across the Pacific, it was the coastal environment of the islands that attracted them to come ashore and settle. Since then, the coastal ecosystems have supported a wide range of traditional practices (Nunn, 2007). These practices are in danger of being lost as the risk of coastal ecosystems degradation increases. An estimated 35% of the world’s mangroves have been lost between 1980 and 2000. The rate of annual decline continues at about 2.1%, which is almost three times the 0.8%

annual rate of tropical terrestrial forest loss (Gilman *et al*., 2006). The rate for the most of the Pacific is more uncertain due to limited baseline studies and lack of standardised monitoring procedures. The variation in estimation of mangrove coverage by different researchers is probably a reflection of the different methods used in baseline resources assessment.

Gilman *et al*. (2006) estimates the economic value of mangrove ecosystems across the Pacific to be between USD 200,000 – 900, 000 per hectare. The specific national value in different countries and areas will most likely vary according to their respective national and local circumstances. For example, mangrove areas of higher national importance, such as for ecotourism, will be valued more than those in remote uninhabited areas. Despite the large range in value, this estimate provides a guide, especially to countries that have not carried out any previous valuation to the benefits of preserving and the cost of losing these resources.

National level climate projections and sea level trends for each of the five MESCAL pilot countries and their impacts on national and local coastal community livelihoods are discussed in the sections that follow.

Vanuatu's Mangroves

MESCAL Vanuatu is implemented locally by the Department of Environmental Protection and Conservation under the Ministry of Lands, Natural Resources, Geology, Energy and Environment.

Mangrove distribution and demonstration sites

There is approximately 20.5 km2 of mangrove forests distributed throughout the islands of Vanuatu (Spalding *et al*., 2010) and their occurrence is known in the following islands:

a) Hui
b) Ureparapara
c) Vanua Lava
d) Mota Lava
e) Santo Island
f) Malekula
    a. Port Stanley
    b. Crab Bay and Amal Area
    c. Port Sandwich
    d. Maskelynes
g) Epi
h) Emae
i) Efate
    a. Eratap
    b. Tounaliu
j) Tanna
k) Aniwa

The Crab Bay-Amal demonstration site is located along the northeast coast of Malekula Island. The site was also the demonstration site for a previous conservation project in 2002, which helped the communities in the area in establishing the Amal-Krab Bay Tabu Eria for better monitoring and management of their marine resources (Hickey, 2006). The other demonstration site is the Eratap Lagoon on the southeast coast of Efate, an area that is increasingly threatened by the expansion of coastal developments. The Crab Bay-Amal site demonstrates the value of sustainable local resource management after a period of exploitation while the Eratap site illustrates an ecosystem at increasing risk of degradation. Figure 65, below, shows Vanuatu's mangrove distribution and the mapped demonstration sites.

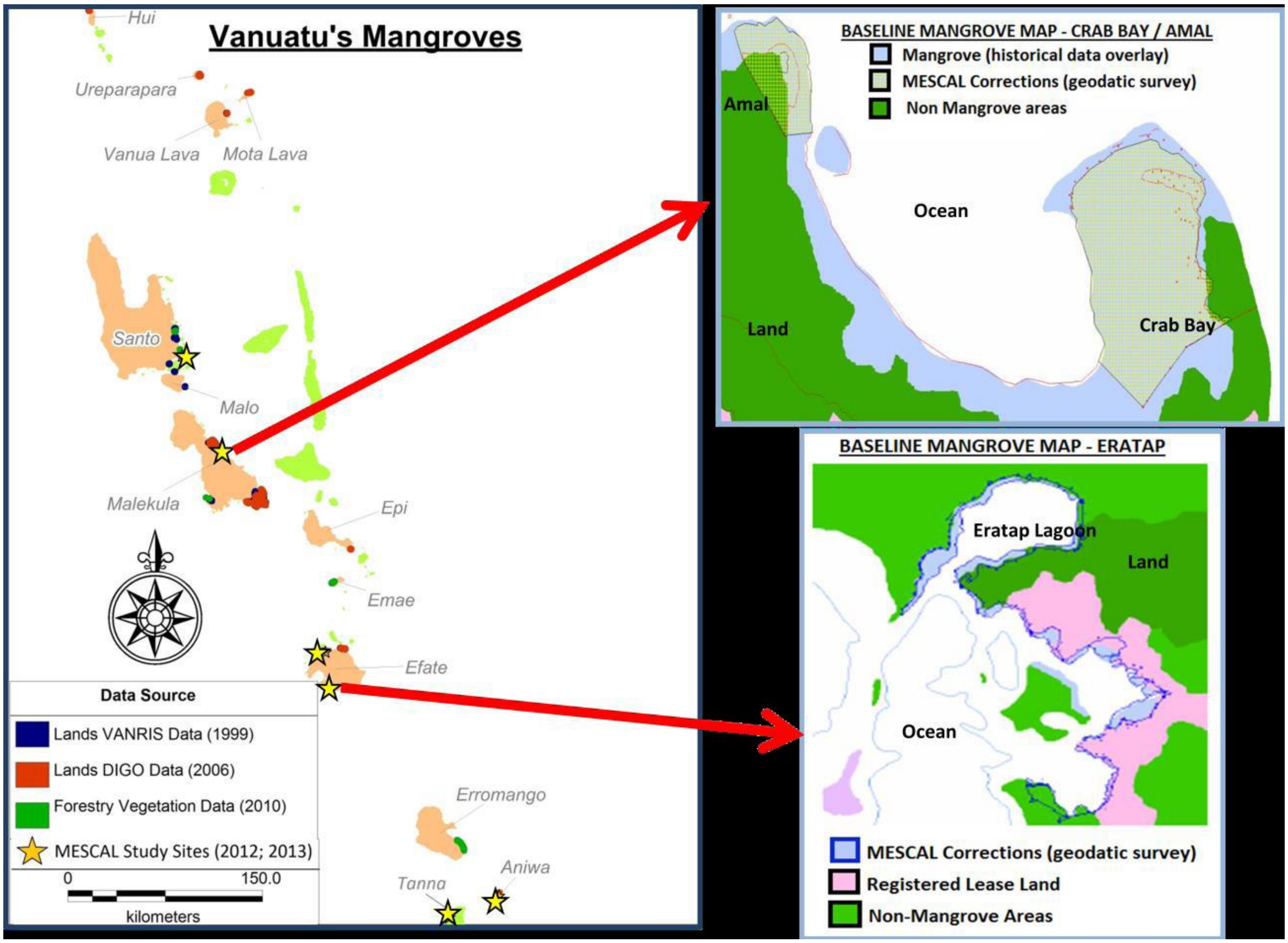

Figure 65: Vanuatu mangrove distribution (left) and MESCAL Vanuatu demonstration sites (Baereleo, 2013)

PCCSP

For Vanuatu, both the surface air and sea surface temperatures have been projected with high confidence; and sea level, with moderate to high confidence, to continue increasing over the 21st century (BOM and CSIRO, 2011e). These projections are presented in detail in Table 28, below.

	Emission scenario	Year			Confidence level
Variable		2030	2055	2090	
Annual surface air temperature (°C)	Low (B1)	+0.6 ± 0.4	+1.0 ± 0.5	+1.4 ± 0.7	High
	Mid (A1B)	+0.7 ± 0.4	+1.4 ± 0.6	+2.2 ± 0.9	High
	Hi (A2)	+0.6 ± 0.3	+1.4 ± 0.3	+2.6 ± 0.6	High
Annual sea surface temperature (°C)	Low (B1)	+0.6 ± 0.4	+0.9 ± 0.5	+1.3 ± 0.5	High
	Mid (A1B)	+0.6 ± 0.3	+1.2 ± 0.5	+2.0 ± 0.7	High
	Hi (A2)	+0.6 ± 0.4	+1.3 ± 0.4	+2.5 ± 0.6	High
Annual mean sea level (cm)	Low (B1)	+10 (5–16)	+19 (10–27)	+32 (17–47)	Moderate
	Mid (A1B)	+10 (5–16)	+20 (8–31)	+40 (20–59)	Moderate
	Hi (A2)	+10 (3–17)	+19 (7–31)	+42 (21–63)	Moderate

Table 28: PCCSP climate projections for Vanuatu (BOM and CSIRO, 2011e)

Surface air temperature for Vanuatu is projected to range from 1.4°C to 2.6°C (average of 2.0°C) higher than the 1990 baseline by 2090, while sea surface temperature is expected to be between 1.3°C and 2.5°C (average of 1.9°C) higher. Sea level rise is projected to range from 17 cm to 63 cm (average of 40 cm) compared to the 1990 baseline.

PSLM

Vanuatu's SEAFRAME station, which is located in Port Vila on the island of Efate, was installed in 1993. A Continuous Global Positioning System (CGPS) was also installed in 2002 to measure the effect of vertical tectonic land movement (BOM, 2010e). One of MESCAL Vanuatu's two demonstration sites, Eratap, is located on the same island, less than 5 km southeast of the station. The other site, Crab Bay-Amal is located about 192 km north northwest of the station, on the island of Malekula. Since there is only one tide gauge, the sea level trend for Vanuatu will be applied to both sites.

The annual mean sea level rise for Vanuatu, between 1993 and 2010, is calculated to be 4.9 mm per year (Table 27), after the effects of atmospheric pressure and tectonic movement have been removed. The linearly extrapolated sea level for Vanuatu to the year 2100 is 529.2 mm above mean sea level. Between the installation of the Port Vila SEAFRAME station in 1993 and the end of 2010, the station has recorded 18 years of data.

Threats to community livelihoods

Vanuatu's mean monthly temperature ranges from about 23°C in July/August, when it is the coolest, to about 27°C during January/February, when it is the warmest (BOM and CSIRO, 2011e). These temperatures border on the upper range of the mangrove's ideal temperatures. Even under the highest temperature rise projections for Vanuatu for the 21st century (Table 28), it would still be well below the 35°C when mangroves start to experience thermal stress.

MESCAL Vanuatu's demonstration sites are both located within bays. PCCSP's projection average of 40 cm sea level rise by 2090 (from a range of 17 – 63 cm), as well as the linearly extrapolated rise of 53 cm by 2100, from Vanuatu's current rate recorded by PSLM, have already exceeded Ellison and Stoddart's 12 cm per 100 year sustainable rate of sediment replenishment (1991) for this type of mangrove setting. This consequently indicates that Vanuatu's mangrove coverage could become severely diminished or totally lost by the end of this century, and in agreement with the outlook presented by Duke *et al*. (2007). Apart from climate-related threats to the mangrove and associated coastal ecosystems, human-induced threats also play an increasing role in endangering these resources.

The biggest anthropogenic threats to mangrove ecosystems identified by MESCAL Vanuatu include overharvesting of timber as firewood and for building houses and boats, overfishing, and encroachment of leased land for conversion into housing and agricultural areas (Baereleo, 2013).

Over 90% of all of Vanuatu's mangroves can be found on the island of Malekula, where Crab Bay-Amal is located, and the need for a mangrove management plan to sustainably manage these resources was highlighted in Vanuatu's latest National Forest Policy (2011). Land tenure issues have been the sources of disputes in Malekula for decades, especially in relation to harvesting of resources. At one point, resources such as crabs and mangrove timber were harvested on a commercial and unsustainable scale to meet demands in Port Vila. It was, therefore, considered a milestone for community-led management of mangroves and other coastal resources when the traditional community leaders in the Crab Bay-Amal area finally agreed to the collective establishment of a *tabu eria* to control resource exploitation (Hickey, 2006). This has allowed the resources to slowly recover and support the local communities' subsistence needs.

Efate, where Eratap is located, is the most urbanised and densely populated island in Vanuatu. With 28% of Vanuatu's population currently living on the island and an annual growth rate of 4.5% (twice the national rate of 2.3%), it is the country's fastest growing population centre (Vanuatu National Statistics Office, 2009). At this rate of growth, the demand for land and other resources will only continue to increase pressure on any undeveloped areas, especially in the coastal zones. The expansion of land leased for coastal development projects is rapidly expanding and approaching the Eratap area. If this trend continues, the impact of land reclamation combined with rising sea level will accelerate the loss of mangroves in this area. Local traditional practices such as gathering of material to make dance costumes and the use of plants as medicine in the area would also be at risk of being lost.

Mangrove areas and resources in Vanuatu are property of the customary landowners. There is currently no legal framework dedicated to the management of mangroves. A review of current legislations under the project will aim to facilitate the formulation of a framework which would guide policy makers to take the necessary measures to ensure the protection of these ecosystems.

While loss of mangrove ecosystems may be inevitable by the end of the century, it is vital that they are sustainably managed to prolong its role in providing for the local communities' in Vanuatu.

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List of Abbreviations

AOGCM	Atmospheric-ocean general circulation model
AR4	(IPCC) Fourth Assessment Report (2007)
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BOM	Bureau of Meteorology (Australia)
CGPS	Continuous Global Positioning System
COSPPac	Climate and Oceans Support Program in the Pacific
GCM	Global climate model
ICCAI	International Climate Change Adaptation Initiative
IPCC	Intergovernmental Panel on Climate Change
IUCN ORO	International Union for Conservation of Nature Oceania Regional Office
MESCAL	Mangrove Ecosystems for Climate Change Adaptation and Livelihoods
PCCSP	Pacific Climate Change Science Program
PMI	Pacific Mangroves Initiative
PSLM	Pacific Sea Level Monitoring (formerly known as SPSLCMP)
SEAFRAME	Sea Level Fine Resolution Acoustic Measuring Equipment
SimCLIM	SimCLIM Open Framework Modelling System
SOPAC-SPC	Applied Geoscience and Technology Division of the Secretariat of the Pacific Coummunity
SPREP	Secretariat of the Pacific Regional Environment Programme
SPSLCMP	South Pacific Sea Level and Climate Monitoring Project (now known as PSLM)
UNCBD	United Nations Convention on Biological Diversity
UNFCCC	United Nations Framework Convention on Climate Change

The Future of Vanuatu's Mangrove Ecosystems: A brief summary of the synthesis of research and management issues

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Introduction

Recognition that mangroves are a vital ecosystem in Vanuatu is a first step in moving towards better management. There is still a lack of information collected about mangroves and catchments in the remote islands of Vanuatu. Projects involved in mangroves are somewhat sporadic in nature and there aren't any systematic long term studies that can be used to accurately identify the trends. Key gaps in the available knowledge (e.g. mapping, accurate boundary surveys, biological assessments) make it difficult for decision makers to make the appropriate informed decision on the management of this key ecosystem. As observed in this project, greater community engagement is an important step in the improved management of mangroves in Vanuatu. Without the support and the interest of the local community, little progress will be made in conserving the issues faced by Vanuatu's mangroves.

Key Achievements

The Mangrove EcoSystems for Climate Change Adaptation and Livelihoods (MESCAL) project has created a large advancement in the creation of awareness, production of important knowledge products and increased knowledge of the species diversity available in Vanuatu. Some of the key achievements of this project have been:

- 8 new mangrove species records for Vanuatu bringing the total to 23.
- Mangrove species distribution has been preliminarily mapped on 5 islands (6 sites) across Vanuatu.
- Rediscovery of endemic gecko (*Lepidodactylus* vanuatuensis) in Malekula. Peviously not known to occur in Malekula Island.
- Completion of first ever baseline mapping and survey of boundaries of mangroves in Eratap and Amal/Crab Bay.
- Completion of Vanuatu's first mangrove above ground biomass estimations for mangroves in Eratap and Amal/Crab Bay.
- Completion of mangrove policy and legislation review.
- Capacity built with in-country Government personnel (Department of Forestry, Department of Fisheries, DEPC) on rapid mangrove biodiversity assessments.
- Completion of socio-economics study for mangroves which is not included in this technical report.
- Completion of Economic Evaluation of mangroves in Vanuatu.

- Completion of a mangrove field guide booklet describing the species found in Vanuatu and its national distribution.

Knowledge gaps

As noted above, there is still much scientific and technical information needed to strengthen the knowledge and management practices in Vanuatu. Based on available information, the following knowledge gaps have been identified.

- There is a need for detailed mangrove map that has national coverage.
- There is a need for documentation of traditional and cultural uses of mangroves as these may vary across the country. If these are not documented and synthesized into a succinct publication, this knowledge may be lost.
- The degree of community awareness of ecological processes, status of biodiversity and how these affect the community is needed to be raised.
- Carbon sequestration work needs to be conducted in Vanuatu's mangrove (similar to MESCAL Fiji) as to place carbon offset figures and reference levels and strengthen the arguments raised on whether to conserve or develop mangrove areas.
- Mangrove species inventory in the Northern group of Islands need to be verified and updated.

With such a diverse range of issues and information gaps there will be a need to systematically address each according to priority level and keep building on these strategies so as to help maintain the momentum created by the MESCAL project in Vanuatu.