Mooloolah River Baseline Mangrove & Saltmarsh Condition Assessment

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December 2017

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Data Report

A Report for Bunya Bunya Country Aboriginal Corporation

As part of the Mangrove & Saltmarsh Dreaming Project funded by a Queensland Indigenous Land and Sea Country Grant

December 2017

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The data presented herein was collected in partnership with Traditional Owners of Kabi Kabi sea country. We thank the Kabi Kabi Traditional Owners and BBCAC for their on-going engagement and support for tidal wetland conservation on country.

EXECUTIVE SUMMARY

This report provides a summary baseline assessment of mangrove and saltmarsh habitat condition and threats in the Mooloolah River estuary. Information presented here is based on data collected by Bunya Bunya Country Aboriginal Corporation and Kabi Kabi Traditional Owners in partnership with tidal wetland scientists at TropWATER, James Cook University. This Mangrove Watch program is part of the larger Moreton Bay and Sunshine Coast MangroveWatch monitoring program.

In 2016, Kabi Kabi Traditional Owners from Bunya Bunya Aboriginal Corporation undertook an initial MangroveWatch survey in the Maroochy River. These surveys were extended to the Mooloolah River in 2017 and included shoreline video assessment of fringing mangrove habitats and saltmarsh threat assessment.

The Mooloolah River MangroveWatch program is part of the broader Moreton Bay and South East Queensland MangroveWatch citizen-science mangrove monitoring program. The Moreton Bay MangroveWatch Program was initiated in 2012 (Mackenzie and Duke 2013) as a partnership between Wildlife Preservation Society Queensland, Healthy Waterways & Catchments, James Cook University MangroveWatch, local community organisations and citizen-scientists volunteers to address ongoing and emerging natural

resource management issues threatening tidal wetland habitats of Moreton Bay and the Sunshine Coast Region.

The data and information collected during the Mooloolah MangroveWatch surveys facilitates assessment of changing shoreline mangrove condition over time and understanding of natural variability in mangrove and saltmarsh health and key influencing factors, including long-term threats to Moolooah River tidal wetland ecosystems. Geo-referenced video imagery collected during MangroveWatch shoreline video surveys provides a visual baseline of shoreline mangrove condition that can be compared to future assessments as required. This baseline imagery will assist management of Mooloolah River mangroves in the event of future large-scale natural or anthropogenic catastrophic events. The imagery collected during MangroveWatch surveys will be uploaded to an online public-viewing platform in the near future. Baseline saltmarsh threat assessments provide an understanding of key pressures threatening the function and resilience of endangered sub-tropical saltmarsh habitat allowing prioritization of management actions and a reference point to compare improving or declining habitat condition in the future.

In addition to scientific outcomes, the MangroveWatch surveys provide Kabi Kabi Traditional Owners and BBCAC staff the opportunity to directly engage with the management and protection of their valuable tidal wetland sea country resources.

Mooloolah River mangroves and saltmarsh are an important ecological component of Kabi Kabi sea country, supporting traditional fisheries, providing habitat for culturally significant birds and animals, and protecting culturally significant areas such as middens and shield trees and sacred sites. Additionally, Mooloolsh River mangroves contribute to recreational and commercial fisheries in the Sunshine Coast region, help maintain and improve estuary and coastal water quality, protect adjacent threatened habitats and species, and trap and store significant quantities of blue carbon.

There has been significant impact to tidal wetland habitats in the Mooloolah River since European colonisation, including the almost complete loss of habitat in the lower estuary. Recent and major modifications to estuary hydrology resulting from canal estate development. The Mooloolah River National Park, gazetted in 1960 and expanded in the late 1990's, protects large areas of remnant tidal wetland habitat.

Tidal wetlands within the Mooloolah River are threatened by a combination of anthropogenic and climate change related pressures, specifically sea level rise. Fringing mangroves are threatened by shoreline erosion which is potentially exacerbated by boat traffic in the estuary. The influence of elevated nutrient loads in the estuary and continuing hydrological disturbance, including altered groundwater flows reduces the capacity of these mangroves to prevent erosion loss. Increasing sea level rise is likely to be increasing the risk of further losses of shoreline mangroves resulting from erosion. Sea level rise is also the major threat to remnant saltmarsh habitat in the estuary. Vehicle and pedestrian access, and dumping of trash reduce saltmarsh ecosystem function and reduce sea level rise resilience. Both mangrove and saltmarsh habitats in the Moolooah River estuary are threatened by development directly adjacent to tidal wetland areas that limits tidal wetland upland migration with sea level rise, resulting in coastal squeeze. Buffer zone weeds further

limit the capacity of saltmarsh habitats to migrate landward increasing risk of habitat loss due to sea level rise.

To ensure the long-term viability of tidal wetlands in the Mooloolah River estuary it is recommended that action be taken to limit anthropogenic disturbance, and where possible, enhance shoreline mangrove habitats to enhance shoreline protection and habitat values. These management actions include;

- Facilitate the construction of living shoreline infrastructure along highly-developed shoreline areas and areas at high risk of erosion.
- Reduce shoreline erosion by further restricting boat wake with either reduced speed limits or better enforcement of existing speed limits
- Continue to reduce nutrient loads to the estuary from runoff.
- Ensure future development in the catchment has no or minimal impact to coastal groundwater flows and estuary hydrology
- Limit vehicle and pedestrian access to vulnerable saltmarsh habitat areas by either creating no-access areas or constructing boardwalks and controlled access points (E.g. Fishing platforms)
- Undertake targeted and continuous weed management of saltmarsh buffer zone weeds, particularly *Groundsel* and *Asparagus fern*.
- Provide facilities for rubbish and trash disposal around popular fishing areas.
- Improve community education on tidal wetland values and vulnerabilities.

The impacts of climate change and human-related disturbance to shoreline mangrove habitats can be directly quantified from the data collected during the MangroveWatch surveys. Mooloolah River MangroveWatch surveys undertaken by BBCAC are not only important for monitoring mangrove condition in the Mooloolah River but contribute to the broader understanding of natural mangrove ecosystem variability and mangrove climate change response within South-East Queensland and globally.

MOOLOOLAH RIVER MANGROVEWATCH PRORGRAM ASPIRATIONS

The aim of the Mooloolah River MangroveWatch program is to provide Kabi Kabi Traditional Owners from BBCAC with the tools and knowledge to identify and map culturally significant sites within tidal wetlands along the Mooloolah river system, monitor endangered salt marsh and mangrove ecosystems, protect nests of endangered water mouse (*Xermoys myoides*) and mentor young Indigenous people to understand and appreciate tidal wetland ecosystems through a traditional owner and researcher partnership. The partnership between scientists and traditional owners is designed to identify management and conservation issues, and implement strategic on-ground actions informed by a scientific approach. It is hoped that this program will establish an on-going knowledge exchange between Kabi Kabi country Traditional Owners, tidal wetland scientists and resource managers, to ensure tidal wetland habitats in Kabi Kabi country maintain their ecological, economic and culturally significant values into the future.

MangroveWatch

Bunya Bunya Country Mooloolah River Traditional Owner Mangrove Surveys 2017

Achievements

3 Traditional Owner MangroveWatchers
3 days of data collection
4 hrs 34 min video
40.25 km of shoreline filmed
618 points of interest marked
2,693 Photo points recorded

Bunya Bunya Country
Aboriginal Corporation

Hands on in Caring for Country

Survey Track

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METHODS USED TO ASSESS MOOLOOLAH RIVER TIDAL WETLAND HABITAT CONDITION AND THREATS

THE MANGROVEWATCH PROGRAM

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 with support from Caring for Our Country an Australian Government Initiative.

MangroveWatch monitoring is being undertaken in Gulf of Carpentaria estuaries, Torres Strait, Daintree River, Cairns region estuaries, Port Curtis & Coral Coast estuaries, Burnett-Mary Region estuaries, Sunshine Coast estuaries, Pumicestone Passage, Moreton Bay including Brisbane and Logan rivers, and Barwon River estuary, Victoria. 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 1 Kabi Kabi Traditional Owner, Kerry Jones, MangroveWatching on the Mooloolah River

THE MANGROVEWATCH APPROACH – SHORELINE VIDEO ASSESSMENT METHOD (S-VAM)

MangroveWatch provides data on the extent, structure and condition of shoreline and tidal wetland habitats in estuaries and along protected coastlines. The generation of this information focuses on the annual collection of geo-tagged video imagery of shoreline habitats using the Shoreline Video Assessment Method (S-VAM) (Mackenzie et al 2016 and Figure 3).

MangroveWatch S-VAM Data Collection is a 5-step process;

1. **Training and Information.**
   MangroveWatch participants are provided with access to a MangroveWatch kit, trained in data collection methods and provided with information on the importance of mangroves, local threats and issues.

2. **Data Collection**
   MangroveWatchers collect geo-tagged video of local shorelines providing local insights and local knowledge over video voice recording

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.

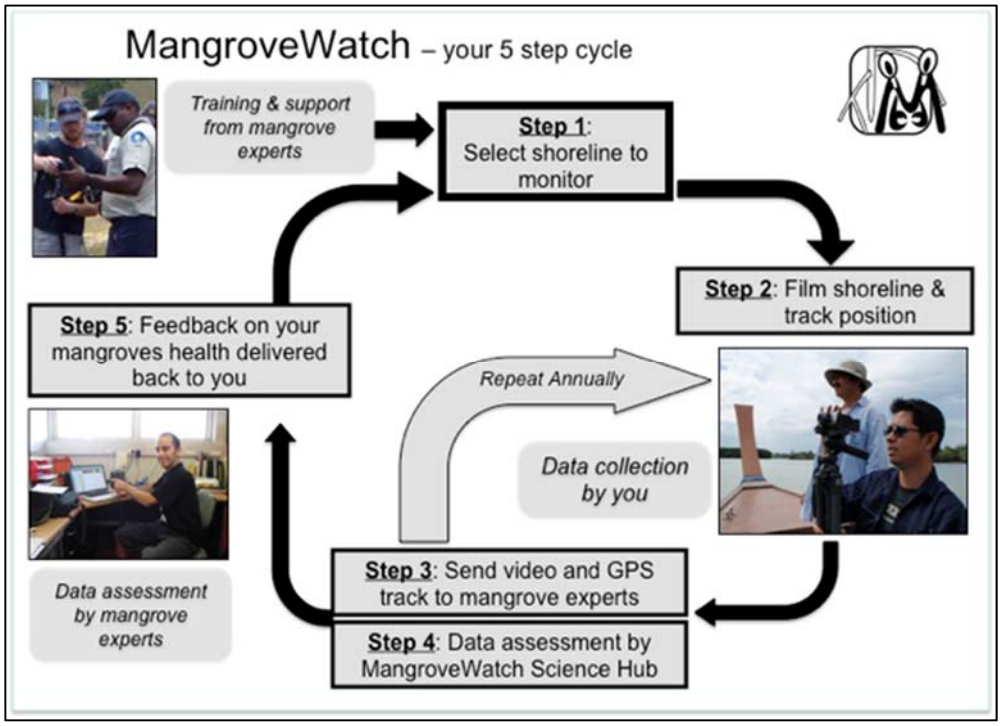


Figure 2 The MangroveWatch approach

Advantages of the MangroveWatch S-VAM Approach

The Shoreline Video Assessment Method (S-VAM) used for MangroveWatch is the perfect tool for indigenous engagement and citizen science to assess shoreline habitats. The advantages of S-VAM 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 and traditional owners 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.

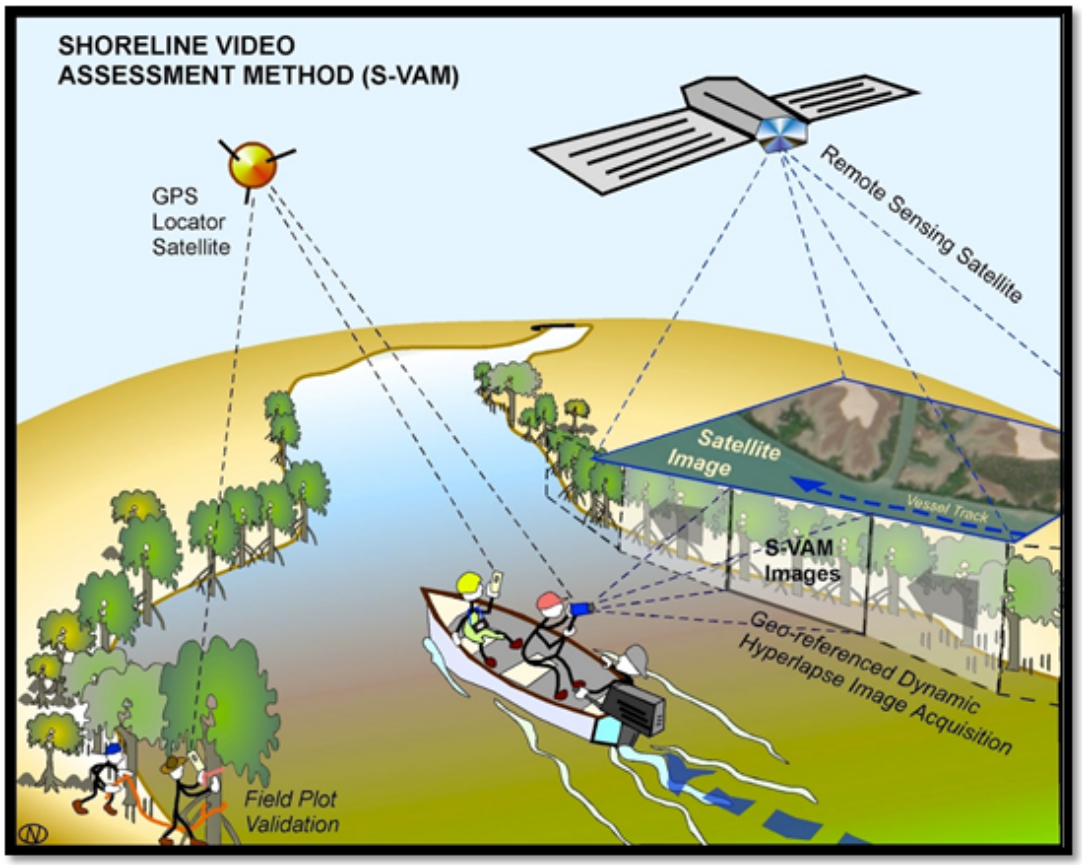


Figure 3 The Shoreline Video Assessment Method (S-VAM). From Mackenzie, Duke et al. (2016)

S-VAM TO ASSESS SHORELINE HABITAT EXTENT, STRUCTURE AND CONDITION IN THE MOOLOOLA RIVER.

In April 2017, Bunya Bunya Aboriginal Corporation Staff and Kabi Kabi Traditional Owners were accompanied by James Cook University tidal wetland researchers to complete S-VAM data collection in the Mooloolah River estuary.

Post-processing of georeferenced data was undertaken to match shoreline imagery to shoreline positions along the Mooloolah estuary following Mackenzie et al (2016). Mooloolah River estuary shorelines were generated from available Queensland State Government spatial layers and modified to approximate recent shoreline position determined from visual inspection of Nearmap aerial imagery circa March 2017. Estuary shorelines were used to create a series of 10 m point intervals in ArcGIS 10.5. Frame images from the shoreline video recordings were matched to 10 m shoreline points using an automated workflow in FME Desktop (FME v2017.1.1.1) developed at St. Leo University, Florida, a partner MangroveWatch organisation.

Criteria-based visual classification of selected shoreline frame images was undertaken to determine baseline mangrove forest structure and condition, shoreline processes and shoreline habitat modification. The criteria used to classify images is detailed in Table 3.

Assessment was made at the centreline of the image using the centre-third of the image for cross-referencing. Classification was restricted to shoreline mangroves only and does not represent the condition of mangroves that may be visible from the shoreline but occur behind beach berms, islands or channels.

Table 1 Shoreline point video image assessment criteria and classification

Variable	Variable Descriptor	Assessment Criteria *Baseline*	Assessment Metric
Fringe Mangrove Cover	The presence of mangroves along the shoreline.	**0)** Mangroves not directly present along shoreline **1)** Mangroves present along shoreline	*% Cover* - Percentage cover of mangroves as a proportion of total shoreline
Shoreline Mangrove Density	The density of mangrove stands along the shoreline	**1) Isolated Individual** *A single mangrove plant present with no nearby mangroves within ~10m* **2) Sparse** *Individual mangrove plant but with other isolated individuals in close proximity not forming a contiguous mangrove stand.* **3) Isolated Stand/Patch** *Multiple individual plants present at assessment point not forming part of contiguous forest extending >20m along the shoreline as determined by mangrove absence or isolated individuals in adjacent frames.* **4) Open Forest** *Mangrove visible at assessment point part of contiguous mangrove fringe (>20m along shoreline) but with large spaces between individuals and canopies not intermingling* **5) Continuous Forest** *Dense contiguous mangrove stand with intermingling canopies*	*Mangrove Density Score* – Mean mangrove density score along shoreline with mangroves present.
Shoreline Mangrove Stand Maturity	The maximum estimated age class of mangroves along the shoreline as determined from expert visual assessment.	**1) Seedlings** *Only seedlings (< ~0.5m tall) present* **2) Saplings** *Only Immature plants (<1.5m tall)* **3) Young Mature** *Only young (~<5 yrs) mature trees present* **4) Mature Established Trees** *Established mature individuals >5 yrs old present but none classified as old mangroves.* **5) Old Mangroves** *Large (>~1 m diameter trunk) trees estimated to be older than 50 yrs old based on size and structure.*	*Mangrove Maturity Score* – Mean mangrove maturity score along shoreline with mangroves present. *% Old Mangroves* – The proportion of mangroves classified as old.

Shoreline Mangrove Condition	The condition of mangroves determined by canopy retreat, exposed branches and twigs (dieback), dead trees and fallen trees.	**Dieback** (exposed twigs and branches) **0) Healthy Trees** *No Dieback present* **1) Minor Dieback** *<30% of canopy with dieback* **2) Moderate Dieback** *30-60% of canopy with dieback* **3) Major Dieback** *>60% of canopy with dieback* **Dead** (no leaves present) **0.5)** few (~1-2) individuals dead (for density scores 3-5) **4)** Multiple individuals dead or majority individuals dead (for density scores 1-2) **Fallen** (trees fallen in water, unlikely to survive) **0.5)** few (~1-2) individuals fallen (for density scores 3-5) **4)** Multiple individuals fallen or majority individuals fallen (for density scores 1-2)	*Mangrove Condition Score* – Sum of dieback + dead + fallen scores to a maximum of 4. *Mean Mangrove Condition Score* - The mean condition score along shoreline with mangroves present. *Density Weighted Condition Score* – Weighted condition score based on stand density. Used to give greater weight to high density stands with poor condition relative to isolated individuals in poor condition.
Shoreline Mangrove Biodiversity & Abundance	Shoreline mangrove dominant species	Presence of visible dominant and sub-dominant mangrove species present along the shoreline. **1) Dominant Species** - Species representing the majority of stems and or canopy cover at an assessment point. May be present as co-dominant species. **2) Sub-Dominant Species** - Species visibly present but not forming a major component of the stem density or canopy cover.	*Percent species dominance* – the proportion of mangroves with species recorded as dominant for a selected shoreline. *Relative Abundance* – the proportion of mangroves where a species was recorded as present. *Habitat Diversity* – Shannon's Diversity Index (*H'*). The proportion of species *i* relative to the total number of species (p_i) multiplied by the natural logarithm of this proportion ($\ln p_i$) with the resulting product summed across species and multiplied by -1: $H = -\sum_{i=1}^{S} p_i \ln p_i$ *Habitat Richness* – the total number of dominant mangrove species combinations along a selected shoreline.

Shoreline Modification	The presence of human-related shoreline physical modification (Eg. Walls, boat ramps, pontoons), and the resulting level of habitat modification.	<u>Structures</u> (classified according to structure type) **0)** Structures absent **1)** Structures present <u>Walls</u> (interacting with the tidal zone) **0)** Wall absent **1)** Wall present <u>Shoreline Modification</u> **1)** Natural – No human modification **2)** Modified – human-related habitat modification but some habitat integrity maintained. **3)** Highly modified – human related shoreline habitat modification resulting in complete alteration of habitat structure or loss of habitat integrity.	*Shoreline Naturalness* – The proportion of shoreline classified as natural. *Shoreline Modification* – the proportion of shoreline modified *Structure density* – the number of structures per km of shoreline.

RAPID ASSESSMENT OF SALTMARSH VALUES AND THREATS IN THE MOOLOOLAH RIVER.

Saltmarsh habitats (RE 12.1.2) provide a multitude of ecosystem services that support and maintain ecological, economic and cultural values in the Mooloolah River as part of the estuarine tidal wetland complex. In the Mooloolah River, saltmarshes continue to have cultural significance to the Kabi Kabi Traditional Owners as a source of traditional fisheries resources including mud crabs and shellfish, as well as being sites of cultural significance likely used as camp sites by Kabi Kabi ancestors while accessing other estuarine fisheries resources in the estuary. Saltmarshes are also essential habitat for internationally protected migratory shorebird species and provide habitat for the EPBC listed vulnerable water mouse (*Xeromys myoides).* Saltmarshes are known to be important habitat for many commercial and recreational targeted fisheries species in the Mooloolah River such as bream, prawns and mud crabs. Furthermore, saltmarshes play an important role in improving and maintaining estuary water quality, trapping and storing sediment and nutrients delivered by direct overland flow from adjacent terrestrial area, tidal waters and during flood events. The capacity of saltmarsh to provide these values varies depending on the spatial context of the habitat within the estuary and tidal wetland complex and the vegetation structure and diversity. For example, some areas may be more valuable as water mouse habitat due to the presence of nests and proximity to adjacent habitat, whereas other areas may have high value for water quality maintenance values based on the their proximity to stormwater runoff points and high vegetation density.

Sub-tropical saltmarsh are one of the most threatened coastal habitats in South-East Queensland. Nearly 60% of saltmarsh habitats have been lost in Moreton Bay since European colonisation, mostly as a result of urban, agricultural and infrastructure development and land use change. Remnant saltmarsh areas remain highly vulnerable to direct and indirect impacts from human disturbance such as vehicle and pedestrian access, altered hydrology and pollution. The vulnerability of remnant saltmarshes is compounded by rising sea levels resulting from global climate change. Hard structures and urban, agricultural and recreational land uses directly adjacent to saltmarsh habitats prevent natural upland migration of saltmarsh habitats with rising sea levels, while at the seaward margin, mangrove encroachment will result in replacement of saltmarsh with mangrove habitat creating a 'coastal squeeze' effect leading to further loss of saltmarsh

habitat. Even in areas where adjacent land is protected within the Mooloolah National Park, coastal weed species like *Groundsel Bush* and *Asparagus fern* degrade buffer zone habitat and restrict saltmarsh plant colonisation, reducing saltmarsh sea level rise resilience.

The loss of saltmarsh habitat in the Mooloolah River will have negative impacts on cultural values of the estuary as well as the economic and recreational values of the region.

Some degree of sea level rise due to climate change is now inevitable. It is therefore imperative to manage local impacts to saltmarsh habitats to minimise saltmarsh habitat loss and maximise remnant saltmarsh habitat ecosystem function. To achieve this requires that local estuary managers understand the specific local values of each saltmarsh area and the specific threats that are likely to limit those values or increase sea level rise vulnerability.

Kabi Kabi Traditional Owners have an extensive knowledge of local saltmarsh values and threats generated from a deep connection to country, lived local experience and generational knowledge. Using expert knowledge and key values and threats detailed in the EPBC sub-tropical saltmarsh conservation advice, we developed a rapid assessment scoring system to assist Kabi Kabi Traditional Owners identify and rank saltmarsh values and threatening processes at saltmarsh sites within the Mooloolah River estuary. The values and threats assessed are detailed in Table 4.

Large and locally significant sites were selected for assessment using local knowledge and Google satellite maps. A 'site' was identified as either a clearly defined saltmarsh area with distinct natural boundaries greater than 30m^2, or in the case of large extensive areas of saltmarsh, a sub-division of a larger saltmarsh area with site boundaries mapped using hand-held GPS guided by natural features. At each site, value and threat attributes were given a score out of 5, with 5 being highly valuable or highly threatened. Threat scores ranged from 0 to 5, with 0 being absent. Value scores ranged from 1 to 5 as it is assumed that each site provides a minimal level of ecosystem function that supports the ecosystem service value attribute, even if not immediately obvious. Value scores are summed such that a site receives a value score and threat score, both to a maximum value of 100, as it is highly unlikely that al values and threats are present at any one site to a maximum value of 5. Value scores were guided by attributes of site location, vegetation structure, habitat diversity and local knowledge. Threat scores were guided by the scale and intensity of the impact or potential impact at each site based on site location, visual site inspection and local knowledge of surrounding landuse. Where possible, photos were taken of each attribute to assist future assessment of changing values and threats. A recommendation for priority conservation values and suggested remediation strategies was made by the Traditional Owners at each site. The resulting scores allow a comparative assessment of saltmarsh values and threats that can assist managers to develop saltmarsh management strategies at both an estuary-scale and for each saltmarsh patch.

Table 4 Scored saltmarsh values and threats

Values	Threats
Total = 21 *Fish Habitat Values* • Accessibility by aquatic species • Proximity to adjacent fish habitat resources (eg. Seagrass, deep channels, rocky outcrops). • Food resource availability indicated by the presence of snails, crabs and insects. • Habitat Diversity *Blue Carbon Storage* • Vegetation type • Sediment type • Vegetation % cover *Water Quality Improvement Values* • Vegetation Density • Algal Mat Cover • Proximity to direct runoff e.g. Stormwater drain • Proximity to point source eg. STP • Proximity to indirect overland runoff • Tidal connectivity *General Habitat Values* • Shorebird feeding site • Shorebird Roost Site • Water mouse habitat • Overall Habitat Value *Recreation Value* • Accessibility • Visual appeal *Cultural Heritage Value* *Coastal buffer to valuable adjacent habitat (e.g. endangered regional ecosystems, wetlands)*	**Total = 22** *Direct Human Impacts* • Vehicle Damage • Cattle Damage • Human Trampling • Mowing • Burning • Habitat Replacement - Infilling/ Landfill/ Urban and Agricultural Encroachment. • Dumping - Trash/Litter/Debris/ Garden waste *Indirect Human Impacts* • Altered hydrology – tidal flows • Altered hydrology – freshwater flows • Chemical Pollution – herbicide e.g. spray drift • Chemical Pollution – eg. Oil spill, industrial runoff • Agricultural runoff – sediment and nutrients • Urban Runoff – stormwater, sewage • Weeds • Coastal squeeze – adjacent barriers to upland migration *Not obviously human related threats* • Shoreline erosion • Surface erosion & scouring • Sediment burial – eg. flood deposits • Drought *Sea level rise impacts* • Mangrove encroachment • Buffer zone retreat (eg. Casuarina dieoff)

Key findings & Recommendations

Mooloolah River Shoreline Mangrove Habitat

Mangrove Shoreline Cover

- Mangroves are present along 52% of the Mooloolah River estuary, 36% of lower Mountain Creek estuary and 1% of Parrearra canal.
- Mangrove cover is low compared to nearby estuaries.
- Urban development and shoreline modification has led to extensive historical loss of lower estuary mangroves. There is only 2.6% mangrove cover along the shoreline of the lower 20% of the estuary.
- Absence of mangroves in the lower estuary places greater importance on protecting mangroves in the mid and upper estuary and in Mountain Creek.

Shoreline Mangrove Biodiversity, Habitat Diversity and Structure

- 7 of 8 possible mangrove species are present in the Mooloolah River excluding *Lumnitzera racemosa*.
- These 7 mangrove species form 28 different shoreline habitat types along the estuary.
- *Avicennia marina* (Grey Mangrove) is the dominant species in the lower half of the estuary switching to *Aegiceras corniculatum* in the upper 50% of the estuary.
- Habitat diversity is highest in the upper-mid estuary (60-70%), ~12.5 km from the estuary mouth.
- Mangrove habitat diversity is lowest in the lower 10% estuary at the estuary mouth.
- 20% of mangrove stands in the lower-mid estuary (30-40%) have old and very large mangroves present.
- Overall mangrove stand development (mean maturity score) is highest in the upper (all sections >60%) ~12.5 km from the estuary mouth. Similarly high mangrove stand development is present in the lower mid-estuary (20-30%) ~3.5 km from the estuary mouth.
- Excluding the lower 20% of the estuary, stand development is lowest in the lower-mid estuary (30-40%) ~6.5km from the mouth, indicating higher levels of disturbance in this part of the estuary.
- Mean stand density is highest in the upper estuary (70-80%), but the highest proportion (60%) of closed-continuous forest is present in the mid estuary (50-60%).
- Excluding the lower 20% of the estuary, mean stand density is lowest in the mid estuary at 30-40% where there is the least proportion of closed-continuous forest.
- Habitat indices suggest that mangroves are more stable in the upper estuary, with greater levels of disturbance in the lower estuary, where mangroves are present.

Shoreline Mangrove Condition

- Excluding the lower 20% of the estuary, mangrove condition improves with increasing distance from the estuary mouth.
- Mangroves are in poorest condition in the lower-mid estuary (20-30%) ~3.5 km from the estuary mouth, where 18% of mangroves are in poor condition.

- Visual inspection of the Condition Map suggests that mangroves in poor condition are mostly located along the Eastern shoreline adjacent to urban landuse.
- There is minimal recent direct damage to mangroves for views and access impacting mangrove condition.
-

Shoreline Modification

- 52% of shoreline habitat in the estuary is modified, including 42% that is highly modified.
- Including Parrearra Canal and lower Mountain Creek, 61% of shoreline assessed is modified, including 48% highly modified.
- 100% of the lower estuary (0-20%) shoreline is modified
- No shoreline modification was observed in the upper estuary (>70%)
- There are 356 artificial structures at 10.7 structures per km across the entire estuary, with the majority (291) being in the lower estuary. There are no structures upstream from ~12.5 km from the estuary mouth (>60%)
- The most commonly observed structures were pontoons and overhanging decks (215, 60% of structures)
- 24% of the shoreline is hardened with wall structures.
- In the mid estuary (20-60%), 12.5% of the shoreline is hardened.
- There are no walls beyond ~12.5 km upstream from the estuary mouth (>60%).
- There are 24 uncontrolled access points along the main estuary and 33 for all shoreline assessed.
- Very little litter and trash was observed in the mangroves and along the shoreline, with litter observed along only 0.2% of shoreline. The low level of litter is due to regular river clean-ups undertaken by community groups and local government.
- A total of 6 abandoned crab pots were observed.

Threats to Mangroves along the Mooloolah River Estuary

- Shoreline erosion
- Urban runoff and stormwater
- Altered hydrology
- Sea level rise

Recommendations for Shoreline Mangrove Management in the Mooloolah River

1. Habitat enhancement – Living Shorelines

The historical loss of habitat and extensive shoreline modification in the lower estuary has led to a likely loss of estuary function. The Mooloolah River estuary has a very high number of artificial structures and high proportion of hardened shorelines. There is likely to be ongoing loss of shoreline habitat and deterioration of habitat quality in the estuary due o sea level rise and associated shoreline erosion.

Estuary managers can help offset historical and future habitat losses by facilitating the creation of living shoreline infrastructure, particularly in the lower estuary. Living shorelines provide opportunities to integrate mangrove gardens and other habitats like oyster reefs, into existing and new shoreline artificial infrastructure. Living shorelines provide equivalent shoreline stability and infrastructure benefits, with the additional benefit of enhancing natural ecosystem services and amenity value, including fish habitat, water quality improvement, carbon storage and enhanced shoreline protection. Recent mangrove habitat creation at Golden Beach, Caloundra, shows that shoreline habitat can be created with minimal cost and minimal impact to other shoreline amenity values such as waterway views and waterway access.

We propose that Mooloolah River estuary managers implement the following;

a) Provide incentives for shoreline landholders to integrate 'living shoreline' infrastructure into existing artificial structures and rock-walls in the estuary.
b) Mandate that all new infrastructure and shoreline modifications, including existing infrastructure modification and maintenance, incorporates 'living shoreline' natural features, such as mangrove gardens.

Shoreline habitat enhancement effort should focus on the lower estuary (0-20%) to increase shoreline mangrove cover to at least 20%, up from the existing 2.6%.

2. Erosion prevention and control

Historical large-scale hydrological modification of the Mooloolah estuary has likely led to the current widespread shoreline erosion in the mid-estuary. This existing erosion problem will be compounded by increasing sea level resulting in the loss of shoreline habitat and decline in estuary values, including fisheries productivity. Boat traffic and elevated nutrient loads further compound the existing erosion issue.

Erosion prevention and control strategies should be implemented in the lower mid-estuary (20-40%) where poor shoreline mangrove condition is primarily linked to shoreline erosion.

Erosion control strategies should include the following;

a) Construction of erosion control structures such as break-walls, using a living shoreline green-grey infrastructure design where mangroves are currently in poor condition (Refer to mangrove condition map).
b) Implement and *enforce* waterway speed limits adjacent to vulnerable shoreline habitat

3. Urban stormwater and runoff management

Elevated nutrient loads delivered to mangrove habitats can reduce mangrove resilience to erosion, storms and drought. Although it is generally accepted that mangroves can effectively trap and store nutrients, improving estuary water quality, the effects of chronic long-term exposure to elevated nutrient loads may lead to loss of other habitat values and loss of ecosystem resilience. Elevated nutrient supply

may be a factor that is increasing the vulnerability of shoreline mangroves to erosion in the lower-mid estuary. Nutrient loads are delivered to mangroves not only via overland runoff and tidal delivery, but also groundwater. The effects of groundwater nutrient enrichment on mangrove habitats in the Mooloolah River estuary requires further investigation.

We propose the following stormwater and runoff management strategies;

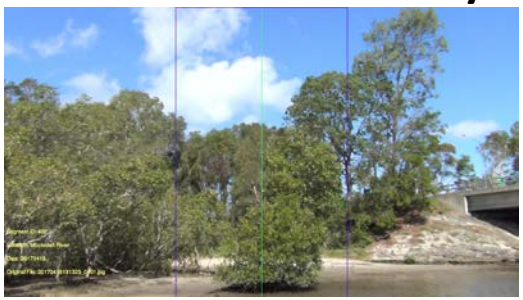
a) Investigate exposure of mangroves to nutrient loads from direct and indirect runoff and groundwater in the vicinity of Parrearra Canal, Brightwater and Parrearra Island.
b) Improve community nutrient-reduction education for residents and landholders adjacent to the Mooloolah River estuary to limit direct and groundwater nutrient delivery to vulnerable mangrove areas.
c) Reduce or prevent direct stormwater entering mangroves along the eastern shoreline between Kawana Way and Komodo Court.

4. Regular shoreline mangrove monitoring

Ongoing shoreline mangrove monitoring is needed to identify areas of active mangrove degradation and prioritise further mangrove rehabilitation actions on the Mooloolah River

Figure 4 Shoreline mangrove habitats along the Mooloolah River estuary

Mooloolah River Estuary Shoreline Mangrove Cover



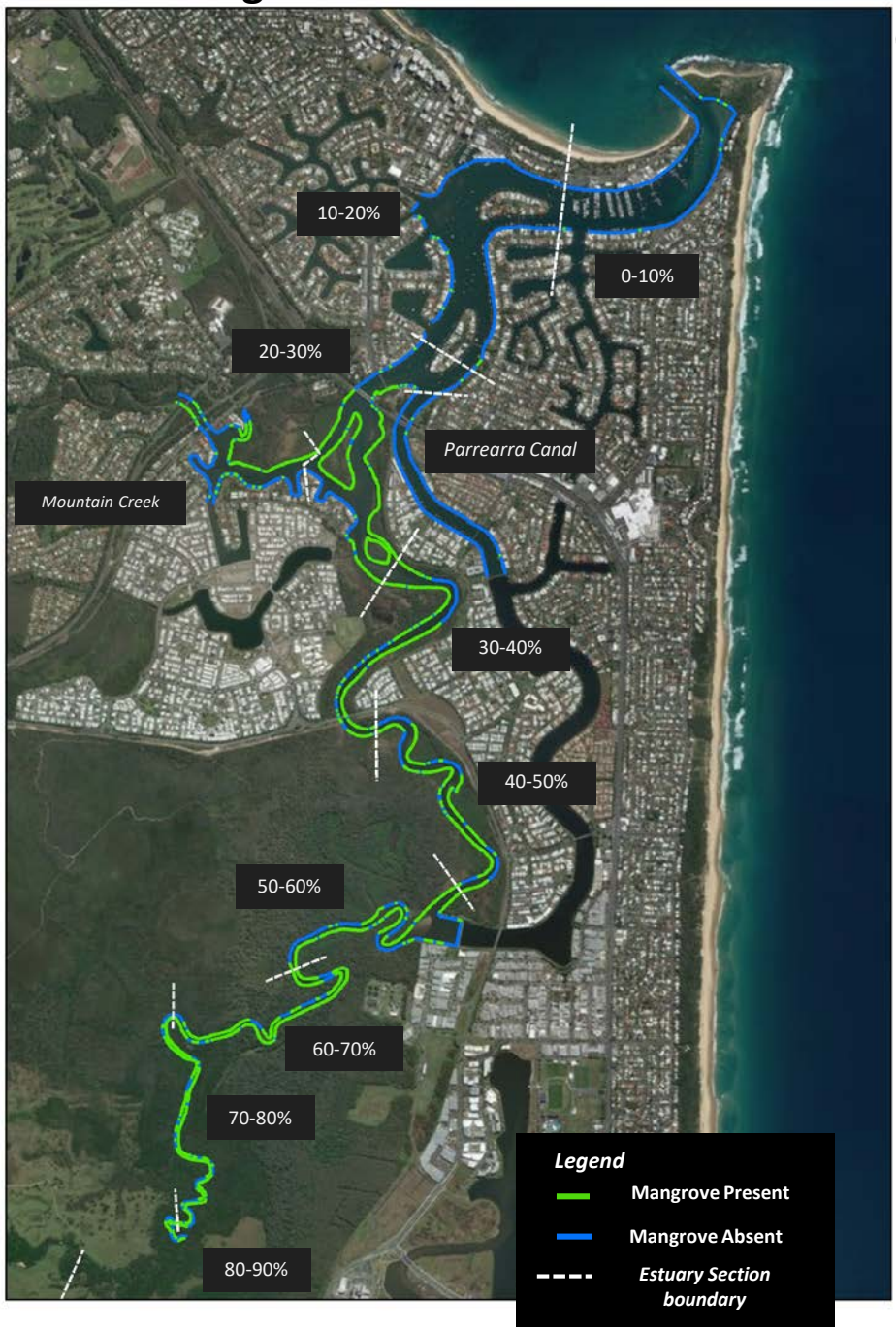
Indicator:
The proportion of shoreline where mangroves are present

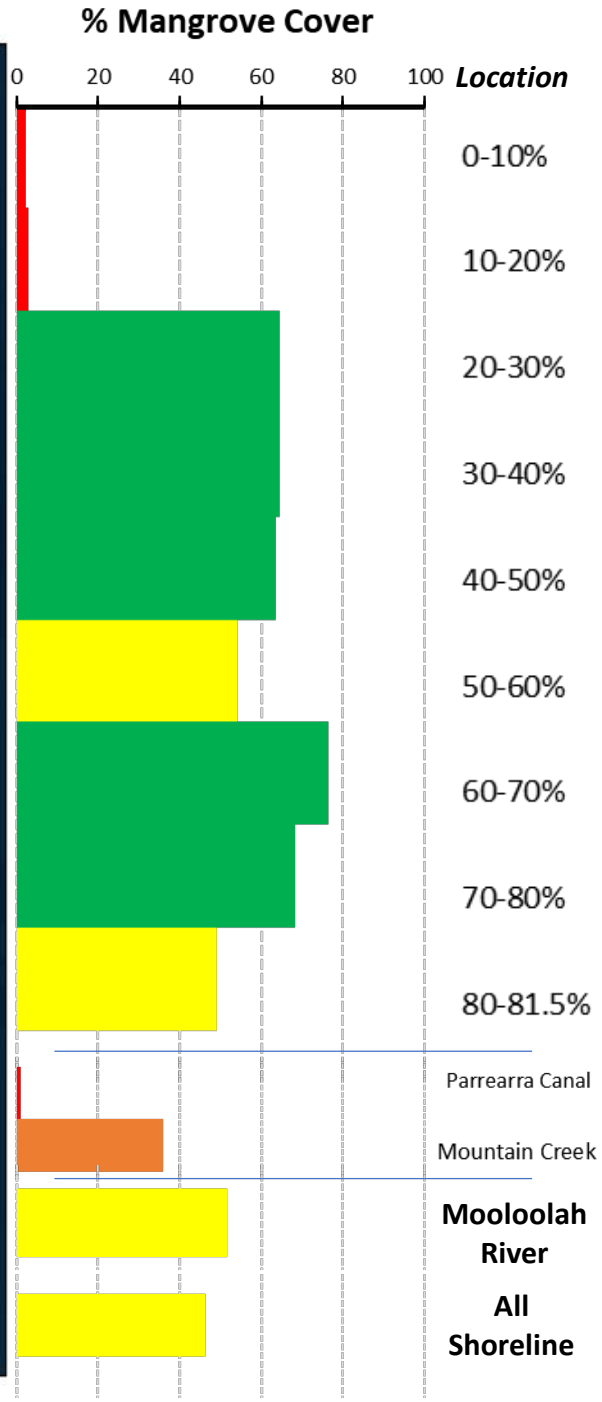
Mangrove Cover Score – **Moderate**
Minimum: 2.3% - Lower 0-10%
Maximum: 76.3% Upper-Mid estuary 60-70%

Mooloolah estuary mangrove cover is low compared to other South-East Queensland estuaries. Development in the lower estuary has resulted in large-scale loss of mangrove habitat. Mangrove cover is much higher in the upper 80% of the estuary, but even these higher figures are low compared to other nearby estuaries. Erosion and weir development reduces mangrove cover at 50-60%. Lower Mountain Ck has only moderate mangrove cover, also due to shoreline development.

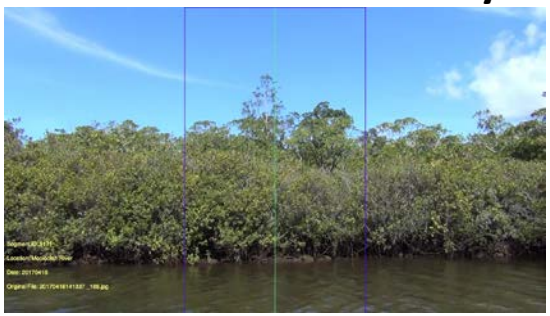
Implications:
Low mangrove cover means less fish habitat, less stable shorelines and less natural capacity to improve and maintain water quality.

Recommended Actions:
Improve mangrove cover in the lower Mooloolah estuary, lower Mountain Creek and Parrearra Canal by incentivising landholder investment in living shoreline strategies such as 'mangrove gardens'.





Mooloolah River Estuary Shoreline Mangrove Density



Indicator:

Mean density score (1-5).

Mangrove Density Score – **Good (3.98)**

Minimum: 1 - Lower 0-10%

Maximum: 4.23 - Upper-Mid estuary 70-80%

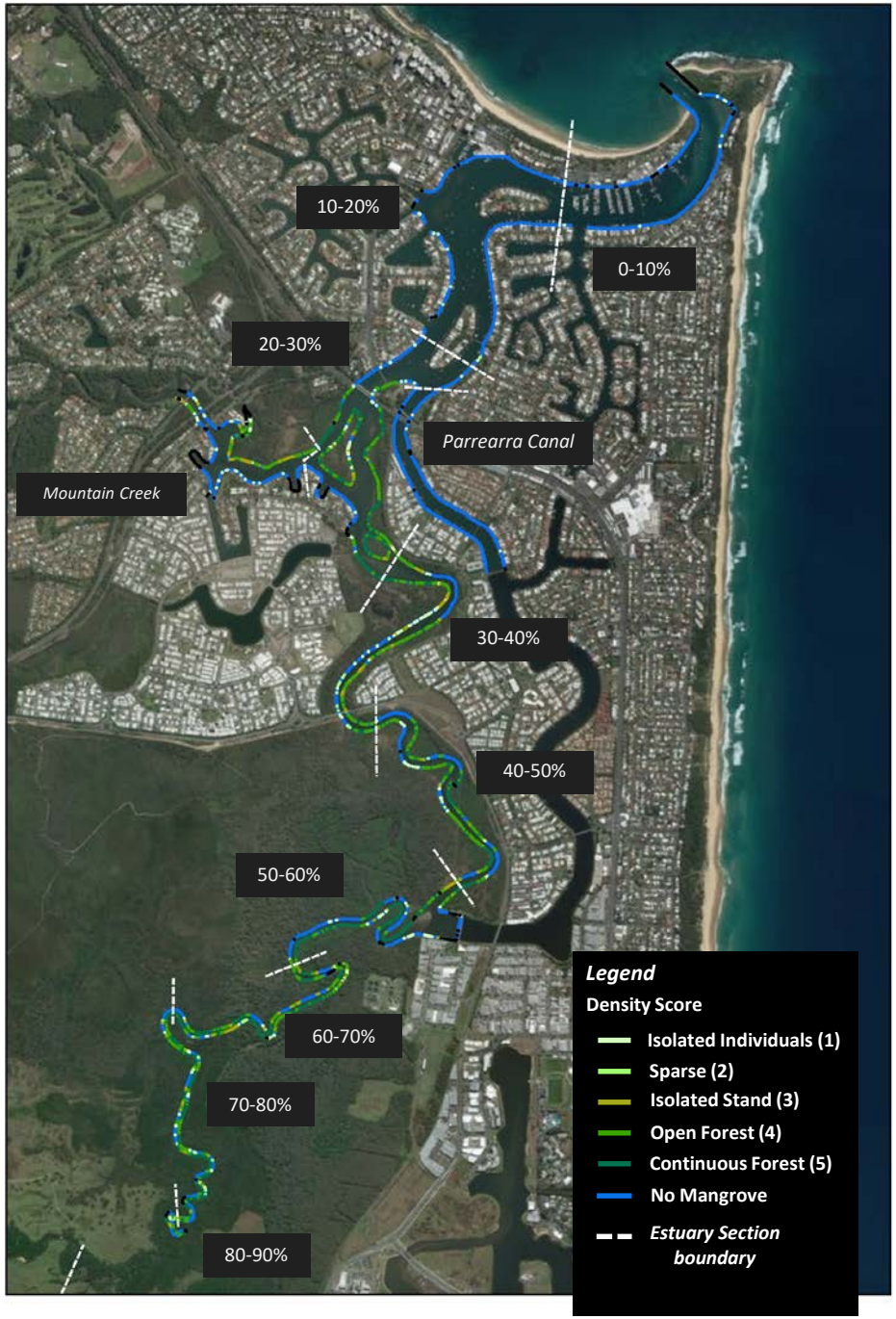
Mooloolah estuary mangrove cover is similar to other South-East Queensland estuaries. The majority of shoreline mangrove (73%) is present as open (36%) and dense (37%) forest. Only isolated mangrove individuals are present in the lower estuary due to estuary modification. Steep banks and erosion limit mangrove development in the lower-mid estuary (30-40%).

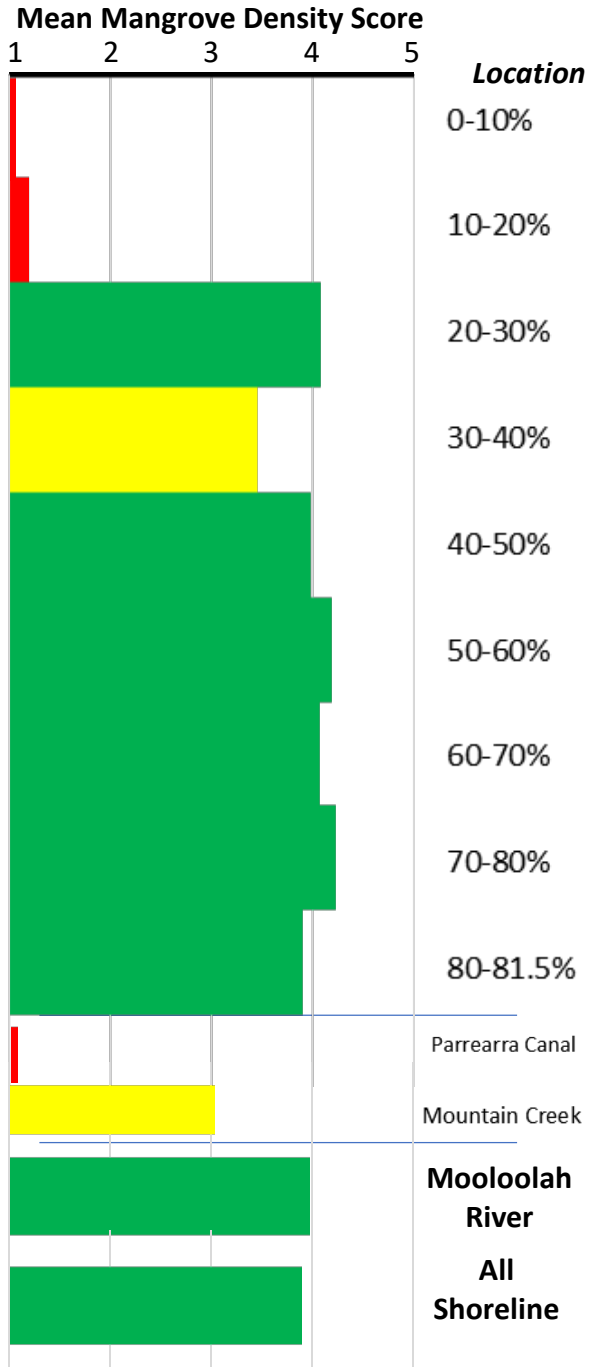
Implications:

Low mangrove density in the lower estuary means less stable shorelines, less natural capacity to improve and maintain water quality, and lower natural carbon storage. The combination of open and dense continuous mangrove stands in the mid and upper estuary provide good fish habitat diversity

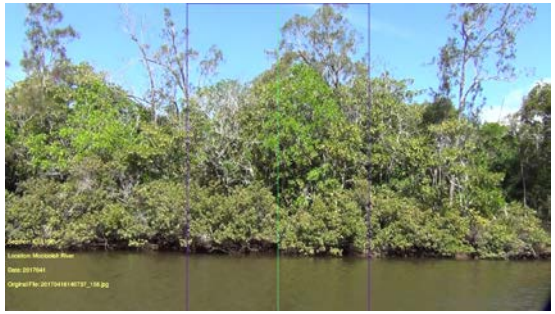
Recommended Actions:

Create 'Living Shorelines' in the lower estuary, Mountain Creek and Parrearra Canal. Habitat creation can be designed to ensure mangrove growth is moderated to maintain river views for shoreline property.





Mooloolah River Estuary Shoreline Mangrove Stand Maturity



Indicator:
Mean stand age (1-5)

Mangrove Maturity Score – **High**

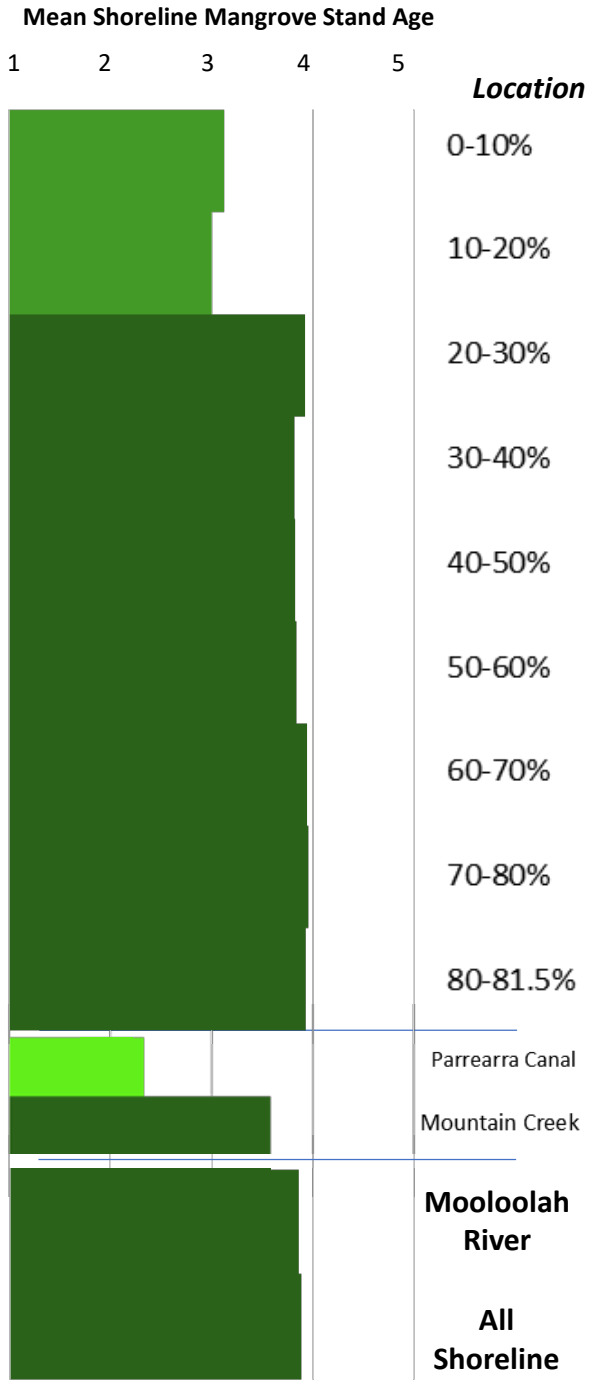
***Overall*: 3.86**
Minimum: *3* - Lower estuary 10-20%
Maximum: 3.95 - Upper-Mid estuary 70-80%
% Mature Stands = 87.7%
% Large old mangroves = 6.5%

Where mangroves are present, they are mostly mature, well developed mangrove stands. This indicates that these mangroves have relatively high resilience to recent flood and severe weather events. The low frequency of large mangrove trees along the shoreline suggests that the estuary is undergoing change over longer time periods and is not a stable-state system. Historical land use change, lower estuary modification, historical flood events and ongoing sea level rise may explain this phenomena.

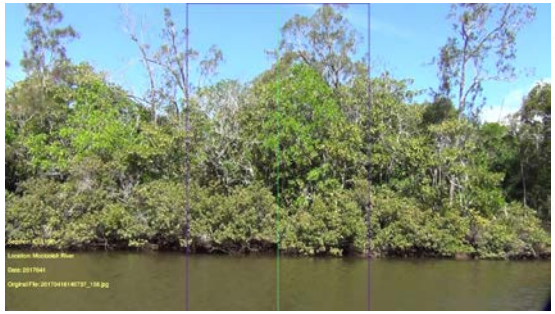
Implications:
Large mangrove trees and mature mangrove stands provide increased ecosystem service value.

Recommended Actions:
The mid-estuary (30-40%) has both the highest frequency of young mangrove stands and large old mangrove trees. This estuary section is therefore both valuable and vulnerable. Efforts to reduce human impacts, including boat wake should be undertaken.

*Note: *Parrearra Canal and the lower 20% of the estuary have very low mangrove cover (<5%)*



Mooloolah River Estuary Shoreline Mangrove Biodiversity & Habitat Diversity



Indicator:

Shannons Habitat Diversity Index (H')

Mangrove Diversity Score – **High**

Shannons Habitat Diversity Index
(*for combinations of dominant species)*
***Overall*: 2.46** (H_{max} = 3.33)
Minimum: *0.9* - Lower estuary 0-10%*Maximum: 2.39* - Upper-Mid estuary 60-70%
Mooloolah River Habitat Richness = 28

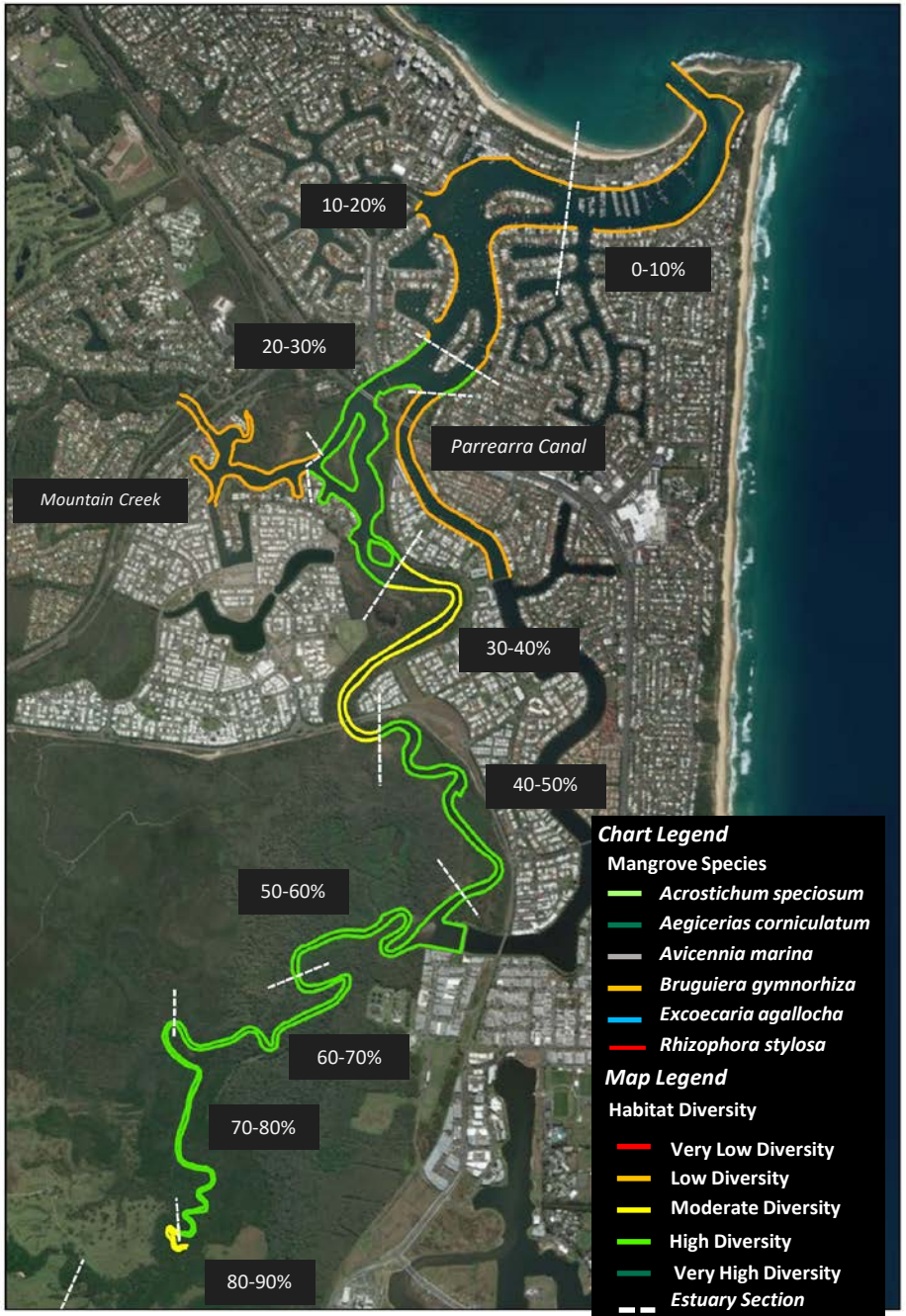
Protected shoreline habitats and high groundwater inputs in the upper 80% of the estuary support a diversity of mangrove species associations. Shoreline modification and very low mangrove % cover greatly limit mangrove diversity in the lower estuary. Six (6) of a possible eight (8) mangrove species form dominant and co-dominant mangrove stands. *A. marina* (Grey Mangrove) is the most common mangrove species, present in 69% of shoreline mangrove.

Implications:

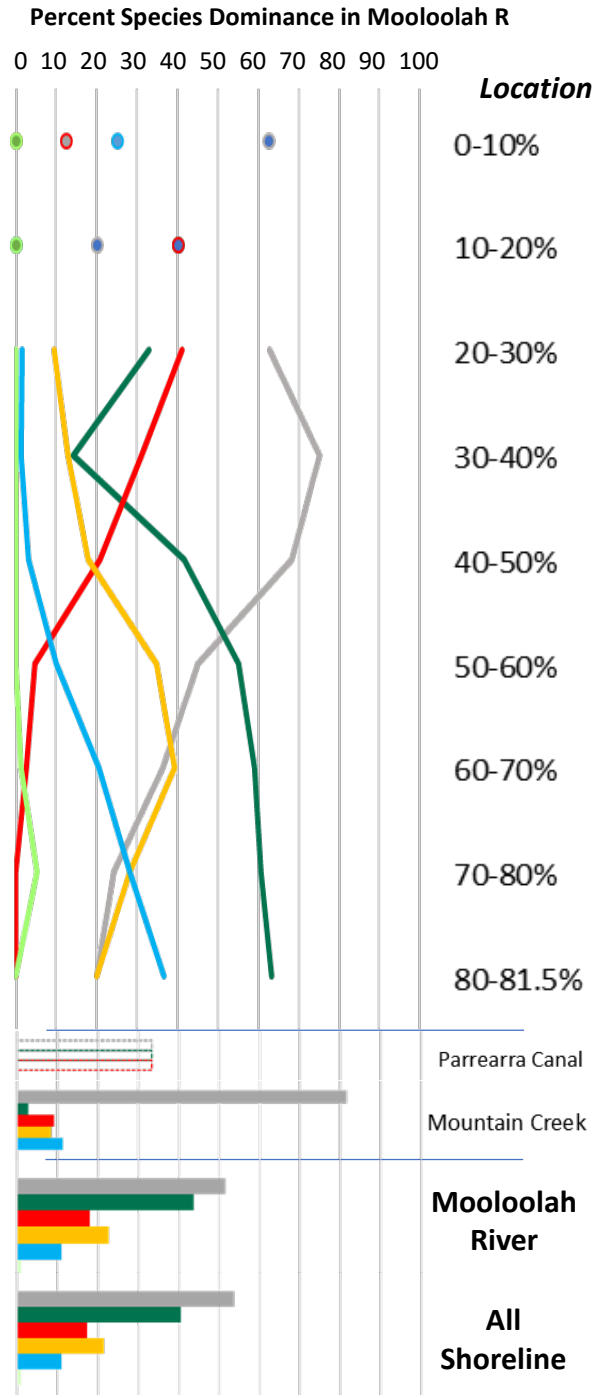
High mangrove habitat diversity increases habitat availability for different fish, aquatic organisms and wildlife.

Recommended Actions:

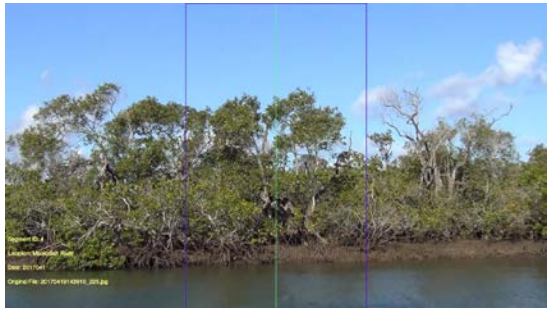
Create 'Living Shorelines' in the lower estuary, Mountain Creek & Parrearra Canal to enhance habitat diversity.
Protect groundwater resources and maintain hydrological connectivity surrounding the estuary and within the catchment.



*Note: *Parrearra Canal and the lower 20% of the estuary have very low mangrove cover (<5%)*



Mooloolah River Estuary Shoreline Mangrove Condition



Indicator:

Density Weighted Condition Score (0-4)

Mangrove Condition Score – **Good**

***Overall*: 3.09**

Minimum: *2.72* – Lower-mid estuary 20-30%

*Maximum: 3.65** - Upper estuary 80-81.5%

Mean Forest Condition Score – 2.93

Mangrove condition increases with increasing distance upstream. Shoreline erosion appears to be the main driver of poor mangrove condition. Erosion in the mid estuary may be exacerbated by increased boat traffic and the effects of sea level rise. The mid-estuary is also subject to greater hydrological disturbance and increased pollutant runoff from surrounding urban land use. In the lower-mid estuary (20-30%), 21% of mangroves have dead trees present and 38% exhibit severe dieback. Mangroves in the Mooloolah River are in poorer condition compared to other SEQ mangrove systems.

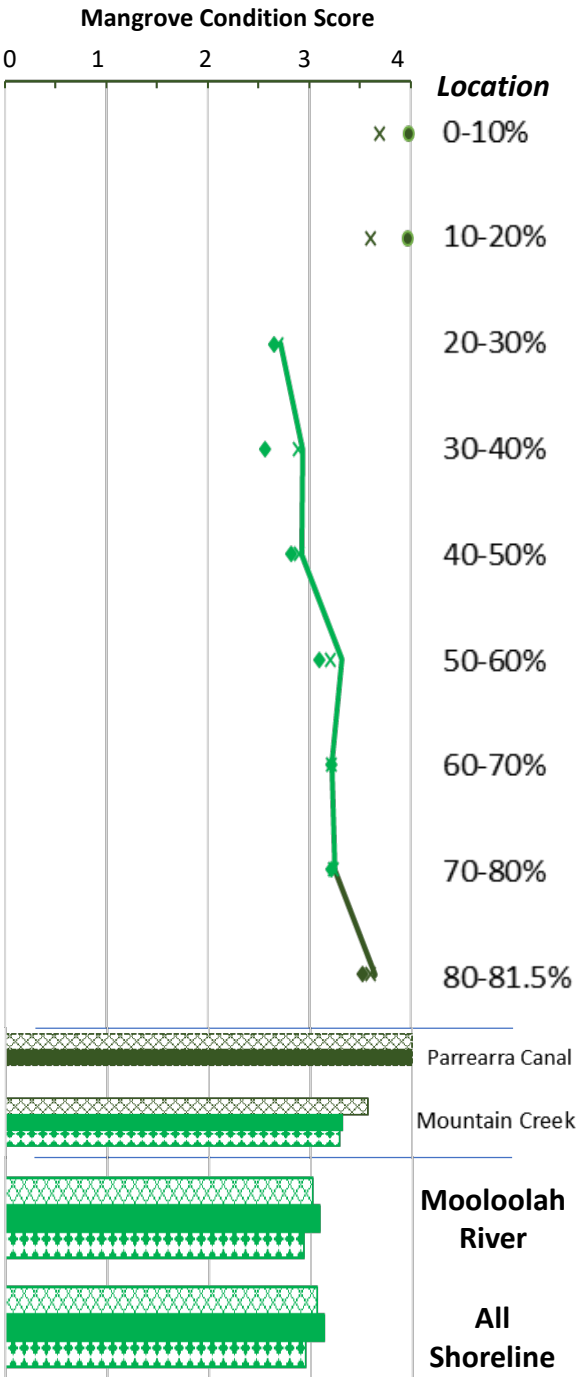
Implications:

Human disturbance may reduce mangrove resilience to dynamic estuarine processes.

Recommended Actions:

Investigate the impacts of boat wake on mangrove habitat. Improve water quality in the lower-mid estuary. Consider shoreline stabilisation works to protect eroding mangrove habitat.

*Note: *Parrearra Canal and the lower 20% of the estuary have very low mangrove cover (<5%). Upper estuary data is limited.*



Mooloolah River Estuary Shoreline Modification

Indicator:
Proportion of shoreline modified

Shoreline Modification Score – **Modified**
% Natural – 71.5%
% Modified – 7.4%
% Highly Modified – 21%

Mooloolah River estuary shorelines are highly modified in the lower estuary (0-20%). Upper estuary shorelines are free from modification and mostly protected within the Mooloolah River National Park. 30% of estuary shorelines are hardened by walls and rip-rap. There are a total of 486 individual structures along the Mooloolah estuary. Pontoons are the most common artificial structure (195).

Implications:
There is limited habitat diversity and natural substrate in the lower estuary. Although artificial structures and modified shorelines can provide fish habitat, their habitat potential is maximised if there is nearby natural habitats. Shading from pontoons and deck platforms reduce fish habitat function.

Recommended Actions:
Encourage 'living shoreline' construction along lower estuary banks. New shoreline modification and artificial structures should be carefully considered, with requirements to incorporate natural infrastructure.

*Note: *Parrearra Canal and the lower 20% of the estuary have very low mangrove cover (<5%). Upper estuary data is limited.*

Percentage Shoreline Modification

% Natural	% Wall	Structures per km	Location
0	**84.2**	29	**0-10%**
0	**83.4**	**55.1**	**10-20%**
66.5	24.3	8.8	**20-30%**
93	5.5	1.6	**30-40%**
97.9	0.5	0.3	**40-50%**
87.5	11.5	1.4	**50-60%**
99.7	0	0	**60-70%**
100	0	0	**70-80%**
100	0	0	**80-81.5%**
0	97.1	33.8	***Parrearra Canal***
34.6	29.4	6.9	***Mountain Creek***
71.5	***24***	***10.7***	***Mooloolah River***
62.9	***30.1***	***12.1***	***All Shoreline***

Mooloolah River Estuary Saltmarsh Threats

Indicator: Mean threat score (0-4)

Saltmarsh Threat Score – **Somewhat Impacted**

Mooloolah River estuary saltmarsh areas are relatively healthy for such an urbanised setting. Dumped rubbish/litter indicates a lack of local community awareness regarding saltmarsh habitat value. All saltmarsh habitats are at extreme risk of sea level rise. Mangrove encroachment and *Casuarina* and *Melaleuca* dieoff indicate recent local sea level rise. Uncontrolled access of vehicle and pedestrian traffic damage saltmarsh plants, exacerbate surface erosion and reduce ecosystem resilience to sea level rise. Weeds like *Asparagus fern* and *Groundsel* within buffer zones limit the natural capacity of saltmarsh to retreat landward with sea level rise.

Implications:

Loss of saltmarsh habitat means loss of important fish and bird habitat, and reduced estuary water quality. Damage to saltmarsh surfaces and loss of vegetation increases sediment runoff to the estuary.

Recommended Actions:

Increase local awareness of saltmarsh value Restrict pedestrian access to saltmarsh areas. Install rubbish bins and fishing facilities at site 10. Prevent illegal camping in coastal habitat. Remove weeds from buffer zones. Ensure urban planning considers future saltmarsh upland retreat and prevent coastal squeeze.

*DSITI, Qld (2015) *Queensland Wetland Data Version 4.0.*
Data available at http://qldspatial.information.qld.gov.au/catalogue/

Threat Score (out of 100)	Key Threatening Processes	Site ID
21	*Vehicle Damage*	1
39	*Altered Hydrology* *Human trampling* *Dumping Rubbish*	2
29	*Vehicle Damage* *Altered Hydrology* *Weather extremes* *Sea Level Rise*	3
27	*Coastal squeeze* *Infilling/Landfill* *Urban Runoff*	4
26	*Coastal squeeze* *Infilling/Landfill*	5
14	*Altered hydrology (historical)*	6
11	*Shoreline erosion*	7
10	*Shoreline erosion*	8
9	*Mangrove encroachment*	9
23	*Shoreline erosion* *Weeds*	10
Mean Score 20.9	***Common Issues*** *Dumping/Rubbish* *Mangrove Encroachment* *Human trampling* *Surface Erosion* *Sea level rise*	

Mooloolah River Saltmarsh Habitat

Saltmarsh Ecosystem Values

- The mean saltmarsh value score across all sites was 56.45 out of 100, ranging between 44 and 65.
- Sites 2 and 3 upstream of Bridgewater Park scored the highest value score, both 65 out of 100.
- Site 4, adjacent to Easter St, Parrearra, received the lowest value score of 44.
- Cultural value was the highest ranked value, with a mean score of 4 out of 5. This high value score demonstrates that all saltmarsh habitats have near-equivalent cultural value, forming an integral part of the sea country landscape in the estuary.
- Water quality improvement value was ranked the lowest ecosystem value, as most sites had perceived low exposure to direct and indirect runoff and point sources except for sites 2 and 4.
- Apart from cultural value, perceived saltmarsh values based on visible habitat attributes varied between sites. This highlights the importance of undertaking site-based assessments to determine ecosystem value, rather than generalised habitat value attributes. Habitat value ranks can be used by saltmarsh managers to prioritise management actions at each site.

Table 2 Mooloolah estuary ranked saltmarsh habitat values

	Site_ID										
Habitat Value	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Overall**
Fish Habitat	4	5	4	5	2	4	2	4	3	4	4
Carbon	5	4	**1**	2	4	2	5	3	**1**	**1**	2
Water Quality	*6*	3	5	2	*6*	*6*	*6*	*6*	*6*	*6*	*6*
Habitat	3	*6*	3	*6*	5	3	3	5	4	5	5
Recreation	2	1	*6*	4	2	5	3	2	5	2	3
Cultural	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	2	**1**

Table 3 Traditional Owner comments regarding saltmarsh values

Site ID	Traditional Owner Comments
1	An important site for the river ecosystem.
2	Fish and general habitat. Cultural significance.
3	A different type of saltmarsh. Habitat for many different animals. Lots of animals. Fish habitat - fish in ponds.
4	Good hunting ground.
5	Food and habitat for mud crabs & fish. Natural beauty. Part of river system. Lots of crabs and snails. High saltmarsh plant diversity.
6	Backs on to national park, fish habitat, water quality and cultural hunting values. Osprey hunting ground.
7	Good crabbing area, some saltpan and NP on Western side, Mud crabs working holes.
8	It's a nice place in good condition. Not many other places with samphire.
9	Groundwater filtration. Cultural artefacts and historical values.
10	It is significant to my people. Only site with *Suaeda arbusculoides.*

Figure 5 Kabi Kabi Traditional Owner, Kerry Jones, inspects a water mouse (*Xeromys myoides)* nest in Mooloolah River saltmarsh.

Saltmarsh Ecosystem Threats

- The mean saltmarsh threat score across all sites was 20.9 out of 100, ranging between 9 and 39.
- Site 2 upstream of Bridgewater Weir scored the highest threat score, with sites 3, 4 and 4 also receiving a high threat score.
- Site 9 received the lowest value score of 9.
- Rubbish dumping, mangrove encroachment, shoreline erosion, sea level rise, and human trampling were the highest ranked threats across all saltmarsh areas.
- Rubbish dumping was observed as an issue at all 10 saltmarsh sites
- Mangrove encroachment were observed at 9 sites.
- Human trampling, sea level rise, buffer zone weeds, shoreline erosion and surface erosion were recorded at 8 sites.
- The mean value to threat ratio score was 3.38.
- Sites 2,4 and 5 had the lowest value to threat ratio scores.
- Based on the ratio of threats to values, saltmarsh management action should be prioritised at site 3 south of Bridgewater weir and site 4 adjacent to Easter St on Parrearra Island.

Table 4 Mooloolah estuary ranked saltmarsh habitat threats

Site ID	1	2	3	4	5	6	7	8	9	10	Overall Rank
Vehicle Damage	**1**	5	**1**	4	-	-	5	-	-	-	**7**
Cattle Damage	-	-	-	-	-	-	-	-	-	-	**-**
Mowing	-	-	-	-	-	-	-	-	-	-	**-**
Burning	-	-	5	-	-	5	-	-	-	4	**14**
Human Trampling	2	**1**	5	4	9	2	5	-	-	7	**4**
Surface Erosion	2	5	12	7	3	2	-	2	3	-	**4**
Sediment Burial	-	13	-	-	9	-	-	-	-	-	**16**
Shoreline Erosion	6	10	-	-	6	2	**1**	**1**	3	2	**3**
Dumping Rubbish	2	**1**	12	8	6	5	2	2	3	**1**	**1**
Infilling Landfill	-	-	5	**1**	**1**	-	-	-	-	-	**12**
Coastal Squeeze	-	5	5	**1**	**1**	-	-	-	-	-	**8**
Mangrove Encroachment	-	5	5	4	6	5	2	4	**1**	4	**2**
Weeds	6	13	12	8	-	5	2	4	-	2	**8**
Agricultural Runoff	-	-	-	-	-	-	-	-	-	-	**-**
Urban Runoff	-	10	5	**1**	3	-	-	-	-	-	**11**
Chemical Spray	-	-	-	8	-	-	-	-	-	-	**17**
Chemical Pollution	-	-	-	-	-	-	-	-	-	-	**-**
Altered Hydrology Tidal -	2	**1**	5	-	9	**1**	-	-	-	-	**8**
Altered Hydrology - Freshwater	8	**1**	**1**	-	-	-	-	-	-	-	**13**
Drought	-	10	**1**	-	-	-	-	-	-	-	**15**
Sea Level Rise	-	5	**1**	8	3	5	-	4	2	4	**4**

Site ID	Traditional Owner Comments *Threats*	*Potential Improvements*	*Other*
1	Altered hydrology	Better local care for the place. More signs.	
2	Runoff from development		
3	Sea Level Rise, Climate Change	Less fertilizer runoff from nearby areas	
4	Development and Sea Level Rise	Access Improvement	
5	Weed, Recreational Use, Erosion	Controlled Access facilities, Weed removal in buffer zone	QPWS weed management, Signs, Fire Management
6	Groundsel	Controlled Weeds and controlled burns	
7	Erosion	Shoreline Stabilisation	
8	In good condition. Probably too much human access	Weed control	Parks need to control groundsel
9	Sea Level Rise, Climate Change	Shoreline Protection	
10	Human Access, Motorbikes, Bikes	Remove illegal campground	Stop people and illegal dumping. Casuarina retreat.

Figure 6 Trash and vegetation damage at a fishing camp at saltmarsh site 10 in Mooloolah River NP.

Recommendations for Saltmarsh Management in the Mooloolah River

1. Improved mapping of saltmarsh habitats

Existing state saltmarsh regional ecosystem mapping and wetlands mapping significantly under-represents the extent of saltmarsh in the Mooloolah River estuary. More detailed, estuary-scale mapping of saltmarsh habitat is needed to assist effective management of these endangered and valuable ecosystems. The current EPBC conservation advice states that the minimum saltmarsh area to meet the criteria for saltmarsh classification is 30 m^2. There are multiple locations, including sites mapped in this report, that meet that criteria, but are not mapped as saltmarsh habitat. Both state and local government agencies have obligations under the EPBC Act to ensure effective management of endangered ecosystems. There is a risk that without appropriate habitat mapping, these obligations will not be met leading to degradation and loss of saltmarsh habitat.

2. Litter and rubbish control

All sites had some level of litter and rubbish. Larger items such as abandoned cars, batteries and tyres are present at Sites 2,3 and 5. Fishing camps and associated litter were present at site 10.

Saltmarshes act as effective natural litter traps during high tides. Degraded plastics and microplastics is increasingly shown to negatively impact wader birds and other aquatic organisms. Mud crabs and high-value fisheries species utilising these saltmarsh areas are likely to ingest smaller degraded plastic in saltmarsh. Microplastics ingestion may impact aquatic organism health and lead to a decline in local seafood quality, with increased likelihood of human microplastics ingestion. Larger rubbish items such as tyres and batteries leach toxic chemicals into the saltmarsh environment with potential negative impacts to ecosystem health.

We recommend the following action to reduce the presence of litter and larger rubbish in saltmarsh areas;

a) Extend community river clean-ups to accessible saltmarsh areas
b) Remove larger items of rubbish from sites 2,3 and 5.
c) Install rubbish bins at site 10 with regular trash removal, or restrict land-based fishing at this site.
d) Improve stormwater litter traps or limit stormwater runoff to saltmarsh areas adjacent to urban areas.

3. Shoreline erosion control

Shoreline erosion is threatening saltmarsh habitat at sites 8 and 10 within the Mooloolah River National Park. Uncontrolled fisher access at site 10 is contributing to shoreline erosion. Given the small area of remnant saltmarsh in the Mooloolah River estuary, all efforts should be undertaken to protect remnant saltmarsh. To reduce shoreline erosion at these sites we recommend the following;

a) Investigate potential erosion control structures to prevent loss of habitat.
b) Improve fishing access at site 10 by installing a fishing platform and access facilities or, restrict access to this site.

4. Sea level rise and mangrove encroachment

Effects of sea level rise, including recent mangrove encroachment were observed at most saltmarsh sites. It is not possible to prevent sea level rise at the local scale. Therefore it is imperative to reduce all other impacts that may impact saltmarsh resilience and restrict further development adjacent to saltmarsh habitats to enable landward saltmarsh migration. Maintaining healthy tidal buffer zones is necessary to assist the long-term survival of saltmarsh habitat in the Mooloolah River estuary. Actions to assist saltmarsh sea level rise resilience include;

- Removing weeds from buffer zones
- Limiting burning along tidal wetland margins
- Reducing direct human impacts from pedestrian and vehicle access.

Buffer zone weeds were present at 8 out of 10 sites with the most prevalent being *Groundsel Bush* and *Asparagus Fern*. Improved weed management targeting *Groundsel* is needed at sites 1, 7 and 10.

5. Access management

Saltmarshes are sensitive environments. But these areas also have high recreational and amenity value in urban areas, accessed by fishers and walkers. Human trampling from pedestrian access was observed at 8 out of 10 sites. Areas of high pedestrian traffic were associated with damage to saltmarsh vegetation and surface erosion, leading to a loss of habitat quality. Pedestrian access control measures should be investigated at sites 1, 2 and 4. We recommend the following potential control measures;

a) Improve community education for residents living adjacent to saltmarsh areas
b) Install educational signs in vulnerable saltmarsh areas
c) Improve controlled access for pedestrians at sites 2 and 7, in the form of a boardwalk or, restrict access to these sites.
d) Restrict landward access to site 1. This is also required to prevent vehicle and bike access to this site.
e) Improve policing of illegal camping in adjacent habitats, particularly sites 1, 6 and 7.

Figure 7 Saltmarsh habitats on the Mooloolah River estuary