MESCAL

MangroveWatch assessment of shoreline mangroves in the Solomon Islands

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1 EXECUTIVE SUMMARY

1) This report documents findings from the program of works for 2012-2013 directed by Dr Norm Duke with the MESCAL Solomon Islands Technical Working Group 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 the MESCAL Solomon Islands Technical Working Group 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 Solomon Islands 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 Maramasike Passage, Solomon Islands.

5) A key outcome of these initial MangroveWatch surveys is a long-term visual baseline of mangrove extent, structure and condition along 10.25 km of Maramasike Passage shoreline 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) Mangroves in Maramasike Passage are of high ecosystem value and support high levels of subsistence resource use due to their high biomass (relative to elsewhere in the pacific), high structural complexity, habitat diversity and healthy condition. Mangrove cutting and harvesting present along 5% of mangrove shoreline shows that greater awareness of the importance of fringing mangroves for shoreline protection and sea level rise buffering is needed locally. Communities should be encouraged to protect fringing mangroves from damage, particularly in currently exposed areas.

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.

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2 INTRODUCTION

In March 2013 the MESCAL Solomon Islands Technical Working Group and associates undertook a survey of fringing mangrove habitats in Maramasike Passage 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 summarising 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.

2.1 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.

2.2 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 coastal resource management***
- ***provides a visual baseline from which to assess future change.***

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

Figure 2.1 Solomon Islands MESCAL mangrovewatching in Maramasike Passage, South Malaita

2.3 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.

2.4 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.

2.5 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 2.2);

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.

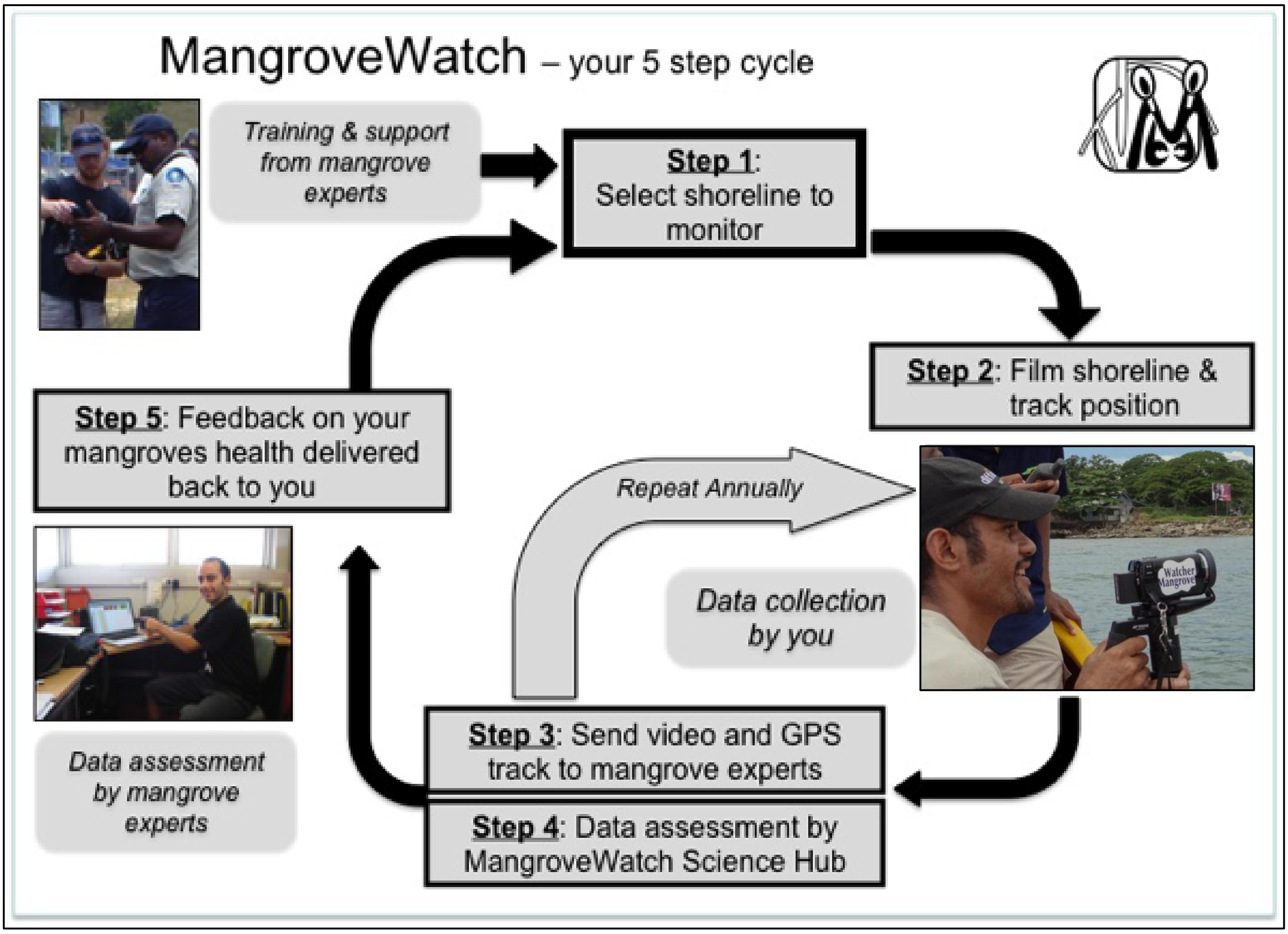

Figure 2.2 The MangroveWatch approach

2.6 Benefits 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.

3 METHODS

3.1 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.

3.2 Shoreline Video Assessment Method (SVAM) survey location

The MESCAL Solomon Islands Technical Working Group surveyed fringing mangrove habitat along Maramasike Passage shoreline, South Malaita (Figure 3.1). The southern shoreline of Maramasike Passage is the MESCAL demonstration site in the Solomon Islands. Mangroves within Maramasike passage are extensive representing a large proportion of Solomon Island mangrove area with very high biomass and carbon storage potential (Duke et al. 2013). Maramasike Passage is an area of relatively high population density and is an important travel route for people of South Malaita. The area has historically experienced sever cyclone damage (Cyclone Namu) and local reports suggest local sea level rise may be occurring in the region. The mangroves of Maramasike Passag are used extensively as a subsistence resource for food, building materials, and firewood. There is an increasing awareness amongst the local population of the need to sustainably manage mangrove resources. In conjunction with the IUCN MESCAL program, WorldFish has established a pilot mangrove management plan implemented by the Eliote community to improve local mangrove resource management (J Albert *pers comm*). There is a pressing need to ensure mangroves are managed sustainably in south Malaita as the region is recognised as one of most densely populated areas in the Solomon Islands and experiencing rapid population growth.

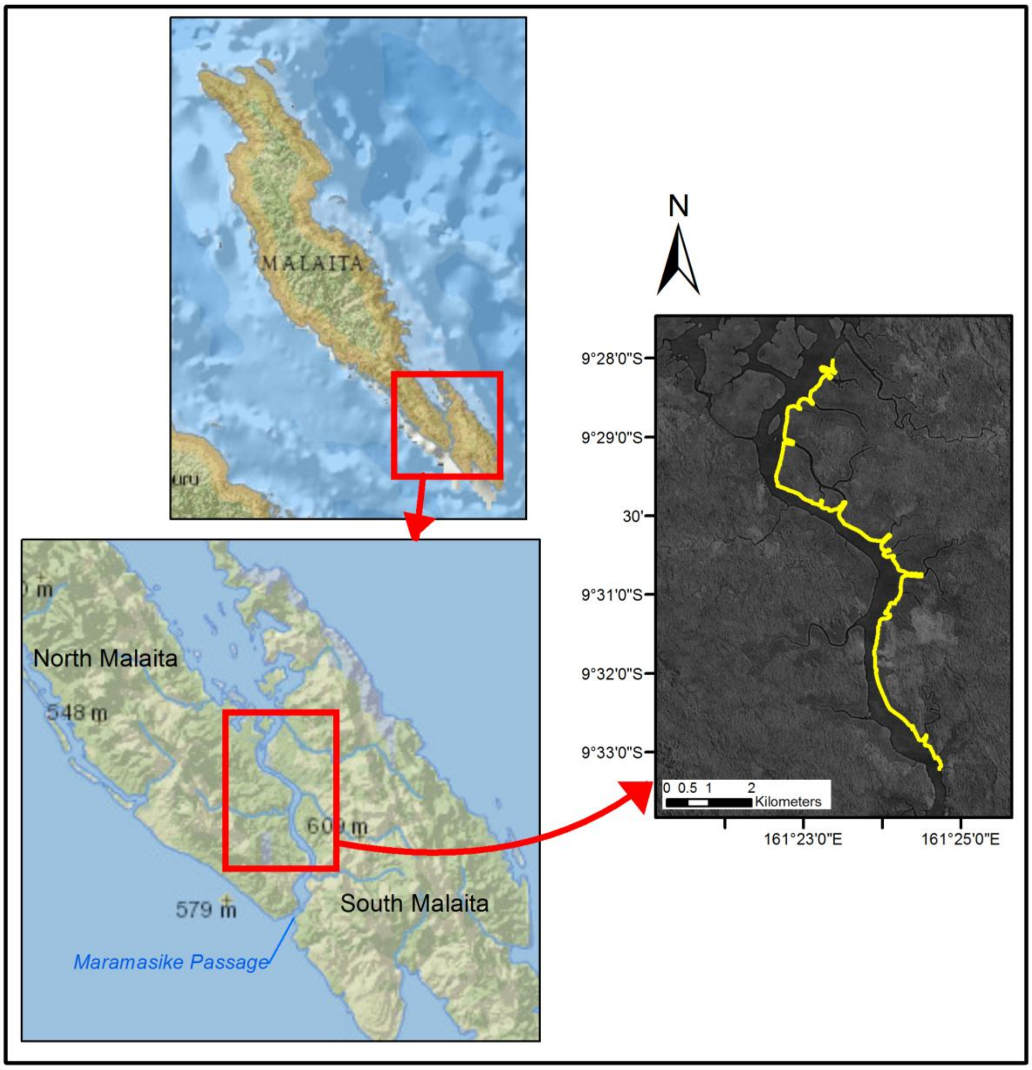

Figure 3.1 Location of MESCAL demonstration site at Maramasike Passage, South Malaita.

3.2.1 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. All classification is based on the visible fringing mangroves intersecting the centre line of the video frame.

A number of factors influence the ability for video imagery to be accurately assessed remotely, and/or accurately geo-referenced to a 10 m shoreline section. Where the following occurs, a *No Data* value is given to the shoreline section, and projected on mapping products;

- Where the boat is positioned far from the shoreline (more than 150 m offshore), the boat does not follow the curvature of the coastline or is travelling at a speed greater than 10 kts per hour, the quality of the imagery collected may not good enough to be accurately assessed and so is excluded from the assessment.
- Where the boat distance becomes greater than 150 meters from the shore, the boat does not follow the curvature of the coastline, or an accurate GPS track from the Garmin GPS is not available, a match between GPS track and adjacent shoreline cannot be made. As such, no assessment data can be related to the 10 m shoreline section, and the imagery data is excluded from the assessment.
- In instances where no Garmin GPS track has been provided, the GPS track is reconstructed from data from the Sony Handycam. As this track is less accurate and not as 'smooth' as the Garmin track, the likelihood of null values occurring is increased.

3.2.2 Features assessed and assessment criteria

3.2.2.1 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 is indicative only but enables comparison between areas within the same region.

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 1). 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 1). The mangrove biomass score is calculated using estimated heights factored to a score out of five based on the upper height value recorded (Table 1). 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). The biomass score is a relative score that is indicative only but enables comparison between areas within the same region.

Examples of mangrove forest assessed as of biomass scores 1 to 5 are provided in Figure 3.2

Table 1 Mangrove biomass assessment criteria

Mangrove Biomass Score	0	1	2	3	4	5
Height classification	No Mangrove	Canopy height <5m	Canopy Height 5-10m	Canopy Height 10-15m	Canopy Height 15-20m	Canopy Height >20m
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

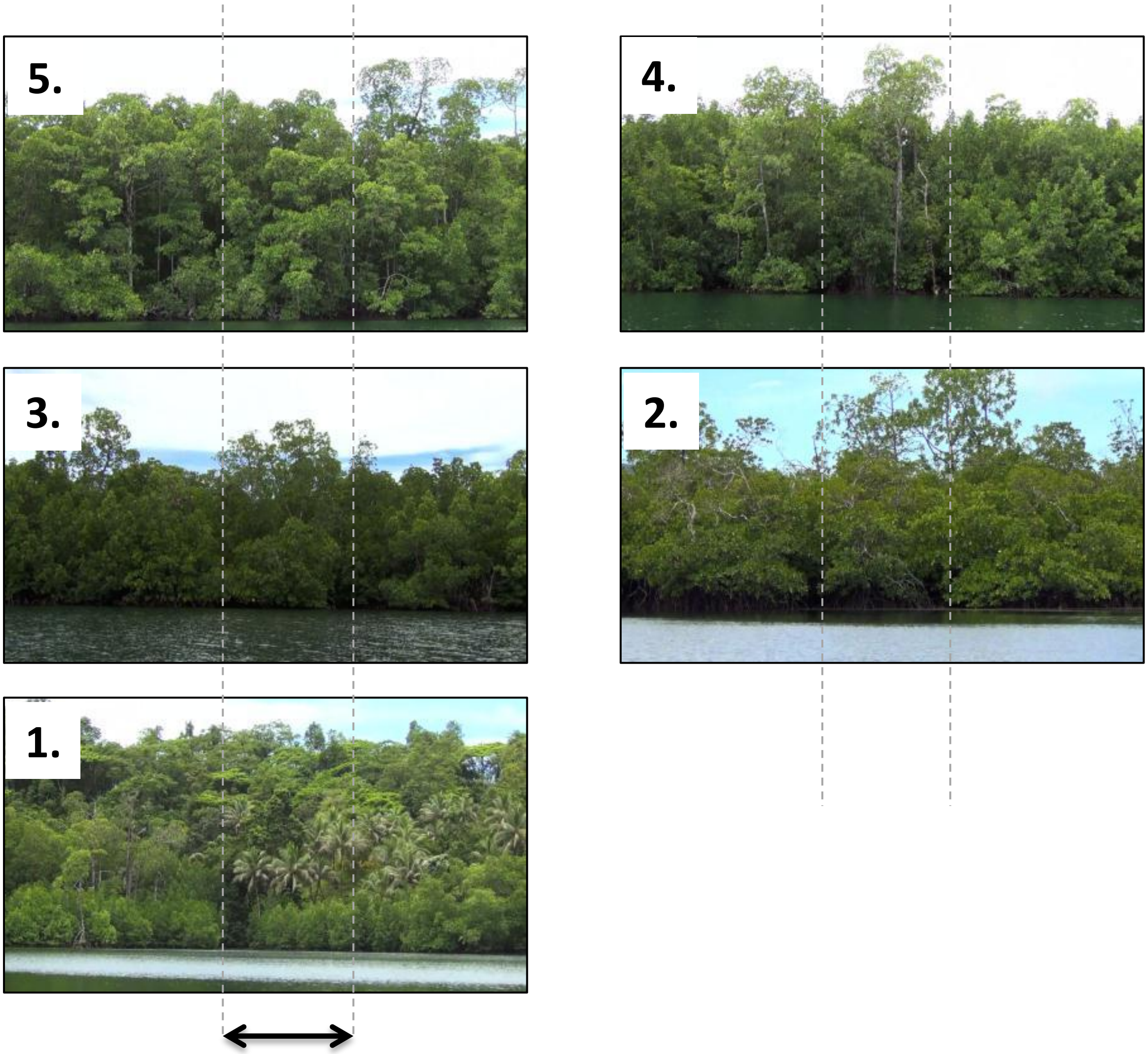

Figure 3.2 Example video stills of mangrove biomass assessment scores

3.2.2.2 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 1 to 5 are provided in Figure 3.3. Canopy density describes mean percentage canopy cover for fringing mangroves and the dominant canopy layer ranked from 1 to 5 as outlined in Table 2. 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

Table 2 Mangrove condition assessment criteria

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.

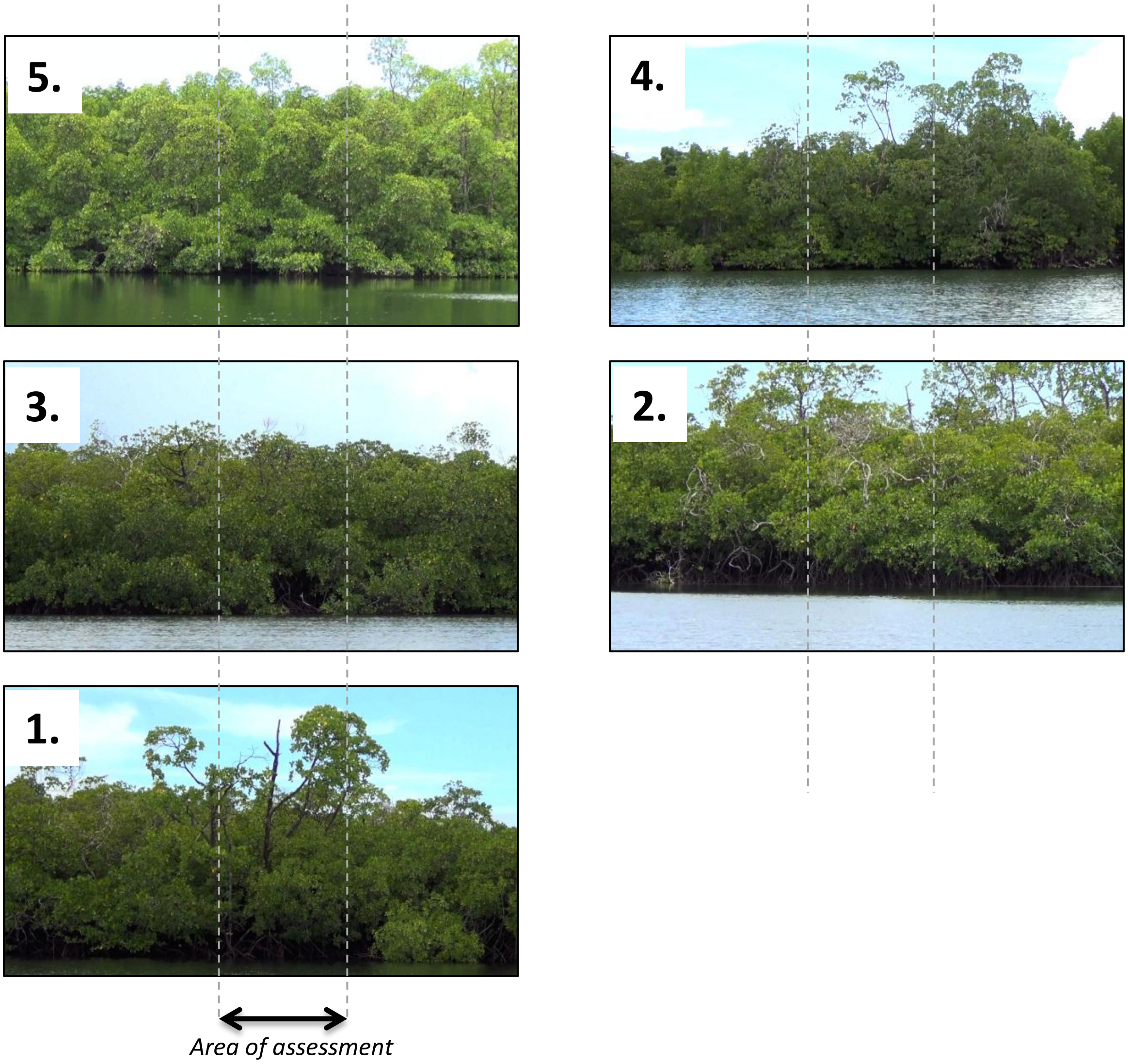

Figure 3.3 Example video stills of mangrove condition assessment scores

3.2.2.3 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 1), canopy cover (as described in Table 2), and the presence of inter-tidally submerged canopy and aerial root structures. Examples of mangrove forest assessed as of physical value scores 1 to 5 are provided in Figure 3.4

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.

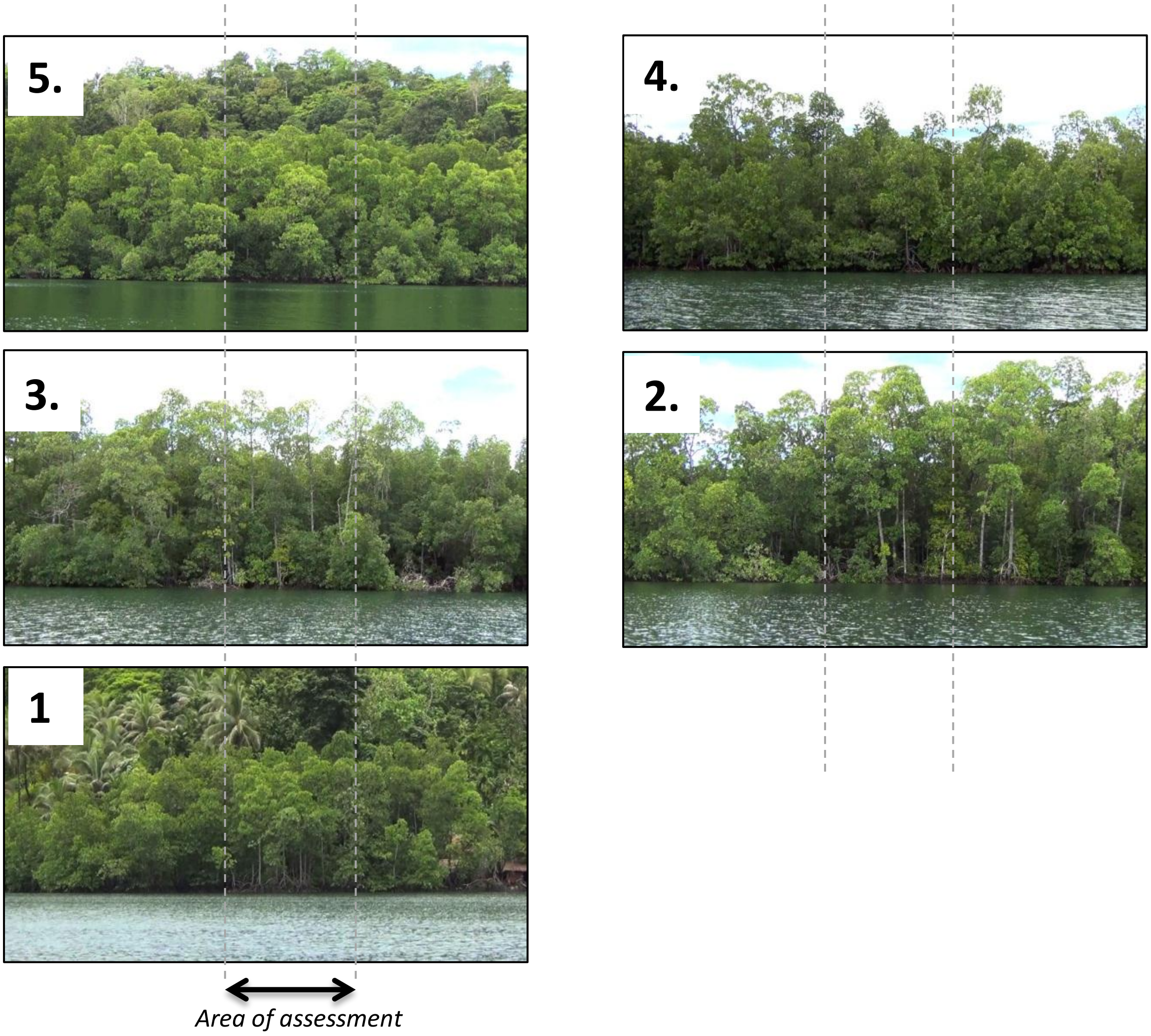

Figure 3.4 Example video stills of mangrove physical value assessment scores

3.2.2.4 Shoreline change and mangrove forest process

Mangrove forest process describes shoreline mangrove habitat identified as retreating, exposed, stable, growing or expanding. Visual indicators were used to classify these conditions (Figure 3.5, Table 3). Exposed bank is assumed to equate to high erosion potential.

Table 3 Mangrove forest process assessment criteria

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

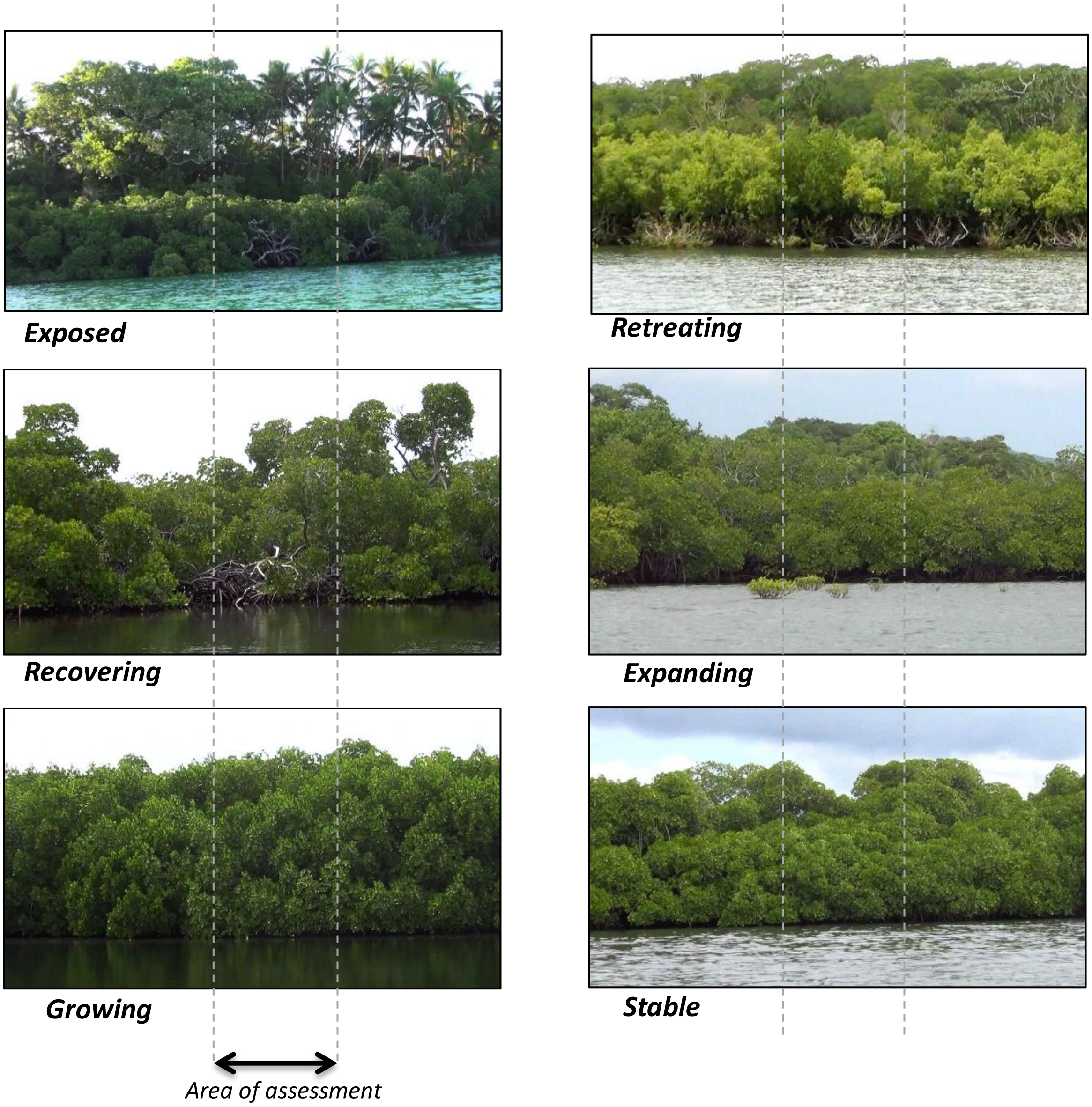

Figure 3.5 Example video stills of mangrove forest process assessment

3.2.2.5 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 kilometre of shoreline, as described in Table 4. The percentage of shoreline with gaps made by human activities determines the human modification score, as described in Table 4.

Table 4 Habitat fragmentation score classification

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

3.2.2.6 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 the Solomon Islands MESCAL demonstration area, such as the presence of access paths, cutting, mangrove removal for coastal development and root burial.

4 RESULTS

4.1 Survey area covered

The MESCAL Solomon Islands Technical Working Group surveyed 10.24 km of the shoreline of Maramasike Passage on 10th October 2012. Figure 4.1 provides detail of the GPS track of survey travel and adjacent surveyed shoreline.

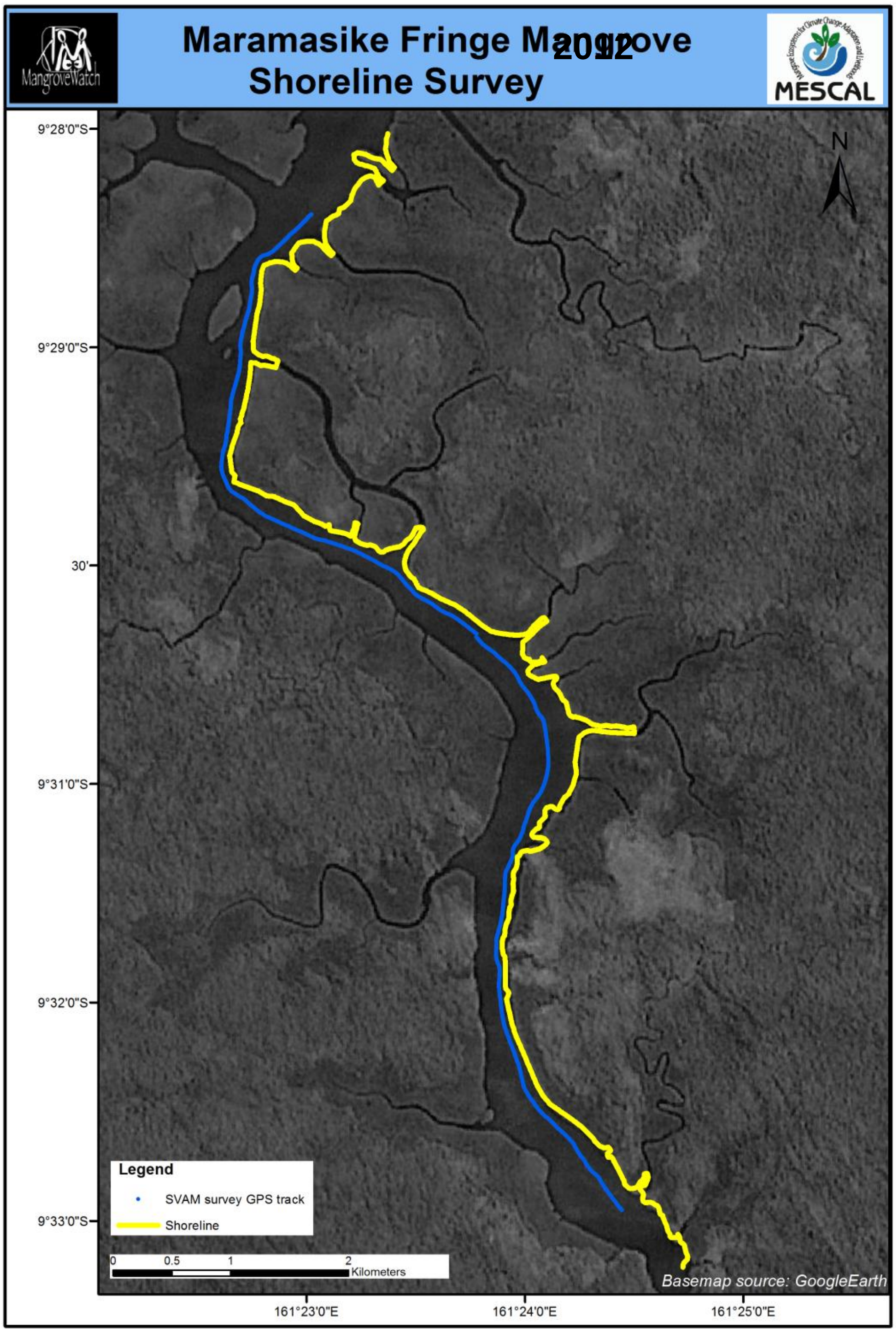

Figure 4.1 Shoreline video assessment, Maramasike Passage

4.2 Forest presence, biomass, physical value and habitat diversity

Mangroves were observed to occupy 9.48 km out of the total 10.24 km representing 92.5% of 10 m shoreline segments assessed. Mean shoreline mangrove percent cover was 92%. Forest height was relatively tall across the surveyed shoreline, being estimated as approximately 17.5 meters. The fringing forest is mostly of moderate to high biomass (70%; Figure 4.2). Forest biomass was greatest at the mid and southern end of the surveyed area. Mean mangrove forest height, structure score and biomass scores are provided in Table 5 and Table 6 provides a breakdown for the assessed forest structure, height, biomass and physical value scores. Figure 4.3 shows the distribution of physical value scores along the surveyed shoreline.

Table 5 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

Mean Height (m)	Mean biomass score[1]	Mean structure score[1]	Mean canopy cover score[1]	Intertidal canopy[2]	Mean physical value score[1]
4 ± 0.02 *Tall*	3.7 ± 0.03 *High*	4.8 ± 0.01 *Closed-continuous*	4.7 ± 0.01 *80-100% cover*	77%	4.5 ± 0.02 *Very high*

Table 6 Percentage of surveyed shoreline classified as falling within each forest structure score

Score	1	2	3	4	5
Height	<1%	2%	20%	51%	26%
Forest structure	0%	0%	1%	15%	84%
Biomass	1%	10%	27%	43%	19%
Physical value	<1%	1%	4%	29%	65%

Mangroves along the Maramasike Passage shoreline are relatively structurally diverse with variations in dominant species composition, stem density, canopy layers and height. The most common mangrove forest type is closed-continuous forest stands dominated by *Rhizophora* and *Bruguiera*, species with high canopy density extending to the tidal zone.

The *Rhizophora* genus dominates the entire surveyed shoreline, with *Bruguiera* species generally co-dominant (Table 7) and often in association with *Ceriops tagal*. *Limnitzera* and *Avicennia* species were also present, but in much lower densities.

Table 7 Fringe mangrove species dominance. Note; percentages add to >100% where species are co-dominant

Species name	*Rhizophora sp.*	*Bruguiera sp.*	*Ceriops tagal*	*Lumnitzera littorea*	*Avicennia sp.*
% of shoreline dominated by species	100%	87%	24%	1%	0.1%

Fringing mangroves in Maramasike passage have high structural diversity (D=10.7) and habitat type richness (r=56) owing to differences in species associations and stem density along the shoreline (see Table 9). The 5 most common habitat types (Table 8) represent only 50% of the shoreline habitats with the majority of the remaining habitat types representing <1% of mangrove habitat. This is reflected in the low habitat evenness score (E=0.09) showing the dominant representation by only a few habitat types.

Table 8 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

Habitat 'type'	*Stem density*	*Canopy cover*	*Intertidal canopy[1]*	*Aerial root structures*	*Canopy layers*	**% Shoreline**
1	Closed-Continuous	80-100%	Yes	Prop Roots & Knee Roots	Upper Canopy Only	23%
2	Closed-Continuous	80-100%	Yes	Prop Roots & Knee Roots	Fringe & Upper Canopy	14%
3	Closed-Continuous	80-100%	Yes	Prop Roots	Fringe & Upper Canopy	8%
4	Closed-Continuous	80-100%	Yes	Prop Roots	Upper Canopy Only	5%
5	Open-Continuous	80-100%	No	Prop Roots & Knee Roots	Upper Canopy Only	4%

Dense closed continuous fringing 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 (4.5 ± 0.0; Figure 4.3).

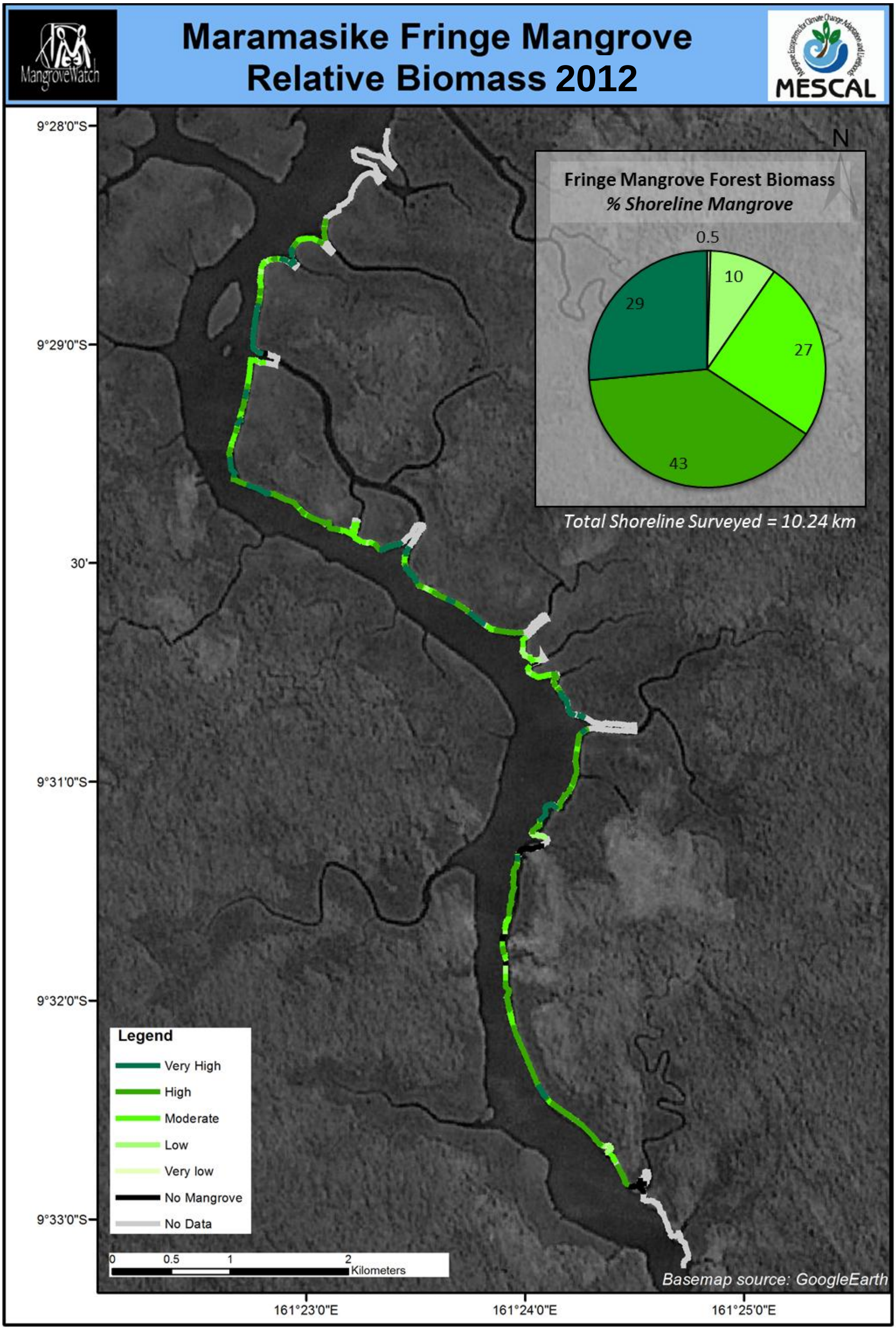

Figure 4.2 Forest biomass, Maramasike Passage fringe mangroves

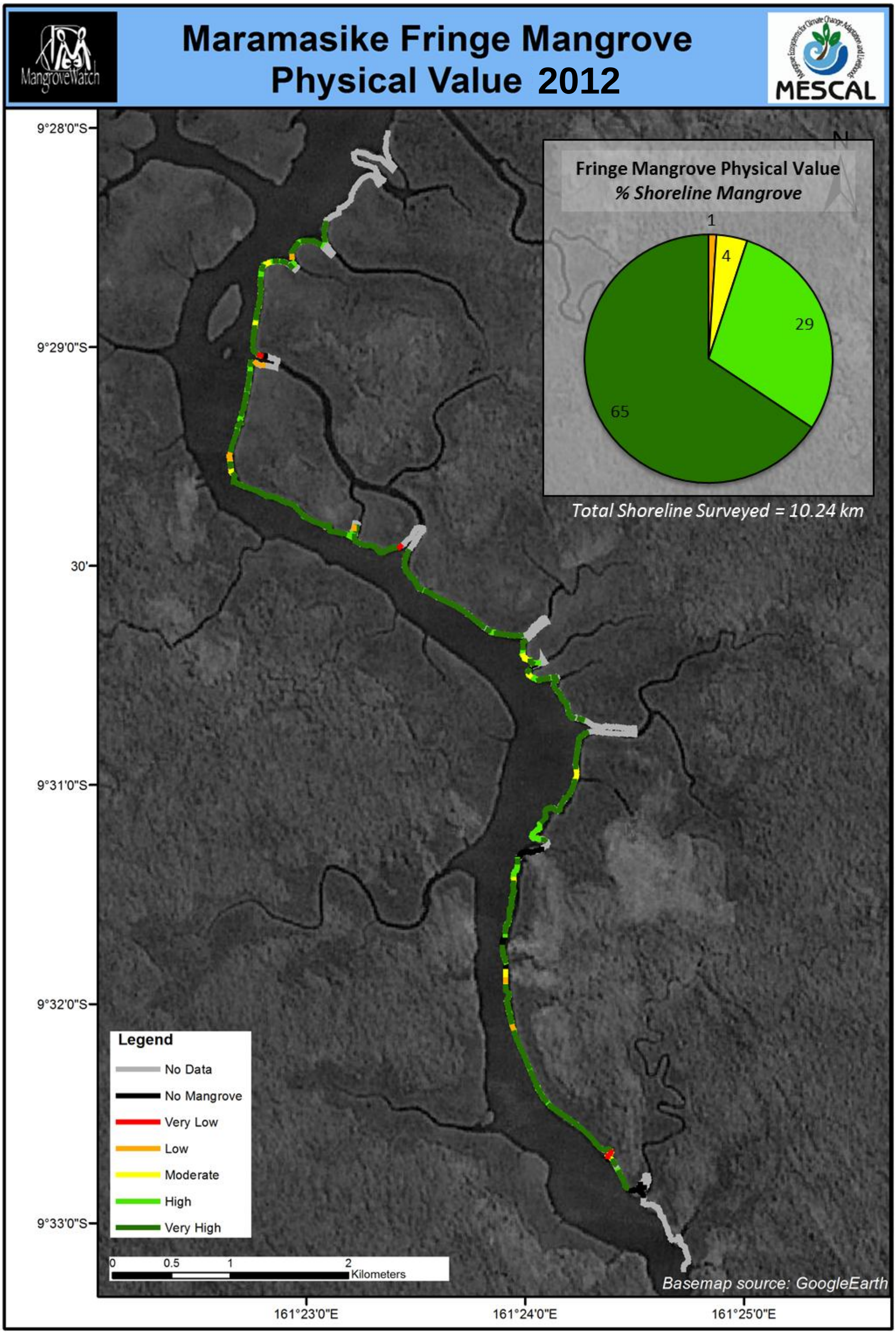

Figure 4.3 Physical value score, Maramasike Passage fringe mangroves

4.3 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 ± 0.02. Seventy-one percent of mangroves were recorded as very healthy, having no visible signs of dieback (Table 9; Figure 4.4). Less than 1% of fringe mangroves were in poor condition. Shorter mangrove stands in the north of the passage were recorded as having the highest frequency of dieback recorded for the survey area (Figure 4.4). Eighty individual dead trees were observed, occupying 8.4% of the surveyed shoreline with 7.8 dead tree per km. The mean canopy cover score was high; 4.4 ± 0.03 (see also Table 8).

Table 9 Mangrove health score distribution

Score	1	2	3	4	5
Dieback	<1%	1%	12%	25%	61%
Canopy cover	0%	0%	2%	28%	71%
Mangrove condition	<1%	1%	5%	22%	71%

4.4 Forest process

Fringe mangrove forest is stable along 68% of the surveyed shoreline, and exhibit clear signs of growth along 24% of the shoreline (Figure 4.5). Exposed mangrove (5%) is present on the concave outer bends of the passage where they are likely to experience higher current velocities. These areas are also sites of high elevation and village sites. No expanding or retreating areas were observed.

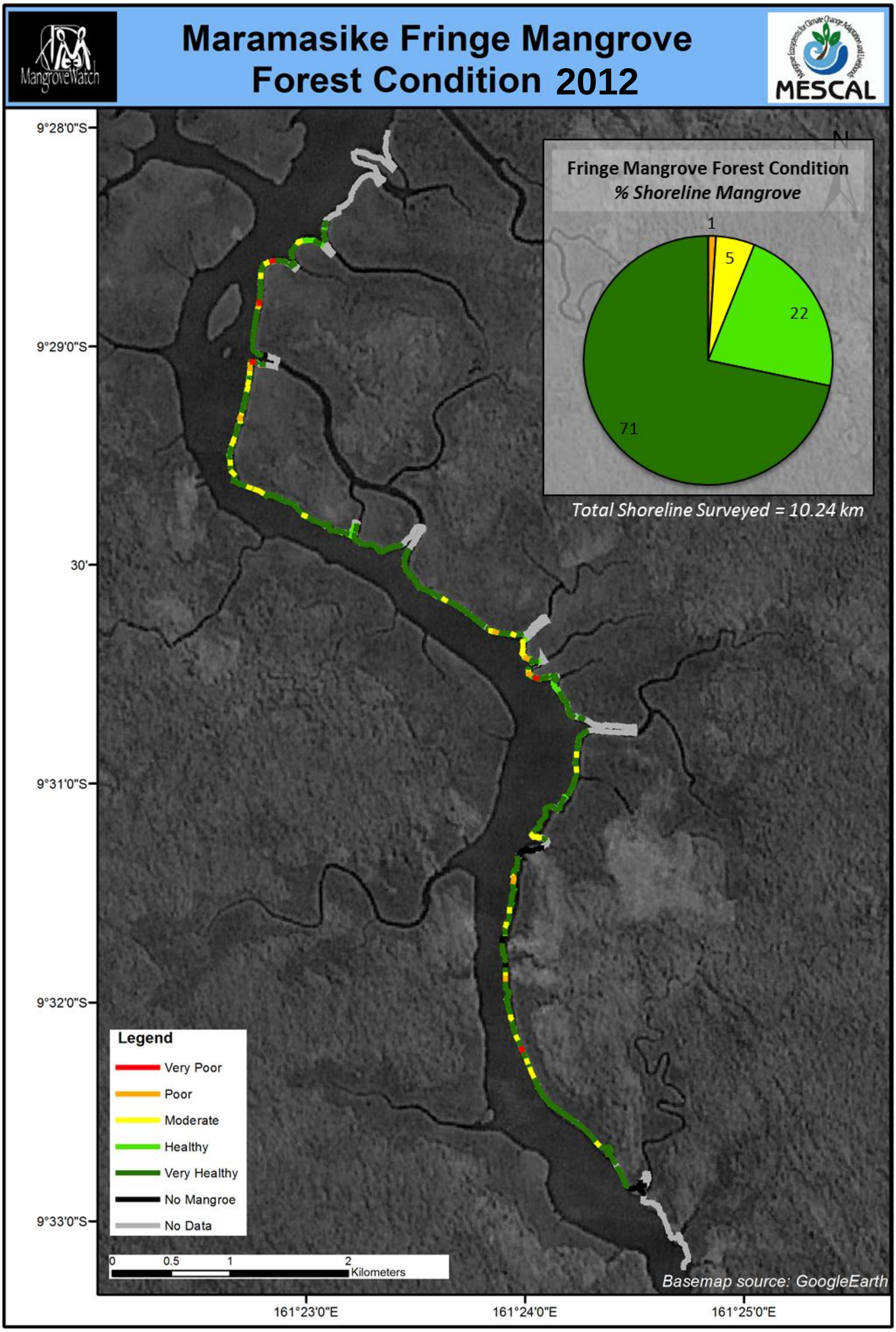

Figure 4.4 Forest condition, Maramasike Passage fringe mangroves

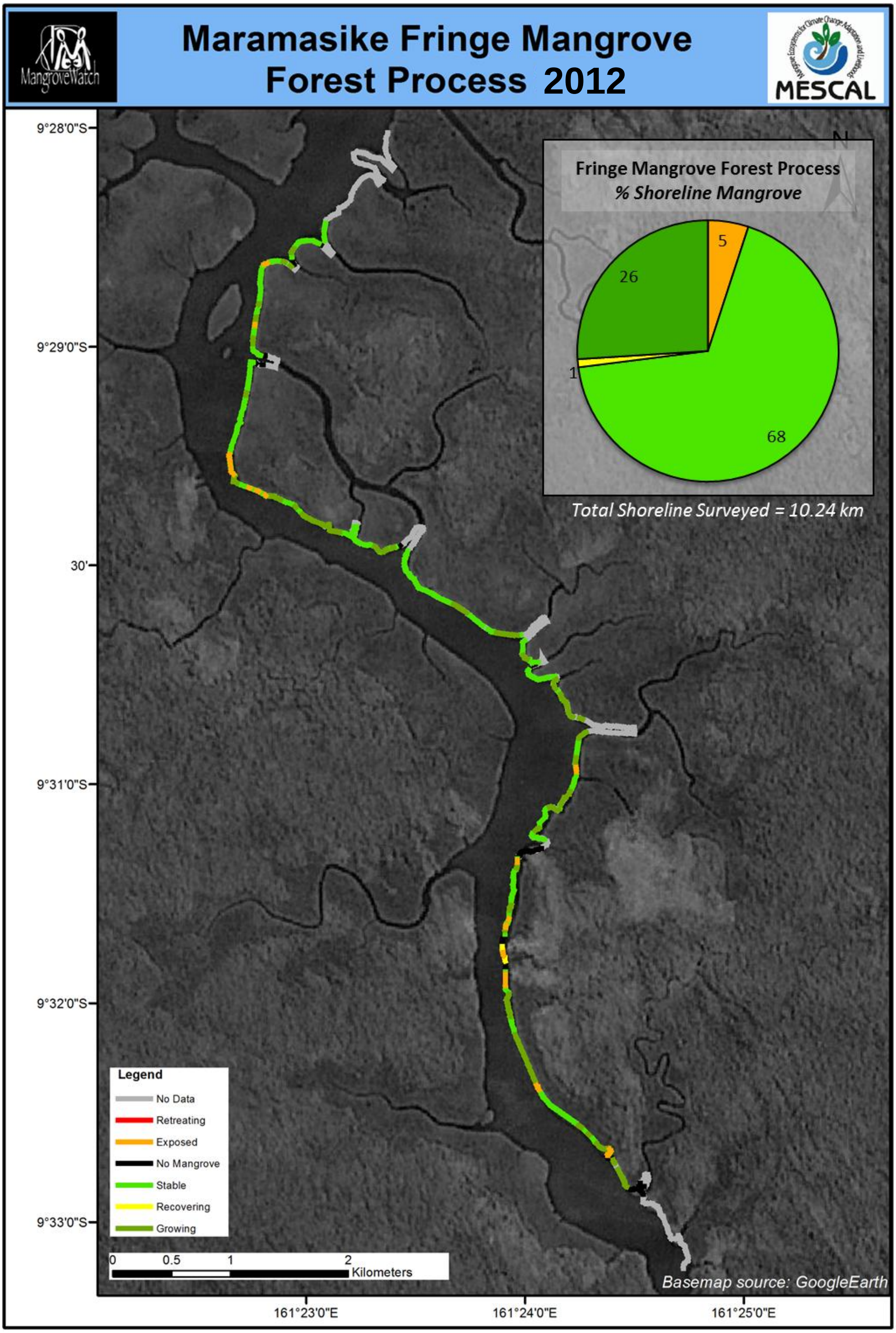

Figure 4.5 Forest process, Maramasike Passage fringe mangroves

4.5 Fragmentation of fringe mangrove forest

Some signs of fragmentation are evident in the mangroves of Maramasike Passage. Eight unnatural gaps in the fringing forest were observed (out of a total of 18 gaps), equating to 1.75 gaps per kilometre of shoreline. The average length of fringe forest patches was 503 m, with most gaps in fringe continuity due to the presence of numerous channels and creeks that flow from nearby steep upland areas. Unnatural gaps in the fringe were created for access to village sites and tabu areas and associated with clearing at village sites on the shoreline (Figure 4.6).

4.6 Drivers of change

Mangroves in Maramasike Passage are exposed to moderate levels of disturbance from natural and anthropogenic drivers (Table 10; Figure 4.7). This is reflected in the general healthy condition of the fringing forest. Overall disturbances resulting in canopy dieback were identified in 15% of fringing mangroves. Anthropogenic disturbance in the form of cutting and clearing was present for 8% of fringing mangrove shoreline. This is a relatively low figure considering the high population density and the many villages that are present both along the main passage shoreline and feeder channels. Natural drivers of change observed were crown damage from exposure to wind, wave and current causing shoreline exposure and light gaps, most likely caused by lightning, strike (Figure 4.6).

Figure 4.6 Drivers of change in Maramasike mangroves: clearing for water access (top left), exposed mangroves (top right), cutting (bottom left), lightning strike damage (bottom right)

Table 10 Drivers of change in fringing mangrove forest

Source	*Driver*	*Shoreline affected (m)*
Anthropogenic	*Unnatural gaps*	210
	Cutting	460
	Clearing	390
Natural	*Light-gap*	40
	Wind	80

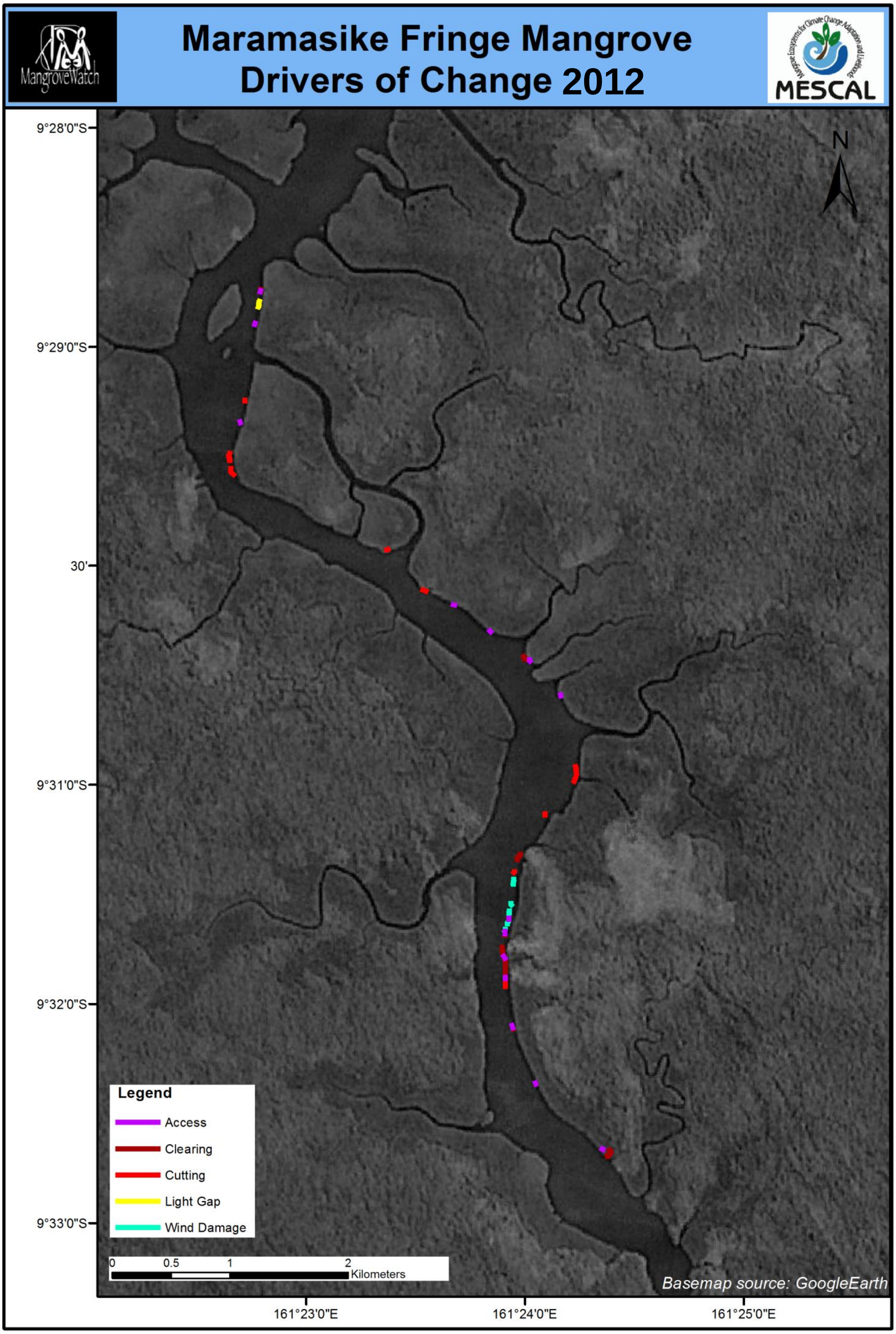

Figure 4.7 Drivers of change, Maramasike Passage fringe mangrove

5 DISCUSSION

This report provides critical baseline information to inform future management of valuable fringing mangrove habitats in the Solomon Islands for the maintenance and improvement of mangrove ecosystem resilience to climate change. Pacific Island Countries and Territories (PICTs) are especially vulnerable 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 10.24 km of fringing mangrove forest of Maramasike Passage, South Malaita; the MESCAL demonstration site in the Solomon Islands. From this data, informed management actions can be taken to ensure mangrove condition and structural integrity is maintained and the mangrove resource managed sustainably.

Mangroves in Maramasike Passage are of high ecosystem value and support high levels of subsistence resource use due to their high biomass (relative to elsewhere in the pacific), high structural complexity, habitat diversity and healthy condition. A key finding of the SVAM survey is that despite large-scale use and potential overexploitation of mangrove resources within basin forest areas, fringing mangrove integrity and condition is largely maintained with only low-level habitat fragmentation observed. The protection of the mangrove fringe is particularly important in Maramasike Passage as the area has historically experienced severe cyclones and is currently experiencing localised sea level rise (J. Albert pers comm). The mangroves of Maramasike Passage have high physical value and capacity to buffer cyclonic storm surge. Additionally, the high frequency of intertidally submerged canopy and dense aerial root structures along the shoreline likely increases sediment trapping potential and facilitates sediment surface accretion allowing these mangroves to 'keep pace' with sea level rise. The high productivity of these mangroves as indicated by their healthy condition will also assist these mangroves to increase surface elevation relative to changes in mean sea level (McIvor et al 2013).

Greater frequencies of dieback and dead trees were observed at the northern limit of the survey. It is possible that here mangroves are currently responding to changes in mean sea level as there were no other indicators of disturbance observed. This area was also the location of mangroves with the lowest relative biomass. Exposed mangroves were also observed on outer concave bends, suggesting these areas may be experiencing high current velocities, which could also be a consequence of sea level rise.

Maramasike Passage mangroves potentially have a high adaptation capacity to sea level rise as indicated by the high frequency of 'growing' mangroves (26%). However, with the combination of sea level rise, clearing and cutting and other natural drivers, there is still likely to be a net loss of fringing mangroves within the Passage, as only 1% of damaged and exposed areas showed signs of recovery.

Mangrove cutting and harvesting present along 5% of mangrove shoreline shows that greater awareness of the importance of fringing mangroves for shoreline protection and sea level rise buffering is needed locally. The establishment of locally managed mangrove management areas within Maramasike Passage will hopefully maintain and improve sustainable mangrove forest use in the region. Local communities should be encouraged to place specific emphasis on protecting fringing mangroves from damage particularly in currently exposed areas. Fringing mangroves and exposed mangrove edges are often targeted for wood resources as they are sites of easy access, which unfortunately leads to further loss of fringe habitat structural integrity and recovery potential {Duke et al 2010).

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, particularly to sea level rise. 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. Maintaining fringing mangrove habitat integrity and condition should be considered a management priority.

The data presented here applies specifically to the demonstration site surveyed, but the issues reported are likely indicative of general trends in mangrove forest management issues for mangroves throughout Solomon Islands 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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