

Southern Great Barrier Reef Coastal Habitat Archive and Monitoring Program: Developing a Mangrove Management Plan Volume 1

Norman C Duke, Jock Mackenzie, Ric Fennessy, Riley Cormier and John Kovacs



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Volume 1

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Environmental
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Project 2.3.4 Working with Traditional Owners and local citizens to better manage GBR estuarine wetlands

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ACRONYMS

AMSN	Australian Mangrove and Saltmarsh Network
BMRG	Burnett Mary Regional Group
CBPM	Community-based Participatory Mapping
CFC	Caring for Country
CFI	Carbon Farming Initiative
CHAMP	Coastal Habitat Archive and Monitoring Program
CLCAC	Carpentaria Land Council Aboriginal Corporation
CS	Condition Scores
DAF	Department of Agriculture and Fisheries
DEHP	Department of Environment and Heritage Protection
DES	Department of Environment and Science
DSITI	Department of Science, Information Technology and Innovation
DoEE	Department of the Environment and Energy
ERMP	Environmental Research and Monitoring Program
FBA	Fitzroy Basin Association
GBR	Great Barrier Reef
GBRWA	Great Barrier Reef World Heritage Area
GBRMP	Great Barrier Reef Marine Park
GDC	Gidarjil Development Corporation
GHHP	Gladstone Healthy Harbour Partnership
GPC	Gladstone Ports Corporation
GSBR	Great Sandy Biosphere Reserve
ISP	Independent Science Panel
IT	Information Technology
JCU	James Cook University
LMAC	Local Marine Advisory Committee
MMP	Mangrove Management Plan
MSS	Multi-Spectral Scanner
NDVI	Normalized Difference Vegetation Index
NESP	National Environmental Science Program
NRM	Natural Resource Management
NU	Nipissing University
PCCC	Port Curtis Coral Coast
PCPA	Port Curtis and Port Alma
PSR	Pressure-State-Response
QCIF	Queensland Cyber Infrastructure Foundation
QWMP	Queensland Wetland Mapping and Classification Project
RRRC	Reef and Rainforest Research Centre Limited
SEQ	South East Queensland
SGAP	Society for Growing Australian Plants
SQW	Skilling Queenslanders for Work
S-VAM	Shoreline Video Assessment Method
SVU	Structural Vegetation Unit
TNC	The Nature Conservancy
TropWATER	The Centre for Tropical Water and Aquatic Ecosystem Research

TUMRA Traditional Use of Marine Resources Agreement
TWQ..... Tropical Water Quality
UNESCO United Nations Educational Scientific and Cultural Organisation
WCI..... Wetland Cover Index
WPSQ Wildlife Preservation Society Queensland
WQRS Water Quality Regulation Score

ABBREVIATIONS

ha..... hectares
km..... kilometres
m..... metres
m/y..... metres per year

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We thank the Ranger team members with the Gidarjil Development Corporation project staff in Gladstone and Bundaberg for their participation and contributions during this project.

We further acknowledge the contributions by a number of community volunteers who assisted ranger surveys during the project.

The partnerships formed have lasting contributions towards the longer term benefits in improving the management of natural tidal wetlands and estuaries of the southern Great Barrier Reef region.

EXECUTIVE SUMMARY

- 1) This is the Final Report where Traditional Owner rangers and local citizens of the Port Curtis Coral Coast (PCCC) Traditional Use of Marine Resources Agreement (TUMRA) area were engaged in developing a Mangrove Management Plan (MMP) to provide a strategic basis for ongoing estuarine monitoring and repair activity for the maximization of water quality outcomes in southern Great Barrier Reef (GBR) waters. Development of this MMP has built essential capacity amongst the Gidarjil Development Corporation (GDC) Rangers and the local community to conduct scientifically-rigorous, ecological monitoring and assessment of key local estuarine resources. The management and rehabilitation strategies are needed for the protection of sea country assets using the partnerships forged between community, scientists and local Natural Resource Management (NRM) agencies. The MMP has enabled rangers and citizen scientists to undertake scientifically valid surveys for estuarine habitat monitoring, management and rehabilitation within the PCCC TUMRA area.
- 2) The project was led by Dr Norm Duke with Jock Mackenzie from James Cook University (JCU) Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) Centre, plus project partners: Prof John Kovacs of Nipissing University (NU) in Canada, Ric Fennessy with Rangers of the GDC, Kirsten Wortel and Sue Sargent with Burnett Mary Regional Group (BMRG), and Rebecca French, Holly Lambert and Shannon van Nunen with Fitzroy Basin Association (FBA).
- 3) The primary undertaking of this program was to build the capacity of Gidarjil Indigenous Rangers for monitoring, managing and rehabilitating estuarine wetland sea country within the PCCC TUMRA, southern GBR. The PCCC is the 5th largest TUMRA of its kind. Estuarine wetlands are an integral component of this sea country, comprising sites of immense cultural heritage significance, including middens, fish traps, and traditional fishery resources. Estuarine wetlands also provide essential ecosystem services that protect the GBR, including water quality improvement. But, shoreline habitats within estuaries of the southern GBR have been badly damaged by repeated, recent extreme flood events. Existing anthropogenic stressors reduce the recovery potential of these impacted estuarine wetlands, reducing ecosystem resilience to future damaging events. Estuarine wetland repair is a priority for improving GBR water quality. However, there are no existing national strategies for prioritizing sites of estuarine wetland rehabilitation, to minimize anthropogenic stressors that maximize water quality improvement and other ecosystem services. A whole-of-system assessment is necessary, incorporating socio-cultural, ecological, and economic considerations, to inform cost-effective, successful investment in shoreline habitat rehabilitation.
- 4) Local stakeholders and end users were specifically sought out and engaged in a series of two dedicated workshops in early 2016 and 2017. The workshops were hosted by the BMRG and the FBA respectively. Both workshops were highly successful with broad and representative gatherings of end users attending. All participants actively contributed to the listing of issues raised and the general exchange of ideas. Attendees included members of all local governments (Rockhampton, Gladstone, Livingstone, Bundaberg), a number of State agency officers (Department of Agriculture and Fisheries (DAF), Herbarium,

Department of Environment and Science (DES)), industry representatives like Gladstone Ports Corporation (GPC) and Bundaberg Sugar, members of the general public, as well as the local NRM groups (FBA and BMRG) and the Gidarjil rangers (Fig. 1).

- 5) Training sessions for rangers were undertaken in conjunction with each of the two stakeholder workshop meetings. Additional training sessions were included as needed, in an on-going effort to accommodate the scheduled field program, changes in ranger staff, and the development of new projects. Training followed the standard estuarine field survey methods used by the MangroveWatch community partnership organisation (www.mangrovewatch.org.au), using mostly the Shoreline Video Assessment Method (S-VAM). Training involved discussions, equipment demonstrations, practice sessions and field surveys in small boats. Dedicated field equipment of cameras, GPS and other items were purchased beforehand, specifically for the training program and the field surveys.
- 6) In collaboration with project partner, Prof Kovacs, evaluation and mapping of mangroves and saltmarsh tidal wetlands was done for all eight estuarine systems with on-going development of methods to be used in the overall data management plan. These plans included the evaluation of values and threats to saltmarsh habitats in the southern GBR region.
- 7) Field surveys of specific estuarine river systems were undertaken by Gidarjil rangers initially with JCU researchers until the rangers achieved confidence in conducting this task independently. The estuarine systems surveyed for this project included: Calliope River, South Trees Inlet, Boyne River, Baffle Creek, Kolan River, Burnett River, Elliott River and Burrum River. One amendment to the selection of rivers had been made to ensure all estuarine systems were within the appropriate PCCC sector of the TUMRA. Assessments were done for each of the eight estuarine systems making observations and capturing imagery of the condition, management issues and the notable drivers of change.
- 8) Regional impacts related to climate change and sea level rise were apparent in all eight estuarine systems surveyed. Specific indicators included: unusually high proportions of shoreline and bank erosion, saltmarsh-saltpan scouring, upland migration, and terrestrial retreat. These factors were exacerbated further by recent severe weather events with intense periods of either drought, cyclonic winds, torrential rains or severe flooding. These influences were notably combined with local environmental issues associated with a range of direct human activities. The resulting overall condition differed for each estuary.
- 9) Calliope River estuary, a modified system of ~794 ha of tidal wetlands, was successfully surveyed by 12 Gidarjil rangers and three community members on three occasions in 2015, 2017 and 2018, filming 51 km of shorelines. Overall condition was scored at 74 with ~53% directly human related impacts. The main local management issues identified were driven by development expansion, shoreline habitat modification, and the loss of tidal wetland areas.
- 10) South Trees Inlet estuary, a modified system of ~1,802 ha of tidal wetlands, was successfully surveyed by eight Gidarjil rangers and three community members on two occasions in 2014 and 2018, filming 32 km of shorelines. Overall condition was scored at 73 with ~50% directly human related impacts. The main local management issues

identified were driven by development expansion, altered hydrology, and the loss of tidal wetland areas.

- 11) Boyne River estuary, a modified system of ~105 ha of tidal wetlands, was successfully surveyed by 10 Gidarjil rangers and five community members on four occasions in 2014, 2015, 2016 and 2018 filming 21.5 km of shorelines. Overall condition was scored at 73.5 with ~48% directly human related impacts. The main local management issues identified were driven by development expansion, agricultural intensification, and the flood damage of tidal wetland areas.
- 12) Baffle Creek estuary, a near pristine system of ~1,209 ha of tidal wetlands, was successfully surveyed by 12 Gidarjil rangers and two community members on two occasions in 2017 and 2018 filming 89.7 km of shorelines. Overall condition was scored at 79 with ~59% directly human related impacts. The main local management issues identified were driven by cattle grazing, vehicle damage of tidal wetland areas, and extreme weather events.
- 13) Kolan River estuary, a modified system of ~969 ha of tidal wetlands, was successfully surveyed by 16 Gidarjil rangers and three community members on three occasions in 2013, 2016 and 2018 filming 51.6 km of shorelines. Overall condition was scored at 84 with ~69% directly human related impacts. The main local management issues identified were driven by altered hydrology, agricultural intensification, bank erosion damage of tidal wetland areas, and extreme weather events.
- 14) Burnett River estuary, an extensively modified system of ~540 ha of tidal wetlands, was successfully surveyed by 13 Gidarjil rangers and two community members on three occasions in 2013, 2016 and 2018 filming 52 km of shorelines. Overall condition was scored at 89 with ~69% directly human related impacts. The main local management issues identified were driven by development expansion, agricultural intensification, altered hydrology, extreme weather events, and the loss of tidal wetland areas.
- 15) Elliott River estuary, a largely unmodified system of ~589 ha of tidal wetlands, was successfully surveyed by eight Gidarjil rangers and two community members on three occasions in 2013, 2016 and 2017 filming 19.4 km of shorelines. Overall condition was scored as 79 with ~48% directly human related impacts. The main local management issues identified were driven by development expansion, ground water extraction, and the vehicle damage of tidal wetland areas.
- 16) Burrum River estuary, a largely unmodified system of ~644 ha of tidal wetlands, was successfully surveyed by 12 Gidarjil rangers and three community members on three occasions in 2013, 2016 and 2018 filming 58.4 km of shorelines. Overall condition was scored as 65 with ~60% directly human related impacts. The main local management issues identified were driven by development expansion, agricultural intensification, altered hydrology, and the loss of tidal wetland areas.

17) Key project recommendations include:

- a. Continue supporting Gidarjil Rangers in the monitoring of estuarine shorelines in their region;
- b. Support on-going shoreline video assessment analyses along with the development of a regional report card on southern Great Barrier Reef estuarine waters.



Figure 1: Gidarjil Rangers and MangroveWatch scientists discuss environmental issues at Wallace Creek during April 2017.



Figure 2: Consultations at community workshops in Bundaberg at the project launch.

1.0 INTRODUCTION

1.1 Project Plan

Mangrove tidal wetland shorelines are to be surveyed and monitored as part of this Coastal Habitat Archive and Monitoring Program (CHAMP) for the southern GBR region. The project was led by scientists from JCU TropWATER. The project was funded by the National Environmental Science Program (NESP) Tropical Water Quality (TWQ) Hub.

Traditional Owner rangers and local citizens of the Port Curtis Coral Coast (PCCC) TUMRA are being engaged in the development of a Mangrove Management Plan (MMP) that provides a strategic basis for estuarine repair activity and maximizes water quality outcomes in the southern GBR region. Development of this MMP is building capacity amongst staff and rangers of the Gidarjil Development Corporation (GDC), as well as within the local community for gathering ecological monitoring and assessment data that is scientifically-rigorous and applied. These management and rehabilitation strategies will help protect sea country resources through our partnership between community, scientists and local Natural Resource Management (NRM) agencies. The MMP is enabling rangers and citizen scientists to conduct scientifically valid surveys of estuarine monitoring, management and rehabilitation within the PCCC TUMRA area.

This report, plus appendices, further shows the progress made for this project towards its three years of assessment and monitoring of mangrove tidal wetlands of the southern GBR region (see Fig. 3). Over the last six months of 2018, the plan has been to continue to generate baseline data, to inform communities of the region about the project, to work with local NRM managers, and to especially raise capacity and confidence amongst the Gidarjil Rangers to initiate and conduct their own independently supervised surveys and monitoring of their local shorelines.

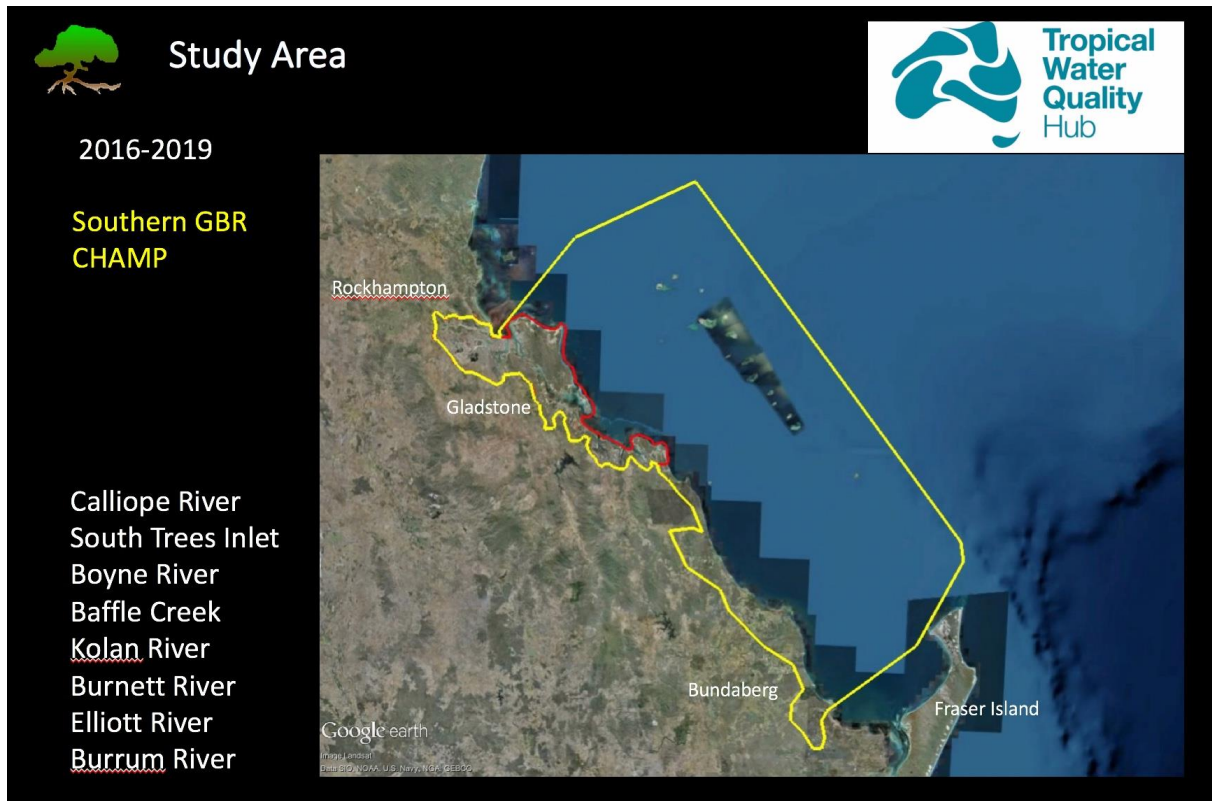


Figure 3: Google Earth satellite imagery of the Southern GBR CHAMP study area (yellow line) compared to the smaller PCPA CHAMP study area (red line; Environmental Research and Monitoring Program (ERMP) project with Gladstone Ports Corporation). The major estuaries in this region are listed as the case study locations throughout the region.

The information presented in this report was derived from the tasks, logistics, planning, personnel and training undertaken with this project. The tasks are fundamental to the project objectives, and they are essential to the projects' success. As a result, the Rangers with the necessary skill levels and facilities for meeting the tasks required; and as specified further below.

Current data presented have been generated as a result of observations made starting with the training sessions, and now extending to field surveys. We have also been building on a priori ad hoc opportunities conducted for earlier projects. While some data may be considered opportunistic, it has been fundamental in the establishment of baseline records as well as being extremely useful as training and familiarisation for all participants.

Briefly, the Southern GBR program set out to complete the work in three (3) components, using:

1. High resolution maps of tidal wetlands, plus historical assessment plus change detection;
2. Shoreline condition monitoring using boat-based video image data acquisition by Gidarjil DC Rangers and community volunteers; and
3. Compilation of any other information pertinent to the health, viability and rehabilitation of tidal wetlands of the region, supporting their role in improving water quality along the southern GBR coastline.

Over the project life, each component will be addressed in detail by personnel from JCU TropWATER Centre who are primarily responsible for the delivery of the program with the TWQH. The program is led by TropWATER specialists in tidal wetland research, who will help characterise shoreline environmental values for the Southern GBR area. This is being achieved through the implementation of the Shoreline Video Assessment Method (S-VAM), used by the community-science partnership program called MangroveWatch, along with an integrated monitoring and archiving program, bringing together partners in field research, remote sensing, information technology (IT) and teaching skills.

This project is an important opportunity to achieve world best practice for compilation and dissemination of data and expert advice gathered from field surveys and stakeholder meetings with key contributors from industry, government, universities and with Indigenous rangers and community volunteers. The planned outcomes will be a comprehensive baseline assessment of ecological condition and health for the region (building on prior surveys like Duke et al. 2003; 2005; 2010; Mackenzie & Duke 2011). The information collected in this project is intended for future use; being a tangible, permanent resource for regional managers, industry stakeholders and community members wishing to maximise conservation benefits while maintaining environmentally appropriate coastal development works.

The project integrates scientific, industrial, management and Indigenous cultural knowledge to better inform environmental managers of tidal wetlands for improved mitigation actions in the Southern GBR region. Our partnership approach is expected to enhance local capacity for implementation of ongoing shoreline assessment as well as maintaining sustainable environmental monitoring outcomes.

The project will promote activities and engagement between traditional owners, environmental managers and industry developed using the following tasks: Consultation with Stakeholders, including Workshops; Training Workshop for Rangers; Field Surveys by Rangers; Data Assessment and Mapping; Potential Restoration Sites; The Mangrove Management Plan; and Datasets for publication.

Key Project Objectives:

- Improve capacity and raise awareness amongst Traditional Owners and local citizens regards improved management of shorelines and estuaries for the southern GBR region.
- Build capacity within a Traditional Owner group to become the lead agency in monitoring, assessment and rehabilitation of estuarine wetlands within sea country.
- Strengthen existing partnerships between Traditional Owners, scientists and NRM agencies to inform strategic investment in estuarine wetland repair that maximizes water quality outcomes for the southern GBR.
- Develop a Mangrove Management Plan for southern GBR that identifies, prioritizes and details estuarine wetland management and repair strategies informed by broad-scale assessment of ecological condition, Traditional Owner knowledge and values and NRM agency regional priorities
- Identify and prioritize shoreline habitat restoration locations and actions to maximize water quality improvement within southern Great Barrier Reef (GBR) estuaries.

2.0 METHODOLOGY AND BACKGROUND

2.1 Actual project operations, logistics and management

The JCU Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) is ideally placed to draw upon a wide range of expertise available and necessary for the delivery of the Southern GBR CHAMP project. The works include monitoring the condition, survival and recovery of shorelines, specifically regards tidal wetlands.

While TropWATER Centre at JCU is the lead agent for this project, we are collaborating in partnership with the following organisations using individual sub-contract arrangements for each, as appropriate:

- a) Gidarjil Development Corporation Indigenous Rangers along with community volunteers in the Southern GBR region, assisted in the field surveys of monitoring and assessment of coastal tidal wetland habitats (Component 2);
- b) Collaboration with Prof. John Kovacs of Nipissing University, Canada, for specialised remote sensing assessments and mapping of tidal wetland habitats in the region (Components 1 primarily, plus taking other opportunities for ground truth and data validation); and
- c) Partnerships with two (2) NRM regional groups, the Burnett Mary Regional Group, and the Fitzroy Basin Association, for development and implementation of the planned Mangrove Management Plan (all components).

While the program is an integrated package, it was achieved under the three broad project components. To a large extent, the project outcomes were influenced and enhanced during the collaborations generated with potential end users and stakeholders in tidal wetlands and shorelines of the Southern GBR region. The core end users are listed in Table 1.

Table 1: Updated and revised list of research end users and stakeholders for the Southern GBR CHAMP.

Research End Users (section/programme/organisation)
Department of the Environment and Energy – Wetland Policy and Projects Branch
Key Stakeholders (organisation/programme)
Queensland Marine Parks, Marine Resource Management (QNPRSR) Fish Habitat Area (FHA) development and management – specifically the declaration of a new Calliope River FHA.
Queensland Fisheries Service (QDAF) fish habitat protection policy
Queensland Parks and Wildlife Service
Gidarjil Development Corporation Ltd
Great Barrier Reef Marine Park Authority, Coastal Ecosystems
Gladstone Healthy Harbour Partnership (GHHP)
Fitzroy Basin Natural Resource Management Group
Burnett Mary Regional Group
Gladstone Ports Corporation, Marine Environment Office
Estuarine Research and Monitoring Program
Wildlife Queensland Coastal Citizen Science
Society for Growing Australian Plants (SGAP)
Conservation Volunteers Australia (CVA)

The milestone activity scheduling for the Southern GBR CHAMP project are shown in Table 2.

Table 2: Project Milestone Activity Schedule 2016-2019.

Milestone Activities	Jun 2016	Dec 2016	Jun 2017	Dec 2017	Jun 2018	Dec 2018	Feb 2019
Consultation with Stakeholders	X	X	X	X	X	X	X
Stakeholder Workshops Bundaberg & Gladstone	X		X				
Training Workshop - Field Team Bundaberg & Gladstone	X	X	X	X			
Field Surveys by Gidarjil Rangers <i>Southern estuaries</i> : Baffle, Burrum, Elliott, Burnett, Kolan	X	X		X	X	X	
Field Surveys by Gidarjil Rangers <i>Northern estuaries</i> : Boyne, Calliope, South Trees Inlet			X	X	X	X	
Condition Data Assessment JCU assessment of Field Survey data about estuarine tidal wetlands		X	X	X	X	X	X
Restoration Protocols & Potential Target Sites				X	X	X	
Towards a Mangrove Management Plan (MMP) for southern GBR, with Traditional Owners	X	X	X	X	X	X	X
Photos to eAtlas/RRRC	X		X	X			X
Data management plan to eAtlas		X	X	X			
Datasets for publication in eAtlas, publication standards				X			X
Milestone REPORTING by JCU GDC Ranger engagement and Data Acquisitions and JCU Assessments	X	X	X	X	X	X	X

2.2 Mapping of tidal wetland resources

Criteria: Mapping of tidal wetland vegetation types along with historical change detection to identify areas of net loss and gain in key habitat components (mangroves, saltmarsh and saltpans)

Project Lead: Dr Norm Duke, TropWATER, JCU

Partners: Prof. John Kovacs, Nipissing University, Canada

Specific Tasks

The team will acquire suitably fine-scaled, multispectral Image data for mapping mangroves, tidal saltmarsh and tidal saltpan flats, as the key vegetation types of tidal wetlands in each of the case study estuaries.

To display areas of mangrove and saltmarsh which had been previously identified, a series of maps were produced for the major estuaries which extend along the Southern Great Barrier Reef study area (Fig. 4).

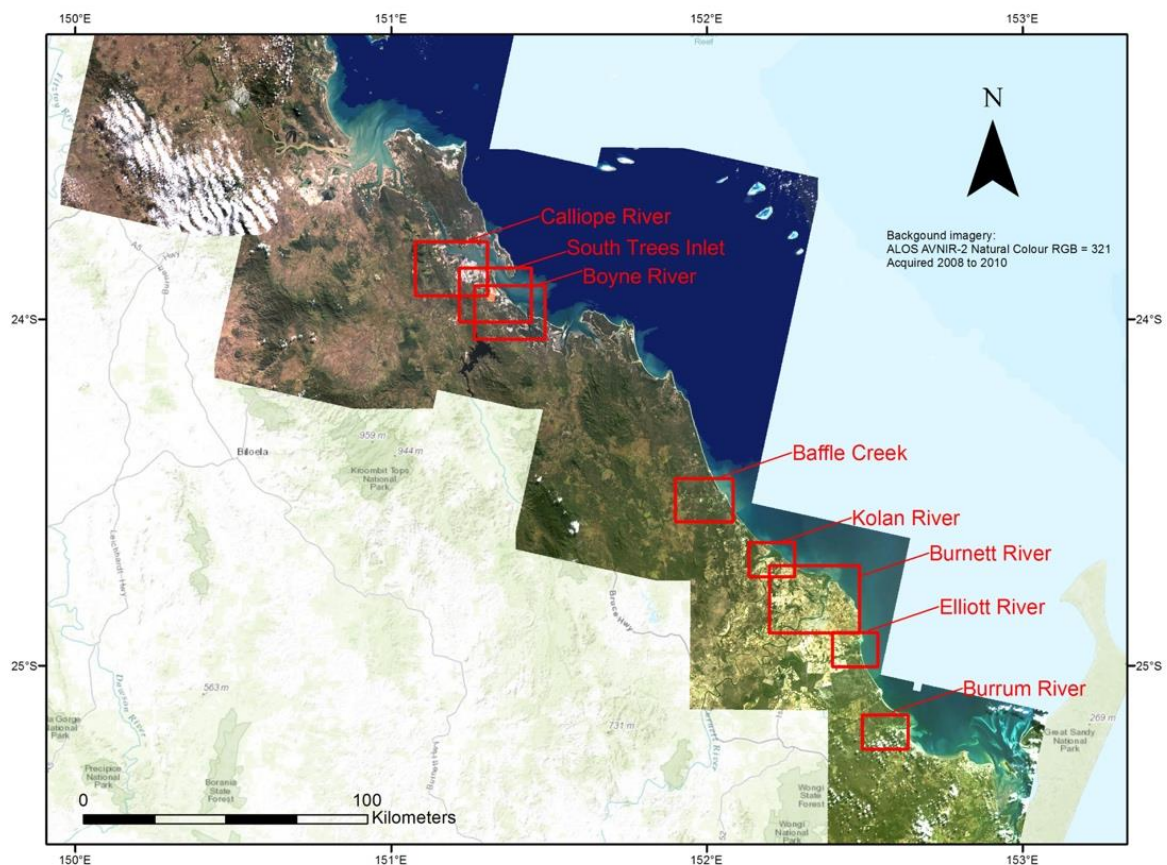


Figure 4: Map of the Southern GBR shoreline showing the location of the 8 estuarine systems used as case studies in this project.

Specifically, polygons were extracted from the Queensland Wetland Mapping and Classification Project (QWMCP) that represents saltmarsh and mangrove ecosystems. The QWMCP was last updated in 2009. Within this dataset, each ecosystem was identified by a

specific three number code that described both the physical and vegetative conditions for each regional ecosystem. In total eight (8) maps were produced for the following major estuaries along the Southern GBR coast ([Progress Report 2](#)):

- Calliope River
- South Trees Inlet*
- Boyne River
- Baffle Creek
- Kolan River
- Burnett River
- Elliott River
- Burrum River

*NOTE: This estuary replaced an earlier choice found to be unsuitable for the current project.

Project mapping specialists:

John Kovacs, Duncan Hill

The plan has been to add to the mapping of each of the eight estuarine systems by also showing change from 1973 to the present day using available Landsat imagery (spatial resolution between 30-60 m), as shown in Table 6. This additional approach has been to develop this further mapping strategy, based on the Elliott River estuary in the first instance. Once the strategy was refined and determined, then the other seven estuarine systems were mapped further in the same way.

The Methods used for strategy development are as follows:

Data acquisition. In total 38 Landsat images of the Elliott River system were acquired dating as far back as 1973 (Table 1). The Landsat 5/7/8 images were from WRS-2 Path 90 Row 77 and Landsat 1/2/4 images from WRS-1 Path 96 Row 77. All images collected were captured at near-anniversary dates, specifically from either the month of August or September. The earlier Multi-Spectral Scanner (MSS) images (1973-1986) were acquired at a spatial resolution of 60 m whereas the more recent ones (1987-2016) were collected at a 30 m spatial resolution. In addition to the satellite imagery, a Queensland 5 m LIDAR digital surface model (<https://data.gov.au/dataset/digital-elevation-model-dem-of-australia-derived-from-lidar-5-metre-grid>) and a Queensland HAT dataset (Dept. of Natural Resources, Mines and Energy) were accessed.

Image processing. All images were first converted to surface reflectance using PCI Geomatica's ATCOR module. From the surface reflectance data the Normalized Difference Vegetation Index (NDVI) was then calculated for each date of imagery.

NOTE: Normalized Difference Vegetation Index: $NDVI = (NIR - Red) / (NIR + Red)$

A study area mask was then produced for those areas of the Elliott River that were found below the HAT line. Specifically, the area below the HAT line (HAT Zone) mask was produced by first converting the vector polyline HAT dataset to a binary bitmap. Water masks were produced from each image using a threshold Normalized Difference Water Index ($NDWI = (Green - NIR) / (Green + NIR)$). The union of the binary water masks was then used to delineate the area of surface water at its maximum extent. The maximum water extent mask was then used to erase

areas of surface water from the HAT Zone mask for analysis. Finally, using the HAT Zone mask, a time series of maps were produced for each vegetation index under the masks (see Fig. 5).

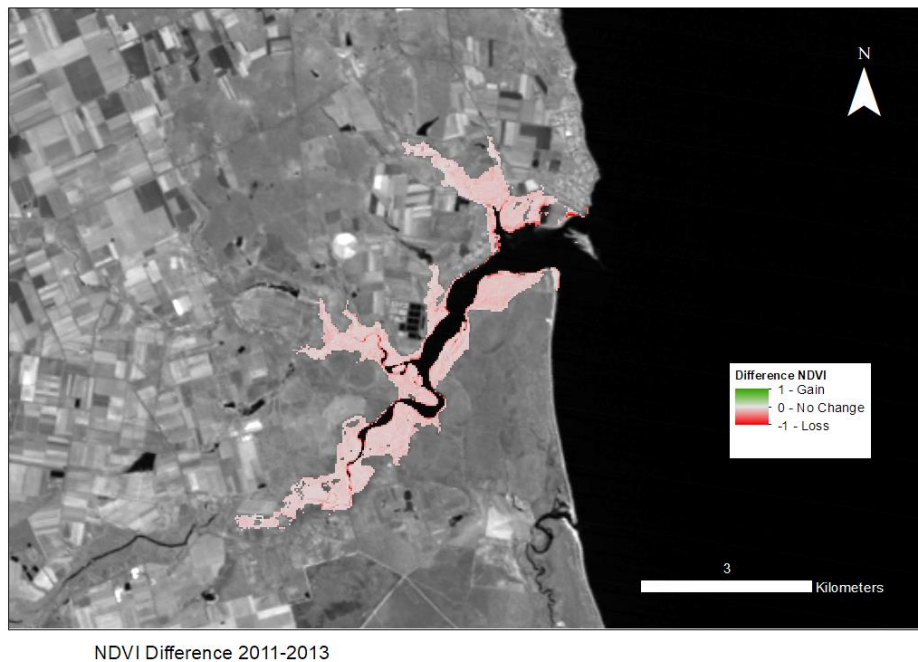


Figure 5: Changes in vegetative condition of mangroves following flooding in the Elliot River between 2011-2013.

2.3 Boat-based shoreline surveys

Criteria:	Shoreline condition monitoring using boat-based video image data acquisition by Gidarjil Rangers and community volunteers.
Project Lead:	Dr Norm Duke, JCU TropWATER Jock Mackenzie, JCU TropWATER
Partners:	Gidarjii Development Corporation MangroveWatch Ltd

Specific Tasks

The methods used in these surveys are geo-referenced videography called the Shoreline Video Assessment Method (Mackenzie et al., 2016). Most imagery was collected by Indigenous rangers – supervised by TropWATER science specialists. All participants were trained by the TropWATER project team. In the study area, Indigenous rangers have been trained, and they are conducting surveys in eight estuarine case study areas. Processing of image data collected by community members will be done by the TropWATER project team at the Mangrove Hub at JCU. Data taken from imagery and from survey diaries are used to further visualise and describe coastline condition, to make ecological assessments of shoreline composition, the status and health of those shorelines. These data and information will contribute directly to the Southern GBR Mangrove Management Plan.

The specific methodology employed was as follows:

1. Collect source video and still imagery taken laterally from small boats around 50 m distance to shoreward margins. Filming will be undertaken such that it covers continuous shorelines of specific sections of estuarine areas and embayments. The intent of the project team is to cover all seaward margins in the study area, but limitations of funding dictate that only approximately 200 km of shoreline will be filmed and assessed. Ideally, the extent of shorelines filmed will include continuous coverage of most mainland and island shorelines (as mangrove seaward margins mostly, but not restricted to them) in the study area. Attention will be made of specific sections of the coastline as the eight (8) estuarine river systems.
2. Training has been given to the Gidarjil Rangers by the project team to ultimately develop their skill base for the effective, independent gathering of imagery and other data for description of shoreline profiles relevant to this project.
3. The project team plans to make annual temporal assessments. There is sufficient funding support in the budget proposed to make at least 2 surveys during the 2 full years of the project, working with the Gidarjil Rangers until the project end in 2018.
4. The choice of days for boat surveys will be determined by the suitability of weather conditions, the time of day, coupled with periods of relatively low to mid tide.
5. Initial, sometimes prior, survey data will be used as baseline condition. Subsequent records will provide measures of differences. Specific observations will describe occurrences of habitat type, condition and change; noting vegetative condition like species type; biomass; dieback condition; presence of plant mutations; notable erosion; root/bank exposure; sediment deposition; presence of seedlings; and seasonal changes along with species present in each habitat assemblage.
6. These findings will provide backup, support and validation for the mapping component.

3.0 COMMUNICATION OUTCOMES AND RANGER TRAINING

3.1 Two Community Workshops

Two community workshops were held in 2016 and 2017. The first workshop was hosted by the Burnett Mary Regional Group in Bundaberg. The second workshop was held in Rockhampton and hosted by the Fitzroy Basin Association.

3.1.1 Bundaberg 2016 workshop hosted by the BMRG



Figure 6: TropWATER scientists in collaboration with the Gidarjil DC and BMRG run the 2016 stakeholder workshop to launch the Southern GBR CHAMP project in Bundaberg, Queensland.

Workshop host: Sue Sargent organised the workshop on behalf of the Burnett Mary Regional Group (BMRG).

The Workshop. On Tuesday 19th April 2016, a first community public workshop was organised by the JCU TropWATER project team and Burnett Mary Regional Group (BMRG) staff at the Environmental Marine Training Centre (2 Marina Drive), Burnett Heads, Bundaberg Port. Invitations to the workshop were dispatched amongst selected nominees as potential stakeholders and end users of the project (see Figs. 6 and 7; Table 3).

Table 3: Invited participants attending the public workshop, as part of the Southern GBR CHAMP program launch on 19th April 2016 at Bundaberg Port, Queensland.

Name	Affiliation
Cheryl Bolzenius	Wetland Care
Peter Brockhurst	Gidarjil DC
Arthur Dahl	Gidarjil DC
Norm Duke	JCU TropWATER
Ric Fennessy	Gidarjil DC

Gabriel Little	Gidarjil DC
Bart Mackenzie	QDAF Fisheries
Jock Mackenzie	JCU TropWATER
Nick Maclean	Bundaberg City Council
Symean Maror	Gidarjil DC
Faye McGowan	Gidarjil DC
Jason Pascoe	Gladstone Ports Corp.
Sue Sargent	BMRG
Anjana Singh	Gladstone Ports Corp.
David Weribone	Gidarjil DC
Shannon van Nunen	FBA

A number of apologies were received with almost universal agreement about the value of the project, and with offers of assistance when needed. The invitation prepared for the community meeting is provided at Appendix A.

Work with this component was initially about building relationships, and informing community, as well as the establishment of the work program and building skills (Figs. 6 and 7). Our goals for field work were met with key contributions from the skilled-up Ranger teams of the Gidarjil DC. Works involved ranger and staff training, support and consultation, briefings on methodology and approach, as well as the compilation and preliminary assessments of field data.



Figure 7: Project workshop for stakeholders and end users of mangroves and saltmarsh habitats launch the Southern GBR CHAMP project in Bundaberg, Queensland.

To facilitate stakeholder involvement, participants were asked to provide a short presentation (4-5 slides max) to help get the conversation started about their contributions to the better manage of mangroves and tidal wetlands in the Southern GBR region.

Specific information requested, included:

- **current projects** – as those actively managing tidal wetlands (mangroves/saltmarsh) in the Southern GBR;
- **main values and threats** to tidal wetlands (mangroves/saltmarsh) in the region and options for their better management;
- **rehabilitation project opportunities** for tidal wetlands (mangroves/saltmarsh) ; and,
- **available primary and secondary resources** (spatial data, on-ground data, imagery, reports, skills and local knowledge) available for the development of a Mangrove Management Plan, over the next 2 years. These ideas and suggestions were collected for further assessment as the project develops.

The training session and survey work by Rangers. On Wednesday and Thursday, 20-21 April 2016, the JCU team conducted ranger training sessions for the Ranger teams from Gidarjil DC, plus a number of community volunteers (Fig. 8). An important part of the training involved the practical application of the Shoreline Video Assessment Method (S-VAM) culminating in its immediate practical application in boat-based shoreline surveys of the Burnett River. This is one of the 8 designated case study estuarine sites. Filming of the Burnett River was completed during these training sessions over two days. Other field training included identification of mangrove and tidal saltmarsh plants, including weeds in these environments. Teams of trainee Rangers were each given the opportunity to join in the boat surveys, whilst the alternate group received training in habitat biodiversity and species identification of mangrove and salt marsh plants.



Figure 8: Field training and surveys followed the community workshop, with practical sessions using the JCU boat 'Guyala' in the Burnett River estuary.

3.1.2 Rockhampton 2017 workshop hosted by the FBA

Workshop hosts. Holly Lambert, Rebecca French and Shannon van Nunen organised the workshop on behalf of the Fitzroy Basin Association.

On Friday 28th April 2017, a second community public workshop was organised by the JCU TropWATER project team and Fitzroy Basin Association (FBA) Staff at the Criterion Hotel, Rockhampton. Invitations to the workshop were dispatched amongst nominees as potential stakeholders and end users (see Figs. 9 and 10; Table 4).



Figure 9: Project stakeholders map tidal wetland issues in their local estuaries.

Stakeholders were invited from a diverse array of backgrounds including; traditional owners, local community group members, local government representatives, state government representatives, regional NRM body staff and researchers.

Table 4: Invited participants attending the public workshop, as part of the Southern GBR CHAMP program Launch on 28 April 2017 in Rockhampton, Queensland.

Name	Affiliation
Arnon Accad	DSITI – QLD Herbarium
Ron Blair	Gidarjil DC
Leise Childs	Livingstone Shire Council
Charles Coleman	Gidarjil DC
Jye Dalton	Gladstone Regional Council
Ian Draper	QDAF Fisheries
Norm Duke	JCU TropWATER
Ric Fennessy	Gidarjil DC
Tobias Flynn	Gidarjil DC
Saranne Giudice	BMRG
Jessie Holland	Gidarjil DC
Holly Lambert	FBA
Dwayne Lingwoodock	Gidarjil DC

Jock Mackenzie	JCU TropWATER
Mark Schultz	GHHP
Anjana Singh	GPC
Shannon van Nunen	FBA
Drew Wickerson	Rockhampton City Council
Maria Zann	EHP

A number of apologies were received with almost universal agreement about the great value of this project, and with offers of assistance when needed.

The objectives of the workshop were as follows;

- To continue and build on the good work already achieved
- Further develop formal networks amongst key end-users
- Identify and highlight tidal wetland and estuarine values and threats in the Southern GBR
- Identify current management actions to protect and improve tidal wetland values in the Southern GBR
- Identify knowledge gaps and management opportunities for monitoring, protecting and enhancing southern GBR tidal wetlands
- Establishment of a citizen-science tidal wetland monitoring program with Gidarjil Rangers and community volunteers to inform future tidal wetland management
- Progress towards a Mangrove Management Plan framework for the Southern GBR

Workshop Introduction and Background. Workshop participants were provided with project updates and background information on tidal wetlands in the region by Dr Norm Duke and Jock Mackenzie (Fig. 10).



Figure 10: Norm Duke (JCU) introduces and updates on NESP TWQ Hub Project 2.3.4 to the 2017 workshop participants.

Stakeholder Presentations. To facilitate stakeholder involvement in the project, participants were asked to provide a short presentation to help get the conversation started about their contributions to the better manage of mangroves and tidal wetlands in the Southern GBR region. A summary of the short presentations is provided below:

Ric Fennessy - Gidarjil Development Corporation (Fig. 11)

- Sharing about current Traditional Owner involvement in CHAMP monitoring

Saranne Guidace – Burnett Mary Region Group

- BMRG Region, and projects in wetlands
- Importance of community engagement in success of projects

Shannon Van Nunen – Fitzroy Basin Association

- FBA Region and projects
- Rockhampton Recreational Fishing Strategy and potential links to existing NESP TWQ Hub program and MangroveWatch monitoring.



Figure 11: Ric Fennessy (Gidarjil) provides an update on Indigenous ranger mangrove monitoring to date.

Maria Zann - QLD Wetlands Mapping Program, EHP

- Mapping and classification and typology of intertidal and subtidal habitats
- Driving habitat change – mapping data (feeding on ground data up)

Arnon Accad – Queensland Herbarium, DSITI

- Regional Ecosystem Mapping
- Historical mapping of ecosystems/communities

Leise Childs – Livingstone SC

- Emphasised need for community monitoring with support from Scientists

Jye Dalton – Gladstone RC

- Commented on GRC sharing available resources to support

Drew Wickerson – Rockhampton RC

- Expressed willingness of RRC to partner with the NESP project with offers of funding, expertise and delivery.

Ian Draper – Qld Fisheries, DAF

- Highlighted importance of the NESP project for protecting marine plants and moving towards selecting High Value tidal wetland areas.
- Commented on the links between environmental offsets in marine habitat and potential links to outcomes from the NESP project.

Anjana Singh - Gladstone Ports Corporation

- Expressed GPC support for the NESP TWQ Hub project as an expansion of the GPC funded ERMP CHAMP to give holistic picture for Southern GBR
- GPC have a number of monitoring projects (beyond mangroves) – data is available if wanted.

Mark Shultz – Gladstone Healthy Harbours Partnership (GHHP)

- The NESP TWQ Hub Project outcomes and data may be useful for inclusion in future mangrove indicators included in report cards

Crocodile Safety Awareness. This project involves extensive traditional owner monitoring of tidal wetlands in known crocodile environments. DEHP officers were engaged to provide a short presentation on crocodile safety when working around tidal wetland areas (Fig. 12). The workshop agenda addressed participant workplace health and safety requirements regarding crocodile safety. As a result of this presentation it was identified that NESP project tidal wetland monitoring, which includes (safely) geo-locating and photographing crocodiles and recent evidence of crocodile activity, can provide important information to EHP wildlife officers regarding crocodile hotspots. All crocodile sightings during NESP TWQ Hub project surveys were submitted to DEHP (now DES).



Figure 12: DEHP wildlife officers, Alex Peters & Robby McLeod giving crocodile safety awareness training.

Community-based Participatory Mapping. A community-based participatory mapping (CBPM) exercise was undertaken to assist with the identification of local issues threatening tidal wetlands within the target project estuaries and surrounds. Following on from presentations by TropWATER staff on tidal wetland values and management issues relevant to estuarine water quality, participants were asked to annotate Google Earth images of the estuaries with outlines of known management issues. Participants were organised into three groups representing regional areas within the NESP TWQ Hub project study area; Fitzroy, Gladstone, Burnett-Mary. Results of the CBPM exercise were digitized in Google Earth (Fig. 4). Issues identified within each target estuary are shown summarized in Tables 5 and 6.

Altered hydrological flows and vehicle damage were identified as the most prevalent issues, affecting five out of the eight estuaries. Cattle grazing, Damage to and removal of tidal wetlands and poor buffer zone vegetation management were also common issues identified. The list of identified issues is by no means comprehensive or exhaustive but will assist in prioritising potential rehabilitation sites and conservation measures to protect tidal wetlands. Based on these outcomes an additional web-based survey will be created and distributed to gain further community input into this process. An important outcome of the CBPM process was the identification of three (3) areas of high cultural heritage value in the Burrum, Burnett and Kolan river systems, identified by representatives from Gidarjil Development Corporation. These sites will be given high priority when identifying potential sites for rehabilitation/conservation.

The CBPM process also identified that there was a less knowledge of threatening processes impacting tidal wetlands in the FBA region, compared to BMRG estuaries. This is likely a consequence of much less attention previously afforded to understanding tidal wetland issues in the FBA region, compared to BMRG.



Figure 13: Community-based participatory mapping (CBPM) of local tidal wetlands in action.

Table 5: Summary of issues identified during community-based participatory mapping. Map locations of issues for each estuarine system are available in the Mangrove Management Plan Vol. 2.

Estuary	Issue							
	Altered Hydrology	Pollution	Cattle Grazing	Vehicle Damage	Illegal Camping	Illegal Dumping	Tidal Wetland Removal/Damage	Poor Buffer Zone Management
Calliope	1	1					1	
South Trees	1	1						1
Boyne	1		1	1				1
Baffle			1	1	1			
Kolan			1	1	1		1	1
Burnett	1			1			1	1
Elliott		1	1	1	1	1		
Burrum	1						1	1
Total	5	3	4	5	3	1	4	5

After the CBPM exercise, individual workshop participants were asked to identify what they considered to be the greatest threat to tidal wetland water quality improvement values in the region and identify tidal wetlands areas or habitat types requiring rehabilitation/ conservation action. The outcomes of this discussion are detailed in Table 6.

Table 6: Key tidal wetland threats and high value tidal wetland areas as identified by project stakeholders.

What's the biggest threat?	What is/ where is the most valuable tidal wetland?
Reclamation – poor water quality	Highly visible urban wetlands
Boat moorings/landings	Kinkuna – dense structure
Clearing of mangroves / Riparian	Mangrove communities
Vehicle Damage	Theodolite Creek –Saltpan / saltmarsh
Coastal squeeze – no buffer	Baffle – near pristine
Loss of saltmarsh – squeeze and SLR – no buffers	Easily accessible saltmarsh areas
Climate Change	Buffer zones
Sea Level Rise	Byelee Wetlands
Development and lack of education	Wapentacke Wetlands
Grazing – erosion	Hot Water Outlet (Calliope)
Damage to mangroves	Marina plains – Curtis Island
Feral animals	Riverine habitats
Erosion	Salt pans

Workshop Discussion – Expected Project Outcomes and Existing Knowledge Gaps.

Workshop participants were asked to suggest outcomes from the NESP TWQ Hub project that would be most useful to establish synergies and linkages with existing organisational aims, conservation aspirations and funding commitments, and also address known knowledge gaps in tidal wetland management. The final NESP TWQ Hub project outcomes will seek to achieve as many of these suggestions as is feasible within the project timeframe and funding allocation. The majority of the below stakeholder expectations align closely with existing proposed project outcomes:

- Detailed mapping of pre-clearing and current tidal wetland extent based on Regional Ecosystem methodology. Mapping should include 1:25,000 scale mapping of tidal wetland communities to species level. This mapping will inform identification of ecological drivers of change.
- Clarification of land tenure issues related to tidal wetlands. Incorporating land tenure into the tidal wetland rehabilitation/ conservation prioritisation process.
- Identify targeted, community-focused tidal wetland projects that have high public exposure to maximise education benefits. Such projects would need to be located in areas with public support and high public access.
- Identify sites with low cost intervention measures (eg. Fencing and bollards) and incorporate cost-benefit analysis into rehabilitation/conservation project prioritisation.
- Include monitoring and evaluation by Indigenous rangers as part of rehabilitation protocols.
- Identify on-ground actions suitable for Indigenous ranger involvement including construction and land management, involving 2 to 3 days work for small ranger teams.
- A map of potential sites provided to stakeholders.

- Consider incorporating ecosystem service accounting tools into cost-benefit analysis for project site prioritisation.
- Incorporate other physical value attributes such as EPBC listed communities, flora and fauna into project prioritisation
- Identify pathways for community engagement in on-ground project delivery and monitoring
- Use NESP project outcomes as a means to leverage funding into tidal wetland management.
- Ensure NESP project outcomes align with local government mangrove management plans.

Workshop Discussion Outcome – Stakeholder Resource Contributions.

Workshop participants were asked to identify any potential resources that could assist the NESP project achieve the expected and listed project outcomes. The following resources were identified as potentially being available:

Fitzroy Basin Association

Identify likely private landholder support

Restoration Guidelines

LiDAR & Satellite Imagery (urban areas)

Local Government

LiDAR

Stormwater drain points

Vessel use for surveys

Fisheries – DAF

Links to DAF Offset Projects

Fitzroy Partnership River Health and Gladstone Healthy Harbour Partnership

Possible indicators of estuarine water quality data

Workshop Discussion Outcome – postponement for Fitzroy River monitoring.

As a result of this workshop, it was decided to postpone surveys of the Fitzroy River estuary, to instead focus these resources on South Trees Inlet. It was pointed out that the majority of tidal wetlands in the Fitzroy River unlike the rest of the study area were part of Darambul traditional lands. As such, further resources would be needed to engage and involve Darambul Traditional Owners. Shannon Van Nunen from FBA assisted with negotiations between JCU researchers and Darambul representatives. Darambul Traditional Owners expressed strong interest in participating in the tidal wetland monitoring and assessment, with a view to being part of a future MangroveWatch program on the Fitzroy River and other estuarine sites within Darambul country. A separate funded program was needed to facilitate establishment of a MangroveWatch traditional owner ranger program for monitoring tidal wetlands in the Fitzroy River region.

3.2 Indigenous Ranger Training & Monitoring Program with Gidarjil Development Corporation

3.2.1 Gidarjil Caring for Country Program Partnership with TropWATER Mangrove Research Hub

Report by Ric Fennessy, Project Manager, Caring for Country Program with the Gidarjil Development Corporation.

Gidarjil Development Corporation is an Indigenous owned company registered since 2000. Its registered business address is in Gladstone and its Head Office is in Bundaberg. The organisation is a member of the Port Curtis Coral Coast Regional TUMRA (Traditional Use of Marine Resources Agreement) that was developed under the Reef Rescue Land and Sea Country Indigenous Partnerships Program. The PCCC Regional TUMRA is the fifth and largest agreement of its kind - it covers an area almost ten times the size of Canberra and the Australian Capital Territory, around 26,386km². The TUMRA area extends from Burrum Heads, south of Bundaberg, north to the mouth of the Fitzroy River and includes Curtis Island off Gladstone.

The Gidarjil Ranger programs have really enjoyed partnering with TropWATER to deliver the Southern GBR Coastal Habitat Archive Monitoring Program (CHAMP) (Fig. 14). Dr Duke engaged Gidarjil's Caring for Country (CFC) program to deliver the shoreline video assessment monitoring (S-VAM) process as developed in the MangroveWatch citizen science program – the CFC program have partnered with Norm and Jock Mackenzie and the MangroveWatch program since 2013 in delivering S-VAM on a number of streams of the CFC rangers traditional sea country (PCCC: Port Curtis Coral Coast as the country from Burrum River in the south to the Boyne River in the north).



Figure 14: Gidarjil Rangers independently surveying shorelines and gathering imagery of the habitat condition of estuaries in the Southern GBR region; Baffle Creek during May.

Norm and Jock are to be commended highly for their engagement with local communities in delivering citizen science. Even more commendable is their engagement with aboriginal communities and organisations (such as Gidarjil) in training and building capacity of their rangers to undertake such citizen science. In the case of Gidarjil and the PCCC traditional owner community the follow-on effects (combined with the CFC rangers engagement by Dr. Col Limpus' in the Queensland Marine Turtle Conservation program) have been very impressive. Prior to the Southern GBR CHAMP, Norm invited Gidarjil Development Corporation in 2014 to be a partnering sub-contractor on a tender submission to Gladstone Ports Corporation for the Port Curtis – Port Alma CHAMP (5-10 years). Gidarjil management then decided to utilise the program as an opportunity to kick-start an office in Gladstone and develop a traineeship Sea Ranger program employing three rangers (early 2015; Fig. 15). A CFC position was shifted to Gladstone to provide the majority of funding for a Senior Ranger position to supervise the three trainees, and a further three staff were employed in the office. By 2016, ConocoPhillips and Queensland Indigenous Land and Sea Rangers committed to funding the three ranger positions and then in 2017 GBRMPA committed to funding the Senior Ranger and Ranger Coordinator positions. The Gladstone staff have also managed some five Skilling Queenslanders for Work programs (6 months each) and a School-based Trainee Ranger program (up to two years) in Gladstone during that period and so providing employment and training for approximately 60 people.



Figure 15: In 2014, the Port Curtis Port Alma – CHAMP project kicked off in Gladstone.

In regards to the further benefits provided by these programs, the Southern GBR CHAMP funds that CFC received for this and turtle conservation work enabled the CFC team to employ extra (casual) rangers to assist with these projects; to purchase a 5.3 metre Polycraft boat to 2D survey and with a specialised turtle jump deck; and to buy out the lease on our first Toyota dual cab Landcruiser which we would then provide to the Gladstone Sea Ranger program. The maintenance, crewing and skippering the vessel and vehicles are now part of the training experience for our Indigenous rangers.

Three of the rangers that were employed casually have continued to have stints as full-time rangers within the CFC program (continuing at present) and two others have gone onto full-time positions in the Gidarjil Sea and Ranger Programs in Bundaberg and Gladstone.

Our partnership with the MangroveWatch Hub continued to bloom and in 2017, the TropWATER team received funding for Jock and two CFC staff to go to Brazil and to assist with training staff from the university in nearby city of Registro – “Universidade Estadual Paulista” (see Fig. 22). One of the rangers Tobias Flynn and the CFC Coordinator Ric Fennessy went on this rewarding trip during late July and into early August.

In late September 2017, Norm also seconded Senior Ranger Des Purcell to assist him with MangroveWatch training with the Li-anthawirriyarras rangers in MangroveWatch at Borrooloola NT (south-western Gulf of Carpentaria). By the end of 2017, Gidarjil had acquired further funding to commence a new land and sea ranger program in Bundaberg, and in 2018 funding was received from the Department of Prime Minister & Cabinet for a second new ranger program in Bundaberg- within 12 months the number of staff employed on ranger programs in Bundaberg had gone from five full-time to fourteen full-time and by the end of 2018 a 9-metre research vessel to 2C survey was purchased. This growth in ranger programs at Gidarjil and the employment opportunities have enabled Aboriginal people to re-connect to their country is significantly attributable to the key successful partnerships that our CFC ranger program has maintained with Norm Duke and Col Limpus.

More recently, Norm and the CFC team have collaborated on proposals for the mangrove rehabilitation projects for the Burnett and Kolan Rivers which are envisaged to commence in late 2019. The land and sea rangers have potted up some 1,500 Grey and River Mangroves from an open drain beneath Gladstone Port Commissions. The projects will use innovative methodologies (including oyster reef regeneration) and in essence will be experimental. This will provide the next exciting phase of the Gidarjil Caring for Country Program – TropWATER Mangrove Research Hub Partnership.



Figure 16: Bundaberg Land and Sea Ranger Team potting up mangroves for rehabilitation projects on the Burnett & Kolan Rivers.

Delivery of the Southern GBR CHAMP was not without its difficulties as the CFC team struggled at times with a high fee-for-service workload and turn-over of staff who had been trained in MangroveWatch methodologies (Fig. 17). Other issues sometimes centred on the use of hired vessels, equipment not being checked properly prior to commencement to monitoring, and trial recordings not being undertaken each day. However, the partnership remained strong and it has provided particularly interesting new work opportunities for the Gidarjil Rangers which have allowed them to develop boat skills and knowledge of estuarine habitats, and to better comprehend the importance of maintaining a focus on acquiring quality data collection. During the last eighteen months, the CFC team has also provided key training of personnel for bringing new sea ranger teams on board to better support the MangroveWatch program along with other sea country management activities.



Figure 17: Gidarjil Rangers independently surveyed shorelines of 8 estuarine systems by gathering specific imagery of habitat condition bordering sensitive Southern GBR waters.

3.2.2 Scheduling of Indigenous ranger training and field surveys

The methods used in these surveys were geo-referenced videography called the Shoreline Video Assessment Method (S-VAM) (see Mackenzie et al., 2016). Most imagery was collected by Indigenous rangers – during initial supervised training by TropWATER science specialists, and afterwards as independent efforts. In the study area, Indigenous rangers were trained, and their goal was to conduct at least two surveys in each of the eight estuarine case study areas (Table 7). Processing of image data collected by community members was done by the TropWATER project team at the Mangrove Hub at JCU. Data were taken from imagery and from survey digital diaries to further visualise and describe coastline condition, to make ecological assessments of shoreline composition, plus the status and health of respective shorelines. These data and information have provided all that has been assessed for this report. The outcomes contribute directly to the Southern GBR Mangrove Management Plan

as well as the enhanced capacity of Indigenous rangers in the conduct and delivery of the environmental monitoring and rehabilitation of local coastal tidal wetlands.

Table 7: A brief listing of S-VAM field monitoring surveys for the eight estuarine systems of the Southern GBR NESP TWQ Hub Project completed by Gidarjil Rangers between 2013 and 2018.

S-GBR Estuary	2013	2014	2015	2016	2017	2018	Total Shoreline (km)
Calliope River			X		X	X	51.0
South Trees Inlet		X				X	32.0
Boyne River		X	X	X		X	21.5
Baffle Creek					X	X	89.7
Kolan River	X			X		X	51.6
Burnett River	X			X		X	52.0
Elliott River	X			X	X		19.4
Burrum River	X			X		X	58.4

The increasing number of surveys per year indicate progress towards successfully meeting project goals in getting S-VAM surveys completed for at least two date intervals within the project timeline. It was essential for this project to work through all the issues from learning new skills, to gaining confidence to delivery of field data to be reliable and useful for scientific assessment.

3.3 Communications associated with this southern GBR Project

3.3.1 Reports and Publications related to the Project

Research Articles

- Duke, N.C. 2016. Oil spill impacts on mangroves: recommendations for operational procedures and planning based on a global review. *Marine Pollution Bulletin* 109(2): 700-715.
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3.3.2 Presentations at Conferences, Community Symposia and Workshops

1) *Presentation title.* **The Southern GBR CHAMP (Coastal Health Archive and Monitoring Program)**

Authors. Norman C. Duke & Jock Mackenzie

April 2016 - NESP Tropical Water Quality Hub workshop, Townsville

Abstract. On Friday 12 February 2016, Dr Duke attended the workshop for Project Leaders organised by the Tropical Water Quality (TWQ) Hub of the National Environmental Science Programme (NESP). Project Leaders were briefed about overall NESP goals and aspirations, as well as shown how they might get support for the successful conduct of their respective projects. An important additional outcome was the sharing of project objectives amongst Project Leaders, with the idea of exploring synergies between projects both within the TWQH as well as other Hubs within NESP.

Traditional Owner rangers and local citizens of the Port Curtis Coral Coast (PCCC) TUMRA will be engaged in developing a Mangrove Management Plan (MMP) that provides a strategic basis for estuarine repair activity and maximizes water quality outcomes in the southern GBR. Development of this MMP will build capacity within the Gidarjil Development Corporation (GDC) and local community to undertake scientifically-rigorous, ecological monitoring and assessment. These management and rehabilitation strategies will protect sea country resources through partnerships between community, scientists and NRM agencies. The MMP will enable rangers and citizen scientists to conduct scientifically valid surveys of estuarine monitoring, management and rehabilitation within the PCCC TUMRA area.

2) *Presentation title.* **Indigenous ranger management of Southern GBR estuarine mangrove wetlands**

Authors. Norman C Duke, Jock Mackenzie and Peter Brockhurst

May 2016 - Australian Mangrove and Saltmarsh Network (AMSN) Conference, Townsville

Abstract. We report on two new projects aiming to improve management of southern GBR estuarine mangrove wetlands. Both enlist the support of local Traditional Owners and volunteers in the area from Rockhampton to Hervey Bay in Queensland. The JCU research team in partnership with the GDC is supported by: the Gladstone Ports Corporation's Estuarine Research and Monitoring Program for Port Curtis and Port Alma areas until 2020; and, by the National Environmental Science Program (NESP) Tropical Water Quality Hub for the wider area of the Port Curtis Coral Coast TUMRA until 2018. Both projects employ MangroveWatch-style monitoring methods (see: www.mangrovetwatch.org.au) like the Shoreline Video Assessment Method combined with walkabout cultural evaluations plus identification of practical shoreline rehabilitation works. One key outcome is to develop a Mangrove Management Plan (MMP) in collaboration with local Natural Resource Management groups, the Burnett Mary Regional Group, and the Fitzroy Basin Association. The MMP will provide a strategic basis for estuarine repair activities and for maximizing water quality outcomes in the southern GBR region. These projects build human capacity and skills amongst Gidarjil Rangers and local community volunteers for the conduct of scientifically-rigorous, ecological monitoring, assessment and rehabilitation. Such management and mitigation strategies will bolster efforts to effectively protect estuarine sea country resources as well as build lasting partnerships between community, scientists, industry, managers and local NRM agencies.

3) *Presentation title.* **Does anyone care if 200 hectares of mangroves fall into the sea around Princess Charlotte Bay?**

Authors. Jock Mackenzie & Norman C. Duke

May 2016 - Australian Mangrove and Saltmarsh Network (AMSN) Conference, Townsville

Abstract. Testing tidal wetland sea level rise response paradigms in Princess Charlotte Bay and implications for local and regional tidal wetland management. Since 2014, MangroveWatch JCU has been partnering with Balkanu Cape York Development Corporation and the Traditional Owners of Alka-Bawar Land Trust to monitor and manage Princess Charlotte Bay tidal wetlands. A key outcome of this program has been quantifying effects of sea level rise on tidal wetlands. Of concern was the discovery that 200 ha of fringing mangroves have been lost in the past 26 years, with a high probability that most fringing mangroves will be lost within 100 years. There are generally accepted logical paradigms of tidal wetland response to sea level rise but there are few large-scale examples of these processes in action. As sea level rises, tidal wetlands shift landward and upstream. But, can upland migration keep pace with the rate of sea level rise? And, how does pre-existing tidal wetland condition influence tidal wetland retreat? Using aerial, boat-based and on-ground data collection and historical aerial and satellite imagery analysis we test these paradigms. The results to date indicate tidal wetland response to sea level rise is not linear, but is a dynamic process differing at spatial and temporal scales, influenced by long and short term climatic events and anthropogenic disturbance. Our results are informing on-ground management of tidal wetlands at the local scale, but have implications for regional tidal wetland management. Understanding how tidal wetlands respond to sea level rise will assist in the development of programs to minimize and mitigate future mangrove loss. But first it is essential to understand the extent of the problem. Without effective local on-ground monitoring it is impossible to effectively manage our remote and vast tidal wetland systems. This program provides a timely example of the importance of research, management and Traditional Owner partnerships to monitor mangroves across Australia's North.

4) *Presentation title.* **Application of MangroveWatch for broad-scale assessment of mangrove condition and dynamics in the Torres Strait Islands.**

Authors. Damien Burrows, Norman C. Duke and Jock Mackenzie

May 2016 - Australian Mangrove and Saltmarsh Network (AMSN) Conference, Townsville

Abstract. Working with traditional owners of the Torres Strait islands, we used the MangroveWatch methodology (www.mangrovetwatch.org) to survey the diversity, extent and condition of mangrove and shoreline habitats on these islands. Local Indigenous land and rangers were trained in the use of MangroveWatch field protocols, and participated in all aspects of fieldwork. This involvement is critical given their prime role as traditional owners and current managers of the resource. A total of 26,054 ha of mangrove forests are mapped throughout the islands. We assessed mangrove condition along 300km of shoreline across 14 islands. Mean extent of mangrove shoreline cover was 67%. Approximately 59% of shorelines were assessed as being in a healthy state and 18% in poor condition – this being indicative of the dynamic coastal environment in Torres Strait where even natural stands undergo significant change. Shoreline processes affecting mangroves varied considerably between individual islands, so management options will also vary. The dominant shoreline process is erosion (21% greater than expansion). Several islands are undergoing significant expansion and loss at different locations. The MangroveWatch methodology allows for a

broad-scale, yet rapid, assessment of mangrove condition, especially in remote locations. It is particularly suitable for meaningful involvement of Indigenous participants.

5) *Presentation title.* **Application of MangroveWatch for broad-scale assessment of mangrove condition and dynamics in the Torres Strait Islands the northern-most Australian islands.**

Authors. Damien Burrows, Norman C. Duke and Jock Mackenzie

July 2016 – MMM4 Conference, St. Augustine, Florida USA

Abstract. The Torres Strait islands lay between northern Australia and southern New Guinea. These islands are of particular interest because of their position between Australia and SE Asia, their predominantly Indigenous population and management, and their low elevation which makes them especially vulnerable to sea-level rise and increased storm surge. The Torres Strait islanders have a unique seafaring culture and they identify strongly with their marine and coastal resources.

Despite being part of Australia, the coastal habitats of these islands are poorly known and this, combined with the threat of rising sea levels and seawater intrusion, resulted in local communities and regional natural resource managers expressing a desire for further information on the state of these ecosystems in order to improve management. We used the MangroveWatch methodology (www.mangrovetwatch.org) to survey the diversity, extent and condition of mangrove and shoreline habitats on these islands. This involved boat and helicopter-based video recording of shoreline habitats using GPS-linked still and video cameras, where the footage is analysed using various metrics back in the lab. This work was supplemented by ground-truthing and analysis of historical imagery. Local Indigenous land and rangers were trained in the use of MangroveWatch field protocols, and participated in all aspects of fieldwork. This involvement is critical given their prime role as traditional owners and current managers of the resource.

A total of 35 mangrove species were recorded, with 2 of these being new records for Australia. A total of 26,054 ha of mangrove forests are mapped throughout the islands. We assessed mangrove condition along 300km of shoreline across 14 islands. Mean extent of mangrove cover along shorelines was 67%, demonstrating how important mangroves are as coastal habitats on these islands. Approx. 59% of shorelines were assessed as being in a healthy state and 18% in poor condition – this being indicative of the dynamic coastal environment in Torres Strait where even natural stands undergo significant change.

Shoreline processes affecting mangroves varied considerably between individual islands, reflecting that management options will also vary. Overall the dominant shoreline process is erosion (21% greater than expansion). Several islands are undergoing significant expansion and loss at different locations. Mangrove cutting is common on the inhabited islands. Sea level rise appears to be directly threatening 13% of Torres Strait mangrove habitat. Evidence of historical mangrove dieback along shorelines appears to coincide with changes in sea level. Historical change was assessed across 11 islands. One island has had a net increase in mangrove area of 13% since 1974 with half of that being regrowth in historically cleared areas.

The MangroveWatch methodology allows for a broad-scale, yet rapid, assessment of mangrove condition, especially in remote locations. In particular, it is suitable for meaningful involvement of Indigenous participants in the gathering of field data.

6) *Presentation title.* **Managing oil spill impacts on mangroves: should we be concerned?**

Authors. Norman C. Duke

July 2016 – MMM4 Conference, St. Augustine, Florida USA

Abstract. Mangroves are widely acknowledged as highly vulnerable to oil spills, but this is measured mostly in terms of severity of impacts on vegetation rather than their longer term recovery and the consequences for associated trophic processes. Little is known about key linkages and functional relationships between the plants and animals making up mangrove habitat. This includes not knowing how long it takes for oil-damaged mangrove habitat to recover. While recovery of forest structure appears to occur within three decades, full habitat recovery may take much longer. From the limited data available, it seems that prevention would be the better option, rather than restoring oil-damaged habitat. But, when mangrove habitat is oiled then an effective strategy is needed.

When petroleum oil deposits on sensitive plant surfaces, it also affects soils and dependant animal life, causing a range of lethal and sublethal impacts that extend widely throughout associated coastal and estuarine ecosystems. Such disruptions also affect ecosystem services, like fisheries production and shoreline protection. And, all such impacts may persist for decades, as well as occurring at any time and at any place. So, for as long as oil is extracted and transported, there will be an ever-present risk to the health and survival of mangrove habitats worldwide. Therefore, it is essential where possible to be prepared.

Preparedness includes evaluation of risks and vulnerability, developed from baseline shoreline surveys, records of earlier impacts and recovery, and using effective longer-term monitoring. For instance, impact severity on mangroves might easily be quantified by the area of tree death along with other pragmatic descriptors, like the estimated volume of oil lost, the types of oil, the area of oiled habitat, and the area of likely sublethal impacts. The situation would also be much improved by an agreed global assessment strategy using standard criteria for the longer term, better management and monitoring of mangrove habitat affected by large oil spills. Only in applying such a strategy will it be possible to adequately understand, evaluate and assist longer term recovery of oil-impacted mangrove ecosystems.

7) *Presentation title.* **Effects of severe flooding on estuarine mangroves – disturbance, resilience and restoration.**

Authors. Jock Mackenzie

July 2016 – MMM4 Conference, St. Augustine, Florida USA

Abstract. “I love a sunburnt country, a land of sweeping plains, of ragged mountain ranges of droughts and flooding rains, I love her far horizons, I love her jewel-sea, her beauty and her terror, the wide brown land for me” (excerpt from Dorethea Mackellar, *My Country*). Australia is a country typified by diverse and iconic landscapes, severe climate and severe weather events, which are at times terrifying in their power and destruction. Mangroves are highly adapted to extreme environments as demonstrated by their survival at the interface between

land and sea, exposing them to short and long-term climate extremes such as cyclones, floods and droughts. But anthropogenic driven degradation of estuarine mangroves may threaten the capacity of mangroves to withstand extreme climate events. Direct damage leading to mangrove loss and fragmentation and indirect effects such as altered hydrology and eutrophication reduce the capacity of mangroves to withstand climate extremes and limits their resilience capacity. It is expected that extreme weather events will increase in both severity and frequency in coming years. It is therefore imperative that we understand how anthropogenic degradation of mangroves influences their resistance and resilience to extreme weather events in order to inform better mangrove management. Recently, a series of severe flood events impacted the east coast of Australia, causing extreme flooding in major coastal rivers and estuaries. These flood events caused widespread loss of shoreline mangroves, with an estimated loss of 30% of estuarine mangroves in some coastal estuaries. Some of the estuaries impacted form part of the monitoring network of MangroveWatch, a citizen-science based program designed to monitor long-term changes in the condition of shoreline mangroves using geotagged video. The MangroveWatch monitoring data enabled assessment of mangrove condition before and after flooding. Here we examine the effect of flooding on estuarine mangroves in three different coastal settings with differing levels of human impacts to assess the effects of estuarine and catchment modification on mangrove resilience to severe flood events. Our results show that shoreline mangrove forest fragmentation, eutrophication and estuarine shoreline modification result in greater risk of estuarine mangrove loss during severe flood events with recovery dependent on pre-existing forest structure, forest continuity, condition, level of anthropogenic disturbance and adjacent land use. This information is used to develop a strategic approach to mangrove rehabilitation investment in the target estuaries and inform future estuarine mangrove management.

8) *Presentation title.* **Assessing Mangrove Dieback in the Gulf of Carpentaria, a Globally Significant Dieback Event**

Authors. Norman C Duke, J.M. Kovacs, A.D. Griffiths, J. Mackenzie and D. Burrows
July 2016 – MMM4 Conference, St. Augustine, Florida USA

Abstract. In October-November 2015, 7,000 hectares of mangroves have suffered dieback along a 1000km stretch of coastline in the Gulf of Carpentaria from Karumba in the east to the Roper River in the west. Presentations on this event at recent national and international mangrove conferences confirm that this is a globally unprecedented event. The dieback appears to have started about the same time Oct-Nov 2015, even across these broad areas. The area of impact is too large to be due to chemical contamination or other localised effects. This is suggestive of extreme climate as the cause. Climate data for that period reveal abnormally low rainfall, extreme air and sea temperatures and even a local drop in sea level. Across the impacted area, the dieback has, at various locations, affected all mangrove species across all tidal zones – it's not just one species or one tidal zone. Of the 1,000km affected, 200km of this includes shoreline mangrove communities, whose death now exposes the shoreline to erosion from storms and cyclones for at least the next 15 years till the forests recover. This event has serious implications for biodiversity, commercial and recreational fisheries, local and Indigenous communities, shoreline protection and for government and management agencies.

9) *Presentation title.* **Mangrove Science & Art Show: The Beauty Within**

Authors. Norman C Duke and Jock Mackenzie

October 2016 – Reef Blitz Citizen Science Workshops, Cairns.

Abstract. MangroveWatch, The Cairns & Far North Environment Centre and the Djunbunji Land and Sea Rangers are excited to be teaming up to deliver some exciting mangrove related events to Cairns residents this weekend as a part of the 2016 ReefBlitz. Mangroves nurture 75% of Queensland's fish catch and protect the Reef by filtering catchment runoff and reducing shoreline erosion. Healthy mangroves support healthy corals with clearer, cleaner water - lower in sediments and chemicals. We're inviting the residents of Cairns to learn more about this unique and vital ecosystem by joining in on educational events over the weekend. Everyone is invited to come along on Saturday to the board walk and discover how much carbon our local mangroves are sequestering, attend a mangrove themed art show in the evening, and on Sunday jump aboard and cruise up Trinity Inlet. Attend one event, two or all three!

10) *Presentation title.* **Mangrove monitoring methods and how rangers can get involved.**

Authors. Norman C Duke and Jock Mackenzie

November 2016 – MangroveWatch training workshop for Indigenous rangers, Normanton & Burketown with the Carpentaria Land Council Aboriginal Corporation (CLCAC).

Abstract. Indigenous rangers are working to evaluate the extent of the massive and mysterious mangrove dieback in the Gulf of Carpentaria. The dieback, involving more than 7,400 hectares of mangroves stretching 1,000 km west of the Gulf town of Karumba, was discovered a year ago, with scientists describing it as “unprecedented”. The Queensland-based Carpentaria Land Council Aboriginal Corporation, with the help of TropWATER at James Cook University, is now training 19 rangers to monitor the situation for the eastern side. The training began on November 12 for Indigenous ranger teams based in both Normanton and Burketown. The program is being led by TropWATER scientist, Dr Norm Duke. “TropWATER is giving its full support towards having well-advised, and science-trained local Indigenous rangers across the north of Australia. The rangers are very keen to improve their recording and dissemination of information so the data they collect is relevant to environmental managers in Government, as well as for science researchers,” he said. Dr Duke said the implications of the dieback are likely to be far reaching. “Locals are justified in their concern for possible impacts on fisheries, coastal productivity, as well as to shoreline stability and more. Losses of shoreline mangroves exposes those shorelines to severe storms and waves that could erode large sections of coastline.” This work has been undertaken and funded at the initiative of the CLCAC as Traditional Owners are extremely concerned about this phenomenon. Through this training, CLCAC Rangers will gain the skills and knowledge to continue monitoring and evaluating mangrove shorelines across the southern Queensland Gulf. Normanton Senior Head Ranger Paul Richardson is keen to see further investigation into this occurrence and opportunities for Indigenous rangers to undertake monitoring. “Traditional Owners are concerned about the recent dieback event and the potential widespread environmental impacts it may have. For example, dieback has occurred across important habitat for migratory shorebirds” Mr Richardson said. Dr Duke said the methods used in MangroveWatch monitoring are readily learnt and applied – requiring participants to simply know how to use a camera and a GPS device. “This is a remote part of the country, so by using such methods in a standard way provides extremely valuable and useful data.” Dr Duke

said it will be a win-win outcome to support Indigenous rangers as guardians of Australia's shoreline resources - especially in the more remote regions of the country.

11) **Presentation title. Update on the largest occurrence of sudden mangrove dieback ever recorded: a lesson in shoreline habitat vulnerability and those who can help!**

Authors. Norman C Duke, J.M. Kovacs, A.D. Griffiths, J. Mackenzie and D. Burrows

November 2016 – Territory Natural Resource Management Conference, Darwin

Abstract. In October-November 2015, 7,400 ha of mangrove forests died along 1,000 km of the southern shoreline of the Gulf of Carpentaria from Roper River in the Northern Territory to Karumba into Queensland. Presentations about the incident at recent national and international mangrove conferences confirmed that this was globally unprecedented. While the area impacted is too large to have been due to accidental contamination or other localised factors, this does not rule out secondary effects on ecosystems resilience. Current evidence suggests that the overall influences were due to the extreme climatic conditions prevailing at the time, coupled with an unusual but short-lived 20 cm drop in sea level. Climate data during the preceding period revealed abnormally low rainfall, extreme high air and sea temperatures, and an unusually long dry spell. Across the impacted area, the dieback affected all mangroves present in the high tidal zone – so the impact was not restricted to just one species, nor part of the tidal profile. Most worrying furthermore, around 10% of the impacted coastline, ~200 km, suffered more or less complete loss of foreshore mangrove communities. Their death now exposes these coastal sections to likely catastrophic erosion from occasional severe storms and cyclones over at least the next 15-20 years until forests recover - assuming they do. Whatever the cause, this event has serious long term implications for biodiversity, commercial and recreational fisheries, local industries and Indigenous communities, raising this as an urgent and emerging priority for government and management agencies to shore up shoreline protection. There is also a pressing need to support longer term monitoring by trained and well-advised groups, starting with Indigenous rangers living along these remote northern shorelines.

12) **Presentation title. Working with Traditional Owners to better manage northern Australia's coastal and estuarine tidal wetlands.**

Authors. Norman C Duke, Jock Mackenzie and Damien Burrows

November 2016 – Territory Natural Resource Management Conference, Darwin

Abstract. There are good reasons for protecting Australia's northern coastal and estuarine tidal wetlands. They provide essential ecosystem services of lucrative resources like fisheries productivity, protection of Australia's northern shorelines, buffering erosion, and bolstering coastal water quality. But, these benefits and the habitats themselves are threatened by human development as well as from occasional climate events like the recent extensive dieback in the Gulf. A national strategy is needed for prioritising at-risk and damaged shorelines to help in their protection and rehabilitation, as needed. Scientists at TropWATER Centre James Cook University are working on a number of innovative projects with Traditional Owner rangers and local citizens to meet these national objectives. These partnerships are delivered in a program called MangroveWatch which raises capacity for shoreline assessment amongst individual groups. Key recent projects with Indigenous partners include: the Southern GBR estuaries with Gidarjil Development Corporation, Eastern Princess Charlotte Bay shorelines with Balkanu, Noosa and Maroochy region with Bunya Bunya Corporation, Torres Strait islands with Torres

Strait Regional Authority, and most recently in the south-eastern Gulf region with the Carpentaria Land Council Aboriginal Corporation. In each project, close partnerships are producing beneficial outcomes that deliver detailed assessments of shoreline health, condition, vulnerability, dominant issues, and prioritisation of shoreline sites for rehabilitation. Indigenous rangers make key contributions as they monitor, assess, manage and rehabilitate estuarine wetlands within their individual cultural landscapes. At the same time, scientists and regional managers obtain first hand observations, data and imagery for better understanding changes taking place in each region. It's a win-win outcome!

Indigenous rangers key to monitoring mangrove dieback. A leading mangrove researcher has called for training of Indigenous rangers to help monitor and prevent mangrove dieback amid fears future cyclones could have serious impacts on the north Australian coastline. The death of more than 7,000 hectares of mangrove forests along 1,000 km of the southern shoreline of the Gulf of Carpentaria from Roper River in the Northern Territory to Karumba in Queensland was globally unprecedented and has left these shorelines exposed to serious threats. James Cook University senior mangrove ecologist and Professional Research Fellow, Dr Norman Duke said he was most concerned about the threat future cyclones would have on the coast. "The mangrove dieback has made these coastal sections vulnerable to severe storms and cyclones for the next two decades which could cause catastrophic erosion until new seedlings grow," Dr Duke said. "Because of the remote location, it is important that we work with Indigenous communities, particular rangers so they can not only work with visiting specialists but also conduct monitoring of the shoreline on their own." Dr Duke will present an update on his research at the 2016 Territory Natural Resources Conference will be held from 22-24 November. The conference will bring together people working in natural resource management from across the Northern Territory.

13) *Presentation title.* Update on the training of traditional owners for shoreline monitoring and the current status of mangrove dieback in the Gulf.

Authors. Norman C. Duke, Damien Burrows & Jock Mackenzie

March 2017 - Australian Mangrove and Saltmarsh Network (AMSN) Conference, Hobart

Abstract. This talk will provide an update on the status of the extensive mangrove areas impacted in the late 2015 incident of unprecedented severe dieback in the Gulf of Carpentaria. This includes the specific training and monitoring being undertaken by traditional owners with JCU's TropWATER Centre that have helped achieve a range of results. Since the issue was first raised at AMSN 2016 in Darwin in May, there have been a number of field and aerial surveys that have significantly raised the levels of knowledge and understanding about the dieback. It is notable that much has been achieved in characterizing the incident - despite an initial lack of committed funding. The situation has now changed. With the combination of studies planned and being undertaken, the stage now is set to build on the valuable baseline information gathered about the incident: to look more closely at the potential cause; to make assessments of recovery and/or further loss; along with, detailed evaluations of key likely implications and consequences flowing from such an abnormally severe and widespread impact on tidal wetlands of northern Australia.

14) *Presentation title.* **Highlighting the value of MangroveWatch program for mangrove management in Moreton Bay and the challenges facing long-term citizen-science based mangrove monitoring.**

Authors. Jock Mackenzie, Norman C. Duke, Damien Burrows, Simon Baltais and Debra Henry

March 2017 - Australian Mangrove and Saltmarsh Network (AMSN) Conference, Hobart

Abstract. There are many opportunities to engage the general public in citizen-science to address the immediate and widespread threats facing mangrove and saltmarsh habitats in Australia. The challenge is to translate citizen-science data to on-ground management action, ensuring long-term sustainability of citizen-science programs, and keeping the 'science' in citizen-science. Here we examine the opportunities and challenges involved in harnessing citizen-science to achieve better outcomes for mangrove management using the example of the Wildlife Preservation Society Queensland (WPSQ) Moreton Bay MangroveWatch program, a long-term mangrove monitoring program in South-East Queensland. WPSQ citizen-scientists have monitored 500 km of shoreline since 2012. The analyzed data shows that Moreton Bay mangroves are generally healthy but there are hotspots of degradation that would benefit from proactive management intervention. What appear to be minor issues, like small-scale mangrove removal, localized runoff, and shoreline erosion, at a whole of system scale collectively equate to a substantial threat, putting Moreton Bay mangroves at risk of a 'death by a thousand cuts'. Effective management of mangroves and prioritization of investment in mangrove rehabilitation and protection requires knowledge of these local issues, identification of high value habitats and degradation hot-spots. The Moreton Bay MangroveWatch program demonstrates that citizen-science can provide this information to managers with low data collection costs and scientifically robust outcomes. But, the future of the Moreton Bay MangroveWatch is uncertain.

15) *Presentation title.* **A mangrove management plan for the southern GBR.**

Authors. Norman C. Duke, Jock Mackenzie and Gidarjil Rangers

April 2017 – Southern Great Barrier Reef CHAMP NESP project workshop, Rockhampton.

Abstract. This talk is about prioritizing investment in tidal wetland rehabilitation to improve water quality in the southern Great Barrier Reef waters. Traditional Owner rangers and local citizens of the Port Curtis Coral Coast (PCCC) TUMRA will be engaged in developing a Mangrove Management Plan (MMP) that provides a strategic basis for estuarine repair activity and maximizes water quality outcomes in the southern GBR. Development of this MMP will build capacity within the Gidarjil Development Corporation (GDC) and local community to undertake scientifically-rigorous, ecological monitoring and assessment. These management and rehabilitation strategies will protect sea country resources through partnerships between community, scientists and NRM agencies. The MMP will enable rangers and citizen scientists to conduct scientifically valid surveys of estuarine monitoring, management and rehabilitation within the PCCC TUMRA area.

16) **Presentation title. New Innovative Tools and Partnerships for an effective National Shoreline Monitoring Program.**

Authors. Norman C. Duke and Jock Mackenzie

May 2017 – National Estuaries Network workshop, Townsville.

Abstract. This talk is about Using Mangroves/Tidal Wetlands for Coastal Monitoring. The aim is to fill knowledge gaps in monitoring of shoreline processes for coasts and estuaries across large areas – adding to existing satellite and aerial image remote sensing, along with on-ground field surveys. An effective assessment framework has been specially developed that is comprehensive, all encompassing use of selected methodologies for rapid and rigorous quantification of condition and health of coastal habitats. The goal was to use current science, familiar technologies like geo-videographic methods (HD digital video cameras with GPS = S-VAM) for monitoring coastal environmental health, with data acquisition on a publically-accessible archive of imagery and assessments. And, these tools need to be easily familiar with community groups in partnerships with science specialists and managers for their practical and valuable contributions to environmental monitoring - adding invaluable first-hand accounts of habitat condition at sites along coastal shorelines.

17) **Presentation title. Golden Beach MangroveWatch shoreline restoration 2014-2017.**

Authors. Norman C. Duke and Jock Mackenzie

August 2017 – Australian Coastal Restoration Symposium, Townsville.

Abstract. This talk is about learning how to rehabilitate damaged shorelines based on a successful project at Golden Beach in southern Queensland. The planting and other ground works have involved the local Bunya Bunya traditional owners along with some dedicated community volunteers. The works involved reprofiling of the shoreline to accommodate the establishment of mangrove seedlings. Supporting structures installed included burying coir logs laid out in a special 'fish scale' pattern to provide an artificial subterranean root mat. This was protected by a layer of gravel whilst the seedlings become established over the next 10-20 years. The proof of the projects success was recorded when the site was inundated and washed over by flooding waters during a particularly violent local storm. Since that time, the seedlings have continued to grow and develop wider support roots. The project is supported by not only local community members but also the local council, state government and industry.

18) **Presentation title. MangroveWatch training workshop for Indigenous rangers in Borroloola with Territory Natural Resource Management Group and the Northern Land Council.**

Authors. Norman C. Duke and Jock Mackenzie

September 2017 – Territory Natural Resource Management field training workshop, Borroloola.

Abstract. Indigenous rangers are working to evaluate the extent of the massive and mysterious mangrove dieback in the Gulf of Carpentaria. The dieback, involving more than 7,400 hectares of mangroves stretching 1,000 km west of the Gulf town of Karumba, was discovered a year ago, with scientists describing it as "unprecedented". The TropWATER Centre, James Cook University, is now training 15 more rangers to monitor the situation. The program is being led by TropWATER scientist, Dr Norm Duke. "TropWATER is giving its full support towards having well-advised, and science-trained local Indigenous rangers across the

north of Australia. The rangers are very keen to improve their recording and dissemination of information so the data they collect is relevant to environmental managers in Government, as well as for science researchers,” he said. Dr Duke said the implications of the dieback are likely to be far reaching. “Locals are justified in their concern for possible impacts on fisheries, coastal productivity, as well as to shoreline stability and more. Losses of shoreline mangroves exposes those shorelines to severe storms and waves that could erode large sections of coastline.” This work has been undertaken and funded at the initiative of the Territory NRM in support of Traditional Owners who are extremely concerned about this phenomenon. Through this training, Borroloola Rangers will gain the skills and knowledge to continue monitoring and evaluating mangrove shorelines across the western NT Gulf. Dr Duke said the methods used in MangroveWatch monitoring are readily learnt and applied – requiring participants to simply know how to use a camera and a GPS device. “This is a remote part of the country, so by using such methods in a standard way provides extremely valuable and useful data.” Dr Duke said it will be a win-win outcome to support Indigenous rangers as guardians of Australia’s remote shoreline resources.

19) *Presentation title.* **Cairns MangroveWatch shoreline monitoring program**

Authors. Norman C Duke, Jock Mackenzie and Geoffrey Redman
October 2017 – Reef Blitz Citizen Science Workshops, Cairns.

Abstract. MangroveWatch, The Cairns & Far North Environment Centre (CAFNEC) and the Djunbunji Land and Sea Rangers are excited to be teaming up to deliver some exciting mangrove related events to Cairns residents as a part of the 2017 ReefBlitz. Mangroves nurture 75% of Queensland’s fish catch and protect the Reef by filtering catchment runoff and reducing shoreline erosion. Healthy mangroves support healthy corals with clearer, cleaner water - lower in sediments and chemicals. We’re inviting the residents of Cairns to learn more about this unique and vital ecosystem by joining in on educational events over the weekend. Everyone is invited to come along to the workshop and training session to discover how to monitor the health of tidal wetlands, with hands on experience in Trinity Inlet.

20) *Presentation title.* **MangroveWatch training workshop for Indigenous rangers in Numbulwar with Territory Natural Resource Management Group and the Northern Land Council.**

Authors. Norman C. Duke and Jock Mackenzie
November 2017 – Territory Natural Resource Management field training workshop, Numbulwar and Ngukurr.

Abstract. Indigenous rangers are working to evaluate the extent of the massive and mysterious mangrove dieback in the Gulf of Carpentaria. The dieback, involving more than 7,400 hectares of mangroves stretching 1,000 km west of the Gulf town of Karumba, was discovered a year ago, with scientists describing it as “unprecedented”. The TropWATER group at James Cook University, is training 10 more rangers to monitor the situation. The program is being led by TropWATER scientist, Dr Norm Duke. “TropWATER is giving its full support towards having well-advised, and science-trained local Indigenous rangers across the north of Australia. The rangers are very keen to improve their recording and dissemination of information so the data they collect is relevant to environmental managers in Government, as well as for science researchers,” he said. Dr Duke said the implications of the dieback are likely to be far reaching. “Locals are justified in their concern for possible impacts on fisheries,

coastal productivity, as well as to shoreline stability and more. Losses of shoreline mangroves exposes those shorelines to severe storms and waves that could erode large sections of coastline.” This work has been undertaken and funded at the initiative of the Territory NRM in support of Traditional Owners who are extremely concerned about this phenomenon. Through this training, Numbulwar and Ngukuur Rangers will gain to the skills and knowledge to continue monitoring and evaluating mangrove shorelines across the western NT Gulf. Dr Duke said the methods used in MangroveWatch monitoring are readily learnt and applied – requiring participants to simply know how to use a camera and a GPS device. “This is a remote part of the country, so by using such methods in a standard way provides extremely valuable and useful data.” Dr Duke said it will be a win-win outcome to support Indigenous rangers as guardians of Australia’s remote shoreline resources.

21) *Presentation title.* **Healthy Habitat equals healthy fish - the MangroveWatch shoreline monitoring program**

Authors. Norman C Duke and Jock Mackenzie

February 2018 – Fishers for Fish Habitat Forum, Logan.

Abstract. MangroveWatch, Healthy Land and Water and OzFish Unlimited teamed up to deliver an exciting Mangrovetwatch event for Logan residents. Mangroves nurture 75% of Queensland’s fish catch and protect the Reef by filtering catchment runoff and reducing shoreline erosion. Healthy mangroves support healthy corals with clearer, cleaner water - lower in sediments and chemicals. We’re inviting the residents of Logan to learn more about this unique and vital ecosystem by joining in on educational events over the weekend. Everyone is invited to come along to the workshop and training session to discover how to monitor the health of tidal wetlands, with hands on experience in Logan River estuary.

22) *Presentation title.* **Healthy Mangrove Habitat equals healthy fish - the MangroveWatch shoreline monitoring program**

Authors. Norman C Duke and Jock Mackenzie

March 2018 – MangroveWatch workshop, Ballina, NSW.

Abstract. MangroveWatch, Ballina City Council and NSW Fisheries teamed up to deliver an exciting Mangrovetwatch event for Ballina residents. Mangroves nurture 75% of Queensland’s fish catch and protect coastal waters by filtering catchment runoff and reducing shoreline erosion. Healthy mangroves support healthy shorelines with clearer, cleaner water - lower in sediments and chemicals. We’re inviting the residents of Ballina to learn more about this unique and vital ecosystem by coming to this special event. Everyone is invited to come along to discover how to monitor the health of their local tidal wetlands.

23) *Presentation title.* **Mass mangrove dieback in the Gulf – 2 years on!**

Authors. Norman C. Duke, Jock Mackenzie and Damien Burrows

April 2018 - Australian Mangrove and Saltmarsh Network (AMSN) Conference, Sydney

Abstract. It was a surprise to everyone when normally resilient mangroves were observed dying en masse in the Gulf of Carpentaria in early 2016 – being concurrent moreorless with severe coral bleaching and a particularly severe el Nino event at the time. What has happened since for mangroves and tidal wetlands? There are many questions – some to do with impact

and whether the situation has gotten worse? To questions about added and consequential impacts on associated marine habitats like seagrass beds, and on turtles and local fisheries. Has there been detectable recovery either as sprouting trees, or recruitment of damaged mangrove forest habitat? Have intervening severe weather events had any effect, like cyclonic winds and flooding in the region. And, of course, there remain questions about the cause. While scientists involved have a short-list of considered hypotheses, the specific cause remains unconfirmed. In this talk, I will update on such key questions, while sharing a number of recent insights from research and monitoring studies undertaken over the last year. One objective in this is to update and prepare the way for a targeted workshop to address concerns about what is being done, plans in affect, and what to do next.

24) Presentation title. Understanding the effects of consecutive severe flood events on estuarine mangroves – the role of citizen-science mangrove monitoring in informing effective mangrove management in a changing climate.

Authors. Jock Mackenzie and Norman C. Duke

April 2018 - Australian Mangrove and Saltmarsh Network (AMSN) Conference, Sydney

Abstract. Recent consecutive severe flood events in south-east Queensland dramatically impacted local communities. Less well recognised has been the impact of these flood events on estuarine ecology, including mangrove habitats. Here we present a study on the effects of consecutive extreme flood events on shoreline estuarine mangrove habitats along 30 km of the Logan River estuary, SEQ. Using detailed analysis of continuous, georeferenced shoreline video data collected by local MangroveWatch citizen-scientists and school students between 2014 and 2017 we answer three questions; 1) Are Logan River estuarine mangroves resilient to consecutive severe flood events? 2) what are the factors that increased shoreline mangrove vulnerability to severe flooding in the Logan River? 3) What are the longer-term implications of more frequent and severe flooding in the Logan River anticipated under current climate change projections? Based on this assessment we conclude that increased extreme flood frequency will dramatically alter the extent and habitat structure of estuarine shoreline mangrove habitats along the Logan River. Of particular note is the likely long-term loss of the upper-estuary *Aegiceras corniculatum* dominated mangrove fringe, prime breeding habitat for commercially valuable prawn species. Maintaining estuarine shoreline mangrove habitat and the continued provision of the ecosystem services they provide under changing climate conditions will require effective ecosystem management and direct management intervention, including limiting shoreline habitat fragmentation and disturbance, weed management and ‘living shoreline’ habitat creation and shoreline stabilisation. Effective mangrove management can only occur if there is sound scientific understanding of the likely ecological response of mangroves to changing climate, knowledge of existing threats and vulnerabilities that will reduce mangrove ecosystem resilience to climate change and community awareness and support for management intervention. This study demonstrates that citizen-science driven long-term mangrove monitoring programs, like MangroveWatch, provide opportunities to improve understanding of mangrove ecological response to climate change impacts, identify local threats and vulnerabilities and directly engage local communities in local mangrove stewardship likely to increase public support for investment in mangrove resource protection.

25) *Presentation title.* **Mangroves. Why are they important? - the MangroveWatch shoreline monitoring program**

Authors. Norman C Duke and Jock Mackenzie

April 2018 – MangroveWatch workshop, Mackay.

Abstract. MangroveWatch with Mackay Christian College teamed up to deliver an exciting Mangrovetwatch event for Mackay residents. Mangroves nurture 75% of Queensland's fish catch and protect coastal waters by filtering catchment runoff and reducing shoreline erosion. Healthy mangroves support healthy shorelines with clearer, cleaner water - lower in sediments and chemicals. We're inviting the residents of Mackay to learn more about this unique and vital ecosystem by coming to this special event. Everyone is invited to come along to discover how to monitor the health of their local tidal wetlands.

26) *Presentation title.* **Mass dieoff of mangroves in Australia's remote north – 2 years on!**

Authors. Norman C Duke, Jock Mackenzie & Damien Burrows

May 2018 – Boden Conference, Canberra, ACT.

Abstract. It was a surprise to everyone when mangroves, believed to be quite resilient, were observed dying en masse in the Gulf of Carpentaria in early 2016. This incident was especially cogent as it was co-incident with severe coral bleaching on the GBR, and a severe el Nino event. The landscape-scale statistics surrounding the dieback of mangroves, where 7,400 ha of forest trees died in 2-3 months along a 1,000 km shoreline, demonstrated clearly that these ecosystems were indeed, highly vulnerable to sudden changes in climate and environmental conditions. It was further remarkable that this incident was not only slow to be reported, but also because of its remoteness on Australia's northern coast, there was little chance of the usual direct human suspects being involved. In this talk, I will share recent insights, observations and concerns for better informing enlightened, effective management actions – like an effective national shoreline environmental monitoring capability.

27) *Presentation title.* **MangroveWatch for assessment of mangrove condition and dynamics in the Torres Strait Islands.**

Authors. Norman C. Duke, Damien Burrows and Jock Mackenzie

June 2018 – Torres Strait Terrestrial Island Ecosystems Workshop, Cairns

Abstract. The Torres Strait islands lay between northern Australia and southern New Guinea. These islands are of particular interest because of their position between Australia and SE Asia, their predominantly Indigenous population and management, and their low elevation which makes them especially vulnerable to sea-level rise and increased storm surge. The Torres Strait islanders have a unique seafaring culture and they identify strongly with their marine and coastal resources.

Despite being part of Australia, the coastal habitats of these islands are poorly known and this, combined with the threat of rising sea levels and seawater intrusion, resulted in local communities and regional natural resource managers expressing a desire for further information on the state of these ecosystems in order to improve management. We used the MangroveWatch methodology (www.mangrovetwatch.org) to survey the diversity, extent and condition of mangrove and shoreline habitats on these islands. This involved boat and helicopter-based video recording of shoreline habitats using GPS-linked still and video

cameras, where the footage is analysed using various metrics back in the lab. This work was supplemented by ground-truthing and analysis of historical imagery. Local Indigenous Land and Sea Rangers were trained in the use of MangroveWatch field protocols, and participated in all aspects of fieldwork. This involvement is critical given their prime role as traditional owners and current managers of the resource.

A total of 35 mangrove species were recorded, with two of these being new records for Australia. A total of 26,054 ha of mangrove forests are mapped throughout the islands. We assessed mangrove condition along 300km of shoreline across 14 islands. Mean extent of mangrove cover along shorelines was 67%, demonstrating how important mangroves are as coastal habitats on these islands. Approx. 59% of shorelines were assessed as being in a healthy state and 18% in poor condition – this being indicative of the dynamic coastal environment in Torres Strait where even natural stands undergo significant change.

Shoreline processes affecting mangroves varied considerably between individual islands, reflecting that management options will also vary. Overall the dominant shoreline process is erosion (21% greater than expansion). Several islands are undergoing significant expansion and loss at different locations. Mangrove cutting is common on the inhabited islands. Sea level rise appears to be directly threatening 13% of Torres Strait mangrove habitat. Evidence of historical mangrove dieback along shorelines appears to coincide with changes in sea level. Historical change was assessed across 11 islands. One island has had a net increase in mangrove area of 13% since 1974 with half of that being regrowth in historically cleared areas.

The MangroveWatch methodology allows for a broad-scale, yet rapid, assessment of mangrove condition, especially in remote locations. In particular, it is suitable for meaningful involvement of Indigenous participants in the gathering of field data.

28) *Presentation title.* **Mass dieoff of mangroves in Australia's remote north – 3 years on!**

Authors. Norman C. Duke and Jock Mackenzie

August 2018 – NESP Northern Australia Hub Workshop, Brisbane

Abstract. It was a surprise to everyone when mangroves, believed to be quite resilient, were observed dying en masse in the Gulf of Carpentaria in early 2016. This incident was especially cogent as it was co-incident with severe coral bleaching on the GBR, and a severe el Nino event. The landscape-scale statistics surrounding the dieback of mangroves, where 7,400 ha of forest trees died in 2-3 months along a 1,000 km shoreline, demonstrated clearly that these ecosystems were indeed, highly vulnerable to sudden changes in climate and environmental conditions. It was further remarkable that this incident was not only slow to be reported, but also because of its remoteness on Australia's northern coast, there was little chance of the usual direct human suspects being involved. In this talk, I will share recent insights, observations and concerns for better informing enlightened, effective management actions – like an effective national shoreline environmental monitoring capability.

29) *Presentation title.* **We are losing mangrove tidal wetlands - so what is being done about it?**

Author. Norman C. Duke

September 2018 – 3rd International Symposium on the Conservation and Management of Wetlands, Sabah, Malaysia.

Abstract. It is now well-documented that mangrove and tidal wetlands are in decline, with many accounts describing ongoing losses and deterioration of wetland habitats worldwide. In addition, recent dramatic and unexpected losses to mangrove habitats are further challenging the view that mangrove and tidal wetlands were tough habitats, resilient and able to rebound from all sorts of damage. It was further worrying when recent observations showed that more isolated areas were also at great risk. For instance, it was a surprise to everyone when mangroves were observed dying en masse in Australia's remote Gulf of Carpentaria in early 2016. This incident was especially cogent as it was co-incident with severe coral bleaching on the GBR and a severe el Nino event at the time. The scale of damage was staggering considering no direct human agent was to blame. The statistics surrounding the mass dieback record more than 7,400 ha of mangrove trees died in 2-3 months along approximately 1,500 km of shoreline. It seems hardly necessary to say, but this incident demonstrated that these tidal wetland ecosystems were indeed, highly vulnerable to the recent extreme changes in climate, sea level and other environmental variables. A key question arising from this occurrence was that if this could happen in such a remote wetland environment, then what must be happening in other, more populated places? In this presentation, I want to share recent insights and observations in support of local and regional efforts to better understand the status of tidal wetlands. And, how these places might be managed better. I would also like to promote enlightened, more effective management actions that build on important conservation initiatives, by enhancing the capacity of local people to assist in regional and national environmental monitoring strategies focusing on vulnerable tidal wetlands along with other shoreline natural environments. The growing consensus amongst stakeholders is that a science-based strategy is highly desirable if we are to effectively deal with the changes taking place in tidal wetlands locally and worldwide.

30) *Presentation title.* **Mass dieoff of mangroves in Australia's remote north – 3 years on!**

Authors. Norman C. Duke and Jock Mackenzie

November 2018 – NESP Northern Australia Hub Workshop, Darwin

Abstract. The latest data are presented from aerial surveys and extensive field studies. It was a surprise to everyone when mangroves, believed to be quite resilient, were observed dying en masse in the Gulf of Carpentaria in early 2016. This incident was especially cogent as it was co-incident with severe coral bleaching on the GBR, and a severe el Nino event. The landscape-scale statistics surrounding the dieback of mangroves, where 7,400 ha of forest trees died in 2-3 months along a 1,000 km shoreline, demonstrated clearly that these ecosystems were indeed, highly vulnerable to sudden changes in climate and environmental conditions. It was further remarkable that this incident was not only slow to be reported, but also because of its remoteness on Australia's northern coast, there was little chance of the usual direct human suspects being involved. In this talk, I will share recent insights, observations and concerns for better informing enlightened, effective management actions – like an effective national shoreline environmental monitoring capability.

3.4 Scoping of a Mangrove Management Plan

3.4.1 Prioritising actions to enhance tidal wetland water quality regulation capacity in Southern GBR estuaries.

Tidal wetlands, comprising mangrove, saltmarsh and saltpans, provide multiple ecosystem service benefits. A key regulating ecosystem service of tidal wetlands is their capacity to moderate and improve water quality. Tidal wetland water quality regulation capacity is of relevance in the Great Barrier Reef Marine Park (GBRMP) area of Queensland where poor water quality, defined by high sediment and nutrient loads, has led to a decline in reef health and reduced reef resilience to climate change. Furthermore, across large areas of land adjacent to the Southern Great Barrier Reef, the natural water quality regulating capacity of the landscape has been greatly reduced through modification and removal of riparian and wetland systems. The loss and modification of upstream water regulating natural ecosystems places even greater importance on maintaining and improving tidal wetland water quality regulating capacity.

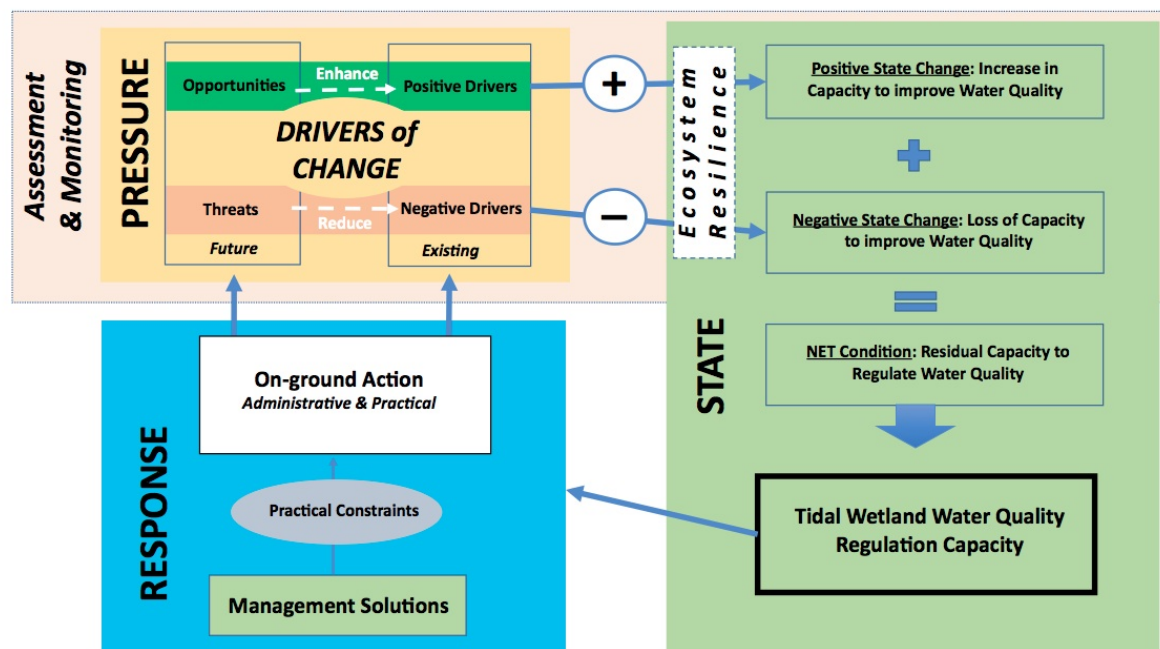


Figure 18: Tidal wetland management support tool – framework based on the State-Pressure-Response model.

In all estuaries of the southern GBR, there are a combination of natural and, direct and indirect anthropogenic pressures that are driving tidal wetland change and degradation. These drivers of change (Duke et al. 2003; Duke 2014; Schmitt & Duke 2016) alter tidal wetland extent, structure, productivity and ultimately tidal wetland ecosystem function, including water quality regulation.

To maintain and enhance tidal wetland water quality regulation ecosystem services within Southern GBR estuaries, it is necessary to understand the capacity of estuary tidal wetlands to regulate water quality, how tidal wetlands are changing over time, how these changes influence water quality regulation ecosystem services and the specific drivers of these

changes. This information can assist estuary managers prioritise investment in specific estuaries and target specific regional and local drivers.

The need to maintain and improve tidal wetland water quality regulating capacity within Southern GBR estuaries requires a four-pronged management response encompassing 1) rehabilitation of degraded tidal wetland areas, 2) restoration of lost tidal wetland areas, 3) tidal wetland habitat creation and 4) minimising future loss and degradation from climate change and sea level rise. As resources for these actions are limited, it is necessary to prioritise these actions, both between and within southern GBR estuaries, to maximise GBR water quality improvement outcomes.

Here we present an ecosystem-service based Pressure-State-Response (PSR) model framework to assist managers identify and prioritise management actions that maintain and improve tidal wetland water quality regulation in Southern GBR estuaries (Fig. 18). This framework is suitable for assessment of tidal wetland condition indicators relevant to estuarine water quality and may also be used in conjunction with broader estuary condition assessments. The tidal wetland PSR state model used in this approach is enhanced by the inclusion of vulnerability and risk indicators as proposed by Rissik et al (2005). Management actions can then be prioritised based on necessity, cost and likelihood of success.

An information hierarchy (Fig. 19) within the PSR framework is provided to guide data collection and outline the flow of information to guide on-ground action implementation.

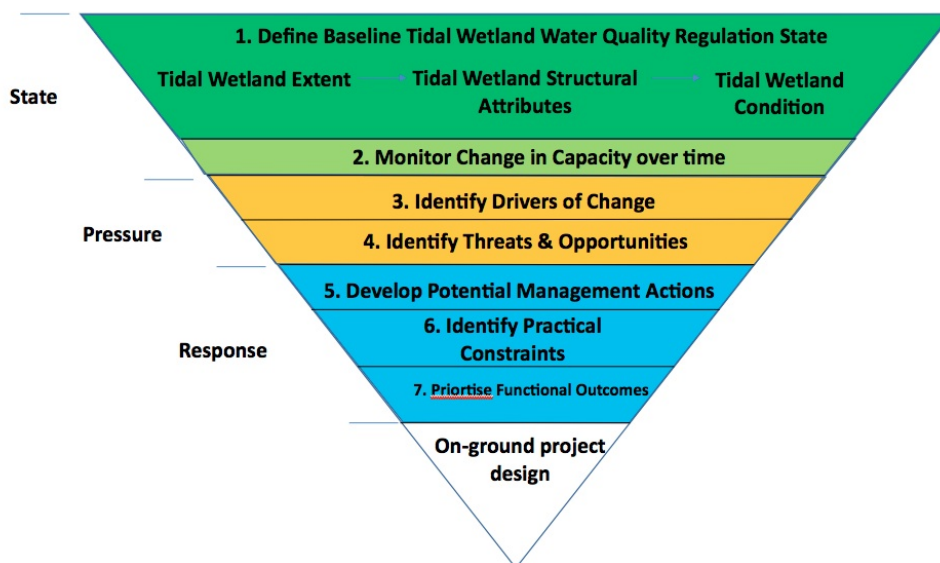


Figure 19: Tidal wetland management support tool – action flow using the State-Pressure-Response model.

3.4.2 Explanation of the Tidal Wetland Water Regulation Capacity PSR model

State. The capacity of the tidal wetland system to regulate water quality. Tidal wetland water quality regulation capacity is determined by spatial, structural and condition attributes and can be assessed at whole-of-estuary scale and within-estuary sub-regions. The capacity of tidal wetlands to regulate water quality is a function of the relative tidal wetland area represented by vegetation structural units, and the productivity of those structural units. Relative tidal

wetland area is a measure of the area of tidal wetland in relation to catchment area, estuary area and tidal wetland perimeter. These indices provide a measure of the area of tidal wetlands available to intercept and moderate sediment and nutrients within riverine, tidal and overland flows. Relative tidal wetland area is a useful measure to compare water quality regulation capacity between estuaries. Estuaries with lower relative tidal wetland area require greater representation of functional high-density vegetation units.

Within estuaries, the tidal wetland area can be further sub-divided into structural vegetation units based on dominant vegetation types and stem density that describe the ability of the tidal wetland area to intercept and moderate those flows and trap sediment and nutrients. The productive capacity (condition) of those vegetation units describes the ability of those vegetation units to then process and incorporate nutrients and sediments within the tidal wetland system, improving estuarine water quality.

The sum-total loss or gain of tidal wetland area, changed tidal wetland vegetation structure and changing tidal wetland condition over time represents a declining a tidal wetland water quality regulation capacity.

Pressure. Pressures define the external forces applied to a tidal wetland area that result in a change in tidal wetland state. Change in tidal wetland regulation capacity attributes over time are driven by direct and indirect anthropogenic drivers and natural forces. These drivers of change occur across varying spatial and temporal scales and often combine to result in observed ecosystem state changes. Positive drivers result in an increased capacity of a tidal wetland system to regulate water quality by either increasing tidal wetland extent, tidal wetland structural density or tidal wetland productivity. Negative drivers reduce tidal wetland extent, tidal wetland structural density and/or tidal wetland productivity resulting in decreased water quality regulation capacity relative to a baseline state. The scale of response of the tidal wetland ecosystem to these external forces is dependent on the existing ecosystem resilience. Management of actions that modify the influence of these drivers of change result in a net change in tidal wetland water quality regulation capacity.

Positive and negative drivers of change that are present or likely to be present within a tidal wetland system present opportunities and threats for tidal wetland water quality regulation. Management of these 'future drivers' can ensure maintenance or improvement of water quality regulation capacity in the long term.

Directly attributing tidal wetland ecosystem state response to specific drivers is often difficult. Understanding the location, extent and intensity of each of the drivers of change present within an estuary can help define the relative importance of each driver observed in relation to the ecosystem state changes observed. A series of indicators have been developed to assist in the identification and evaluation of each of the drivers of change influencing tidal wetlands in the Southern GBR.

Response. Management responses that address tidal wetland drivers of change in an estuary can result in net positive improvements in tidal wetland water quality regulation capacity through increasing tidal wetland area, increasing tidal wetland vegetation structure and improving productivity. This can be achieved by reducing the influence of negative drivers or enhancing positive drivers of change. Management responses can also address threats and

enhance opportunities. The type of management response is dependent on the driver of change present and the extent of tidal wetland change over time. Within any one estuary, there are often multiple future and current drivers influencing tidal wetland state. Due to the limited resources available, it is necessary to prioritise these actions using a cost-benefit approach that accounts for relative cost of implementation vs the potential benefit for water quality improvement. The potential net benefit of any management action is relative to the need and the likelihood of project success. The ‘need’ is a measure of the estuary and sub-estuary scale nutrient and sediment inputs. As actual water quality data is often not available at the scale necessary to inform this process, spatial variables such as proximity to direct and indirect sources, adjacent land use, estuary position, tidal position and sub-catchment land use can be used as a proxy for ‘need’. Management action likelihood of success is influenced by socio-economic factors such as land tenure and other estuary values. These factors can be determined spatially and through incorporation of local knowledge in the monitoring and assessment process. Consideration of practical ecological constraints and risk factors is necessary to inform appropriate on-ground outcomes.

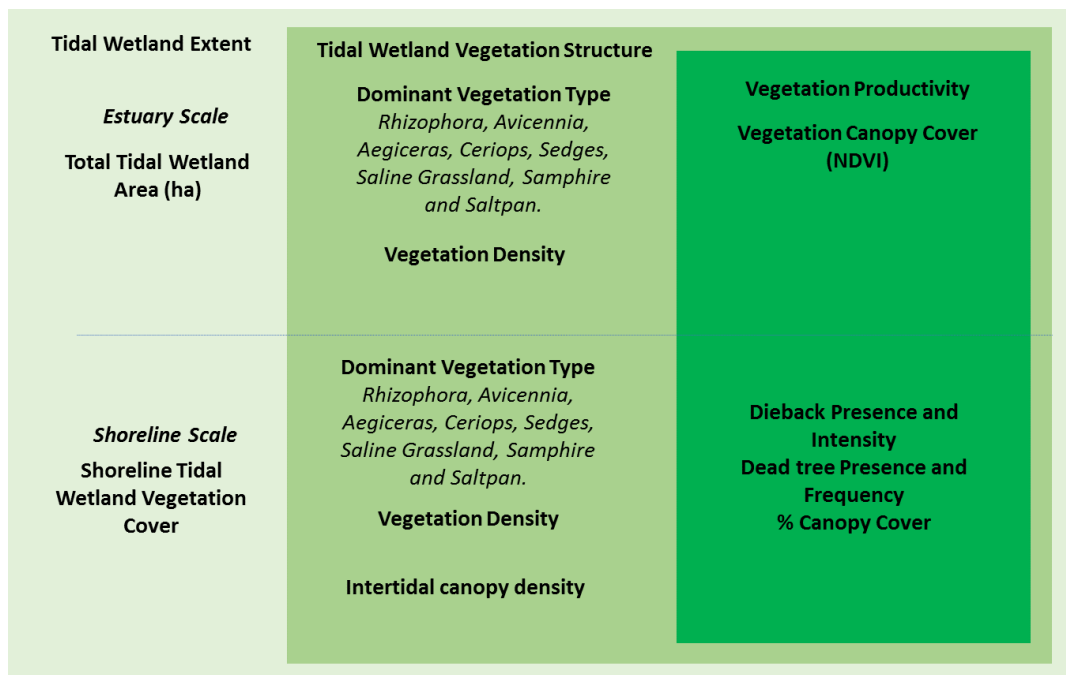


Figure 20: Tidal Wetland Water Quality Regulation State Indicators.

Monitoring and Assessment. There are a number of indicators that can be monitored and assessed to determine baseline tidal wetland ecosystem tidal wetland regulation capacity, change in capacity over time and associated drivers. Continued monitoring of these indicators provides opportunity to evaluate the success of management actions and the modifications or additional actions.

3.4.3 State Baseline and Change Indicators

Indicators of tidal wetland regulation capacity can be broadly grouped into three main categories; extent indicators, structural indicators and condition indicators (Fig. 20). These can be assessed at the whole of system scale and along estuary shoreline margins. Estuary

shoreline vegetation attributes are of particular importance for water quality regulation capacity assessment, as estuary shoreline vegetation has the maximum exposure to tidal and riverine flows. The structural attributes define tidal wetland structural units that can be ranked according to structural attributes relevant to water quality regulation. These structural vegetation units (SVUs) can then be ascribed condition scores (CS) based on productivity attributes giving each vegetation unit a water quality regulation score (WQRS).

$$SVU_{WQRS} = SVU_{RANK} * CS$$

The overall tidal wetland regulation capacity is the mean proportional area (SVU % Area) weighted WQRS for all vegetation units.

$$Tidal\ Wetland\ WQRS = \sum_{i=1}^n \frac{(SVU\ \% \ Area)_i \times SVU(WQRS)_i}{\sum_{i=1}^n SVU\ \% \ Area}$$

3.5 Data management

Data Manager: Eric Lawrey, Australian Institute of Marine Science

Data management was arranged with Dr Lawley at AIMS as required for the project outcomes. Briefly, there were three kinds of data generated with this project, and each involved different data sets including:

1. Shoreline surveys of the eight estuarine systems – as continuous geo-tagged video and still imagery of estuarine shorelines along with data for each image frame of status and condition – acquired on two or more occasions;
2. Mapping data for each of the eight systems to accompany the shoreline surveys – as terrain views; plus elevation data; plus vegetation indices; historical differences; and change detection – all in GIS spatial files;
3. General geo-tagged imagery of participant activities in management workshops, field surveys, as well as methods and definitions used.

4.0 Projects Arising from this Southern GBR Project

4.1 Monitoring tidal wetlands in the Port Alma Port Curtis area

Project Title. Monitoring the survival and recovery of shorelines, specifically Tidal Wetlands (Mangroves/Saltmarsh/Saltpan)

Project Overview. The Port Curtis and Port Alma (PCPA) coastal habitat archive and monitoring program (CHAMP) is a six year program with the Environmental Research and Monitoring Program (ERMP) of the Gladstone Ports Corporation (GPC) that commenced in late 2014. The project is directed by Dr Norm Duke with Jock Mackenzie from James Cook University (JCU) along with key project partners: Prof. John Kovacs of Nipissing University in Canada, Traditional Owner Land and Sea Rangers of the Gidarjil Development Corporation, and Prof Ian Atkinson with the eResearch Centre at JCU. This project has run concurrently with the NESP TWQ Hub Southern GBR project. And, like this program, it supports the partnership between marine science specialists and traditional owner rangers to deliver the systematic monitoring of condition, survival and recovery of shorelines, specifically for mangrove and saltmarsh tidal wetlands of the region (Fig. 21).

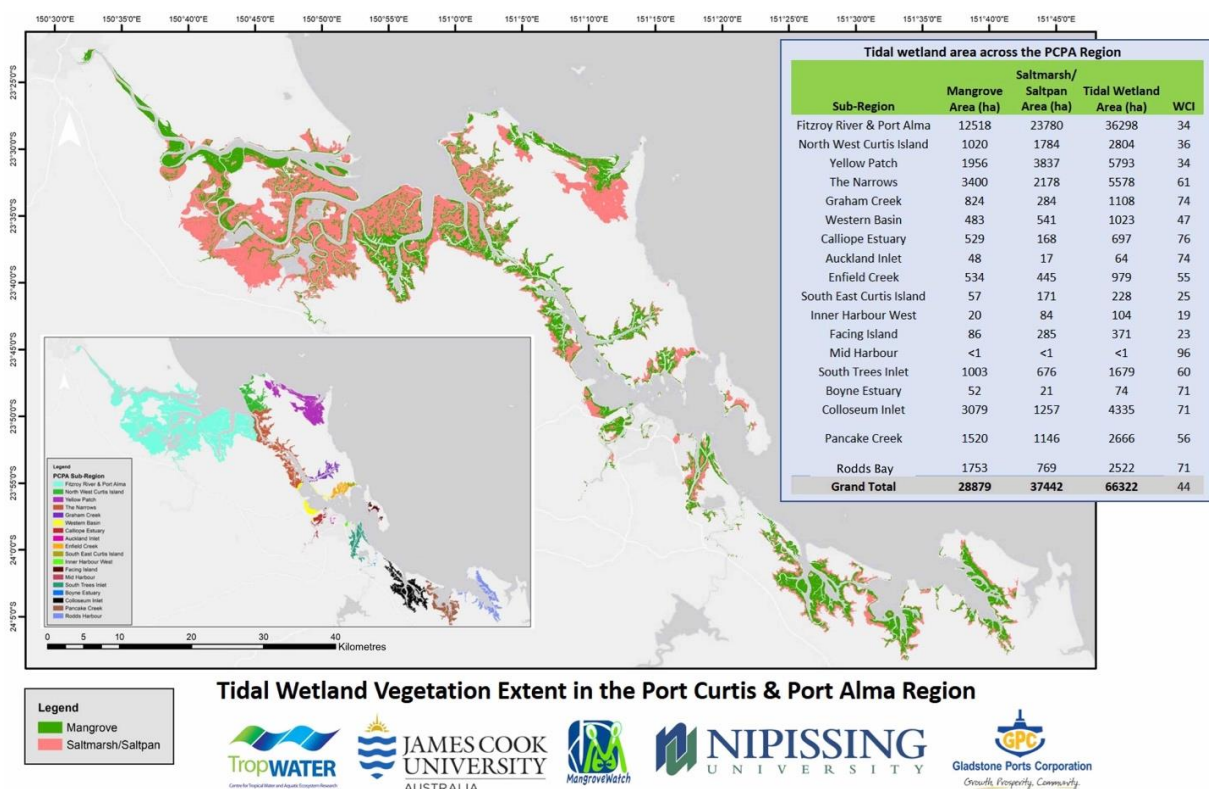


Figure 21: The 2016 mapped areas of mangrove and tidal saltmarsh-saltpan extent in the Port Curtis and Port Alma study area.

As previously noted, the program commitment is to undertake and complete five components of monitoring works and evaluations within the PCPA study area, including:

1. High resolution maps of tidal wetlands, plus historical assessment (change detection);
2. Normalised Difference Vegetation Index (NDVI) mapping of tidal wetlands;
3. Shoreline condition monitoring using oblique aerial image data acquisition;

4. Shoreline condition monitoring using boat-based video image data acquisition and traditional owner rangers; and
5. Public access and data entry portal for display of current and past mapping.

The integration of these components is fundamental to the success of the program. All efforts continue to be made to ensure each component is connected with each other component. And, the methodologies applied to the mapping, the aerial surveys, the field works, and the public outreach are all linked to the central archive database now in advanced development.

As noted previously, the program is chiefly lead by science specialists in tidal wetlands, who are characterising shoreline environmental values for the PCPA study area as compared to neighbouring reference areas. This is being achieved through the mapping and evaluation of natural tidal wetland resources using the Shoreline Video Assessment Method (S-VAM) linked to the integrated monitoring and archiving program, and bringing together partners in field research, remote sensing, information technology, teaching skills and traditional knowledge.

While TropWATER at JCU is the lead agent for the purposes of contracting with GPC, we are collaborating with partner organisations through individual sub-contracting/partnership arrangements, as appropriate:

- a. Gidarjil Development Corporation (GDC) Indigenous Sea Rangers along with community volunteers in the Gladstone region, are assisting in the monitoring and assessment of coastal tidal wetland habitats (Component 4 chiefly, plus 3);
- b. Collaboration with Prof. John Kovacs lab team at Nipissing University, Canada, for dedicated remote sensing assessments and mapping of tidal wetland habitats in the region (Components 1 and 2 primarily, plus using 4 for opportunities in ground truth and data validation);
- c. Partnership with Queensland Cyber Infrastructure Foundation (QCIF) and the JCU e-Research Centre for the development and implementation of the planned online facility (Component 5 primarily, plus all other components eventually).

This project is considered an important opportunity to achieve world best practice for compilation and dissemination of data and expert advice gathered from tidal wetland field surveys and meetings with key stakeholders from industry, government, universities and with Indigenous rangers and community volunteers.

The program is planned to raise awareness amongst communities about the values, condition and threats to coastal tidal wetlands. In addition, by encouraging best practice management of these fragile ecosystems, human communities can contribute to the preservation of high value coastal nursery habitat and coastal shoreline buffering from erosion and deposition, as well as the protection of neighbouring coastal habitats, like seagrass meadows and coral reefs.

4.2 Report Card indicators for mangroves of Gladstone Harbour

Project Title. Development of mangrove indicators for the Gladstone Harbour Report Card

Project Overview. MangroveWatch researchers with TropWATER Centre at James Cook University have developed a primary suite of three key condition indicators for the regular

monitoring of the overall health of tidal wetlands including mangroves, salt pans and tidal saltmarsh habitats within the Port Curtis study area in partnership with the Gladstone Healthy Harbour Partnership (GHHP). This monitoring scheme will be used in the GHHP 2017–2018 report card.

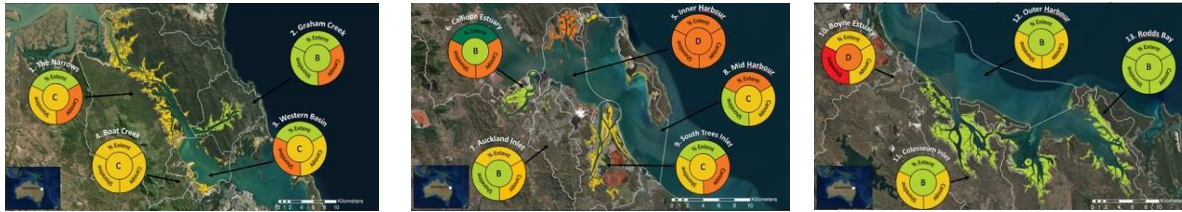


Figure 22: 2017–2018 Report Card – Mangrove Tidal Wetland Habitat.

The three indicators were measured for each of the 13 GHHP environmental reporting zones (Fig. 22). These include 'Extent', 'Canopy' and 'Shoreline'. They represent independent parameters of condition quantifying recent change to relative measures of mangrove extent, canopy density and presence of shoreline dead trees. The overall zone scores show that the 2017–2018 condition of mangrove habitat was satisfactory to good, with Boyne Estuary having the poorest condition.

The current project findings represented a significant new reference point and baseline for the likely longer term application and monitoring of tidal wetland ecosystems throughout the Port Curtis study area. As such, this reporting framework, and specifically the indicators identified, provide a valuable baseline benchmark of structure and condition for comparative assessments both into the future, as well as back in time.

Decisions regarding the choice of indicators were based on expert opinion underpinned by robust scientific data, research publications, field observations and practical experience of these highly-specialised natural ecosystems. The authors have also relied on their specialised and in-depth knowledge of the study area including a number of recent projects funded by the Gladstone Ports Corporation Environmental Research and Management Program and the NESP Tropical Water Quality Hub.

Before the indicators could be developed, it was necessary to re-evaluate and map the 13 environmental reporting zones used by the GHHP. This enabled the same zones to have relevance to both tidal wetlands as well as their prior focus on marine habitats. Upland boundaries were created for individual land catchments and drainage areas relating to each of the 13 zones. This resulted in an increase in assessment areas, described as sub-zones. For example, the division of The Narrows (Zone 1) into mainland side and Curtis Island shoreline sub-zones (sub-zones 1a & 1b). The total number of tidal wetland sub-zones needed to represent the 13 GHHP reporting zones was limited to 22. These new sub-zones provide the basis for comparative assessments of tidal wetlands and associated marine habitats throughout the Port Curtis study area.

The three condition indicators were selected in consultation with the GHHP Independent Science Panel (ISP). These include: 'Extent'; 'Canopy'; and 'Shoreline'. Each indicator was developed from independent datasets collected from relevant remotely sensed sources and backed up by field surveys.

‘Extent’ - the Wetland Cover Index (WCI) indicator was based on the WCI metric for the proportion of the area of mangrove to the total area of tidal wetlands for each sub-zone at the time of image acquisition. Area measures were taken from high resolution satellite imagery for each of the key vegetation units of mangroves and for tidal saltmarsh and saltpans. For this first report, the period of evaluation was based on imagery acquired in 2016. The WCI indicator shows changes in vegetation cover that might be related to direct loss and damage from human activities and/or from natural losses and gains with periodic storms, flooding, longer term changes in rainfall and sea level rise. Between 2016 and 2018, mangrove extent contracted more in northern areas

‘Canopy’ - the mangrove canopy condition indicator was based on satellite measures of the Normalised Difference Vegetation Index (NDVI) taken from the same imagery used for the WCI indicator. In this case, canopy reflectance measured using the mapping algorithm of the NDVI was used as a proxy measure of foliage health and canopy density. These assumptions can be verified across a broad selection of field sites where measures were made of the number of leaves counted in living leafy shoots of shoreline fringing canopies of *Rhizophora stylosa* mangroves.

‘Shoreline’ - the shoreline condition indicator was based on the assessment of oblique aerial imagery at 50m interval points along all of the mangrove-dominated shorelines of each sub-zone and zone. The Shoreline indicator in this case was scored for the presence/absence of dead trees within each interval. The results were then compared and validated against field summary scores made for each sub-zone during the aerial survey.

Overall, the scores were consistent with a number of changes taking place within mangroves and tidal wetlands observed across the region. Scores reflected notable and recent detrimental impacts resulting from changing climatic conditions, decreasing rainfall, severe flood events (notably more for riverine estuaries) and rising sea levels (notable as terrestrial retreat in particular) coupled with pressures from on-going port activities (like pollution, direct damage and boat traffic).

4.3 International exchange program for Indigenous rangers in Brazil and Australia

Project title. Enhancing traditional owner capacity to protect mangroves against climate change through cross-cultural exchange.

Project Overview. An Australian National Commission for UNESCO 16-17 Grant enabled a collaborative exchange between traditional owners in Brazil and Australia based on the NESP 2.3.4 project. This took place between July 2017 and December 2017.



The protected area in Australia was the Port Curtis and Coral Coast Traditional Use Management Area (PCCC TUMRA) which includes part of the Great Barrier Reef World Heritage Area (GBRWhA) and Great Sandy Biosphere Reserve (GSBR). In Brazil, the protected area was the Cananeia-Iguape Coastal System, part of the World Heritage Site Atlantic Forest South-East Reserves (<http://whc.unesco.org/en/list/893>), São Paulo state, Brazil. The organisations involved had previously undertaken

mangrove monitoring in UNESCO World Heritage Areas and Biosphere Reserves in Australia and Brazil. Their partnership has allowed cross-cultural knowledge exchange between these two culturally distinct Indigenous groups actively engaged in traditional owner mangrove management and facing similar climate change and human impact management challenges.

Mangroves are a valuable natural resource in many UNESCO managed regions. Due to the combined impacts of human stressors, climate change and natural process, these habitats are disappearing faster than any other forest type. Enhancing and empowering Indigenous traditional owner management of mangrove resources in areas like the Great Barrier Reef World Heritage Area (GBRWhA), Great Sandy Biosphere Reserve (GSBR) and the Atlantic Forest South-East Reserves will generate better outcomes for mangrove conservation. This project established a research collaboration partnership between James Cook University and Universidade Estadual Paulista and their existing Indigenous representative partner organisations; Gidarjil Development Corporation (<http://www.gidarjil.com.au>) (Australia) and AMOAMCA – Associação de Monitores Ambientais de Cananéia. The research undertaken and the partnership notably strengthened the capacity of local traditional owners to effectively engage in mangrove ecosystem monitoring and research to inform better mangrove management in UNESCO managed areas.

This project also assisted UNESCO in its strategic objectives for natural sciences outlined in the Medium-Term Strategy for 2014-2021 (37 C/4).

The project had five specific outcomes:

1. It strengthened the capacity of two traditional owner groups to undertake effective mangrove management by enhancing the role of Indigenous rangers as empowered citizen-scientists.
2. It promoted cross-cultural collaboration and knowledge sharing between two culturally distinct Indigenous groups in similar latitudinal and climatic zones to improve mangrove resilience to climate change through traditional owner management in three UNESCO managed areas (Fig. 23).
3. It created an international partnership between scientists and traditional owners to enhance mangrove knowledge exchange and improve communication of traditional owner values, observations and knowledge to inform mangrove management.
4. It promoted international scientific cooperation on developing innovative mangrove monitoring and assessment methods that promoted Indigenous and citizen-scientist engagement and addressed the critical challenge of managing mangroves under threat from climate change.
5. It established a MangroveWatch partnership between Brazil and Australia that improved knowledge about climate change impacts on mangrove ecosystems,

management challenges and effective management solutions in geographically and culturally distinct, but climatically, latitudinal and geomorphologically comparative UNESCO managed areas.

Overall, the exchange project supported mutual visits, workshops and training sessions for the improvement of Indigenous monitoring and management of mangrove estuarine areas by local traditional owners in Brazil and Australia's southern GBR area.



Figure 23: Workshop participants in Brazil exchanging ideas and plans for improving Indigenous monitoring of threatened tidal wetlands and mangroves.

4.4 Managing Wallace Creek mangroves

Project Title. Wallace Creek Reserve Project

Project Overview. Gidarjil Caring for Country (CFC) program are working in partnership with Gladstone Ports Corporation (Bundaberg Port), MangroveWatch and Burnett Mary Regional Group to manage and rehabilitate Wallace Creek at Burnett Heads to offset current threats and impacts to ecosystems like acid sulfate soils, dumped waste including asbestos, suspected illegal fishing, and recreational vehicle access impacting on saltmarsh flats (Fig. 24).



Figure 24: Wallace Creek reserve within the development area of the expanding Port of Bundaberg needs an environmental custodian, and Gidarjil Rangers are up for the challenge.

The Gidarjil CFC program is supported by Working on Country Program funding provided by the Australian Government (Department of Prime Minister & Cabinet). This supports the group to operate primarily around the Bundaberg-Lowmead region. It employs a permanent full-time staff of four rangers, one admin assistant, and a project manager, one part-time staff engaged in sea country management projects and casual staff in accordance with the demands of fee-for-service work programs. The Indigenous rangers also work with the Green Army program on various NRM projects including: Gidarjil's Skilling Queenslanders for Work (SQW); Natural Resource Management program; and Gidarjil School Based Sea Rangers also participate in these projects in the Bundaberg Region.

In August 2016, Gidarjil Rangers partnered with Tangaroa Blue for a marine debris clean-up project at Wallace Creek. Gidarjil CFC and Tangaroa Blue also aided training of the Green Army, Gidarjil SQW NRM and Gidarjil School Based Sea Rangers in Marine Debris clean-up work to build their local community's capacity to undertake environmental projects. From this work and other similar projects, Gidarjil Rangers are well placed to manage sensitive environmental and culturally significant areas with their extensive experience and close associations with Traditional Owner groups in preparing and implementing land management projects.

The goals of the Wallace Creek Reserve Project are:

- 1) To manage, monitor and rehabilitate the Wallace Creek Reserve in Burnett Heads/ Bundaberg Port;

- 2) Minimise threats to Wallace Creek habitats and to ensure sustainability and survival of native flora and fauna species and traditional knowledge through managing pollution, inappropriate access & suspected illegal fishing;
- 3) Provide education and training to raise awareness of the local community to sustainably manage and take an active interest in Wallace Creek mangrove and saltmarsh ecosystems; and
- 4) Continue to work with JCU's Dr Norm Duke and Jock Mackenzie with the MangroveWatch program to monitor and manage these valuable mangrove ecosystems.

The project will contribute to the implementation of Local NRM strategies and plans in a coherent and effective way, through working closely with Gladstone Ports Corporation, Bundaberg Regional Council and Burnett Mary Regional Group programs. One outcome is the building of capacity of the local Indigenous community to make a valuable contribution to managing their land and sea country. Careful management of these areas is necessary to ensure their ongoing protection and contribution to the region's natural resources.

The Wallace Creek Reserve Project would include but not limited to, pollution and marine debris management (Table 8). Marine debris comes from both land and sea-based sources and can travel immense distances. It can pose a navigation hazard, has the potential to transport chemical contaminants and transport invasive species. It can also, entangle wildlife or be ingested. Marine Debris not only causes death or injury to wildlife it negatively affects tourism and poses a threat to human health. This issue is particularly relevant with nearby Sea Turtle Rookery's at Mon Repos. Management of access into Wallace Creek is needed to protect high intertidal flats and saltmarsh. Illegal access to Wallace Creek has become a major threat to the area and there is also suspected illegal fishing in the creek.

Wallace Creek project can be used as an educational tool for the local community, PCCC Traditional owner groups, Burnett Mary Regional Group, Government, Industry, school groups, and the Gidarjil CFC Junior Ranger Program.

Gladstone Ports Corporation (GPC), the land owner, has supported a proposal to their Community fund, and Local Marine Advisory Committee (LMAC) for funding needed for the construction of a community boardwalk through the Wallace Creek reserve area. And, in further collaboration with GPC, funding has been sought from other sources also, including: the Carbon Farming Initiative (CFI). This initiative provides funding for landscape restoration projects to farmers and landholders. CFI allows farmers and land managers to earn carbon credits by storing carbon or reducing greenhouse gas emissions on the land. These credits can then be sold to businesses wishing to offset their emissions.

Table 8: Priorities listed and quantified regards the Wallace Creek Reserve Project.

Proposed Wallace Creek project priorities			
Priority	Projects	Outcome	Measures
Very High Priority	Access to Wallace Creek Reserve Recreational vehicles accessing Wallace Creek has become a major impact and threat to the saltmarsh and suspected illegal fishing in the creek.	• Access to be restricted with fencing including gates for controlled vehicle access. • Signage in place to raise awareness of impacts and threats to Wallace Creek, and relevance of access controls • Saltmarsh Rehabilitation and Protection will be the major outcome.	• Pre and post site evaluation of natural rehabilitation • Records of attempted incursions through the fences.
Very High Priority	Install flow channels through levee.	• Counter development of acid sulphate soils and associated decline of mangroves. • Re-establish connectivity between the mangrove communities either side of the levee.	• Monitoring of tree health of selected effected mangrove plants. • Water quality monitoring
High Priority	Pollution/Marine Debris management,	• CFC Team will minimise the affects of marine debris in Wallace Creek and have teams doing regular cleanups activities including education and signage.	• Marine Debris Data Collection -Location, Size, what was collected. • Pre and Post site evaluation of marine debris in Wallace creek area
Medium Priority	Revegetation	• To create a buffer zone around the perimeter to help the natural rehabilitation Wallace Creek	• Survival/success rate of the planted buffer zone • Success rate of Wallace creek natural rehabilitation after planting buffer zone using transect studies
Medium Priority	Mangrove Watch	• Working in partnership with the Mangrove Watch Program to address environmental management needs.	• Data Collection – through video, transect studies and photo monitoring to contribute to decision making of environmental management needs.
Medium Priority	Weed Control	• Ongoing management of weeds in the Wallace Creek Reserve in collaboration with NRM programs such as Green Army, SQW	• Ongoing site evaluation of success of weed control management and natural regeneration of native species.

Rehabilitation works are needed for the sustainability and survival of native flora and fauna species. Traditional knowledge can assist better management of mangroves and saltmarsh areas in the region. The Wallace Creek Project will encourage responsible use of the reserve by limiting access points and boat ramps, enhancing buffer zones through revegetation work, encouraging natural rehabilitation of mangrove and saltmarsh ecosystems, encouraging marine debris clean-ups, and the ongoing monitoring and management of threatened tidal wetland ecosystems.

4.5 Kolan River bank rehabilitation – a proposal in partnership with land owner Bundaberg Sugar



Figure 25: Kolan estuarine bank identified as in need of rehabilitation from the NESP Southern GBR project. The yellow arrow marks the location.

Proposal Title. Rehabilitation of estuarine living shorelines (mangroves, saltmarsh and shellfish) along the southern GBR coast: Kolan River

Project Overview. A development permit has been sought for a proposal to restore and rehabilitate living natural shoreline habitats along sections of the Kolan River estuary (Fig. 25). On-ground works will be used to stabilize and revegetate a section of badly flood-eroded and retreating shoreline that threatens not only tidal land and riparian communities but also adjacent agricultural lands. On-ground works will involve placement of rock, soil and buried coir logs to modify and restore shoreline slope and create an environment that encourages long-term establishment of riparian plus intertidal saltmarsh and mangrove. These living structured-shorelines will supplement constructed river bank verges with planted riparian vegetation to help prevent further shoreline retreat and improve fish habitat value. This technique has previously been used in southern Queensland, as well as overseas in the southern USA, to protect tidal wetlands with the creation of additional fish habitat there. The current project proposed for central Queensland will be the first to combine the re-establishment of three key biologically structured living shoreline habitats, including riparian, saltmarsh-mangrove and limited exposed rock for oysters and mussels. These ‘living shorelines’ were present historically in the region, and they are expected to enhance and protect fish habitat values within this Queensland estuary. As the rehabilitation project involves

construction of infrastructure within tidal areas, with few, if any, disturbances to existing marine plants (present along the eroded shoreline face), and local collection of mangrove and saltmarsh plant material for planting, plus local shellfish, appropriate permits will be sought through Queensland DAF under the Fisheries Act 1994.

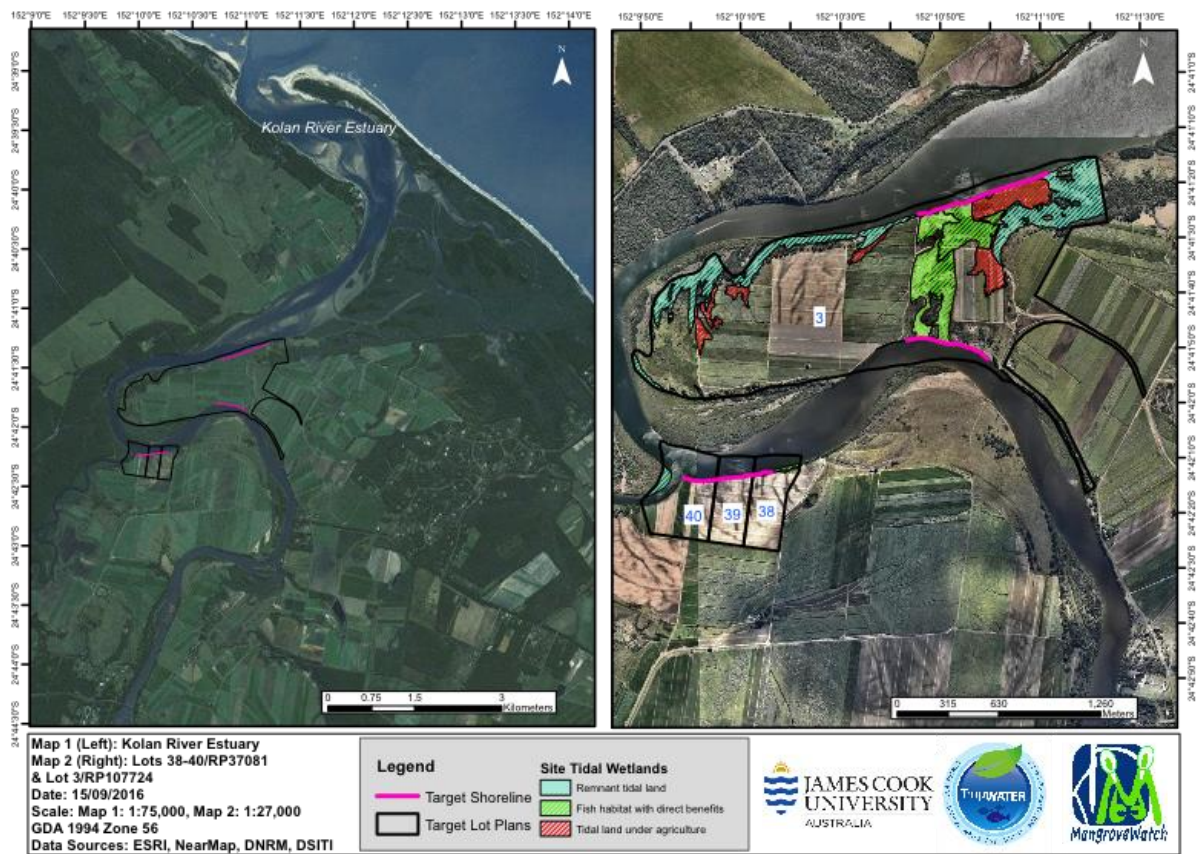


Figure 26: Proposed Kolan River Fish Habitat bank rehabilitation project, specifically for allotments 38-40 with Bundaberg Sugar.

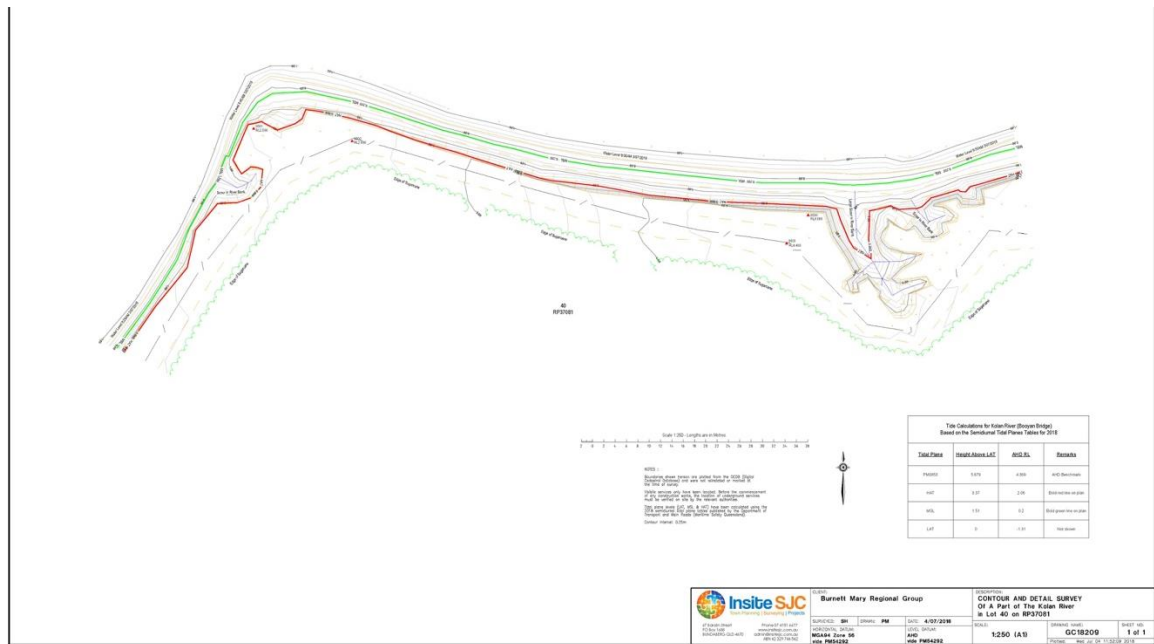


Figure 27: Plan view of planned rehabilitation works in the Kolan estuary.

Justification. These proposed works will be undertaken along a single shoreline section totalling around 500 m of the lower Kolan River estuary on land controlled by Bundaberg Sugar Corporation Ltd (Figs. 26 and 27). The site is located adjacent to farmed cane land, near Yandaran Creek (Lots 38-40/ RP37081). Recent flood events resulted in severe shoreline erosion which threatens productive farmland. The proposed living shoreline works will stabilize shoreline considered to be at high risk of erosion, protecting both agricultural assets and facilitate natural habitat regeneration on recreated tidal land. These works will also create new fish habitat and increase connectivity between existing tidal wetland habitat patches. To minimise the risk of failure, close attention to detail and multiple strategies will be employed to assess effectiveness, this includes both the level of shoreline infrastructure deployment, mangrove planting, and shellfish habitat structure installation. A detailed plan map of the site is shown in Figure 26 to compare with the Shoreline Video Assessment surveys conducted by Gidarjil Rangers during the NESP project for the whole system in 2015-2017.

Specific points of justification include:

- 1) The Kolan River is a degraded estuary due to poor water quality, modified flow and limited agricultural buffer zones. But, the estuary has high conservation value as demonstrated by the presence of the 'Mouth of the Kolan Conservation Park' and the Kolan River FHA. The Kolan River estuary supports fisheries values including an important commercial prawn fishery; recreational finfish area; Indigenous fishing; bream; estuary cod; flathead; garfish; grey mackerel; mangrove jack; sea mullet; school mackerel; whiting; banana prawns (NPRSR, 2012).
- 2) Recent flooding has severely damaged fish habitat in the upper Kolan estuary.
- 3) The project site is located in the mid-estuary and offers an opportunity to improve fish habitat connectivity there.
- 4) The creation of oyster reef environments elsewhere have improved adjacent water quality and facilitate seagrass colonization. There is also historical evidence of seagrass in the Kolan River estuary. The aim is to use natural living habitats to help improve overall water quality in the Kolan River estuary.
- 5) The selected shoreline is adjacent to agricultural assets, as such fish habitat rehabilitation works will serve to provide multiple benefits, including shoreline protection, water quality improvement and create a wildlife corridor, reducing habitat fragmentation. The additional economic benefits of shoreline stabilization provide further incentives for the maintenance of living shoreline assets by the landholder into the future.
- 6) The creation of new fish habitat and protection of naturally reclaimed fish habitat will serve to help offset historical losses.
- 7) Our project partner, and landholder, Bundaberg Sugar, currently manages large sections of estuary shoreline in the region. Many of these areas are experiencing erosion. The successful implementation method for the establishment of living shorelines to promote fish habitat and agricultural asset protection in the Kolan River, will encourage future private investment in fish habitat creation elsewhere. These works will supercede current hard infrastructure methods, with minimal habitat benefits being used by landholders in the region to prevent shoreline erosion.
- 8) These works present an opportunity to enhance Indigenous stewardship of the Kolan River estuary and will provide opportunities to improve skills of Gidarjil Indigenous Corporation employees and school-based trainees.

While there is a risk that future flood events may result in further losses of living shoreline assets, this is not expected to add further risk to adjacent landholders or estuarine habitat. It is likely that even in the worst-case scenario of a large-scale flood event resulting in loss of assets, the presence of living shoreline infrastructure will minimise shoreline erosion and protect adjacent tidal lands and agricultural assets.

Shoreline Rehabilitation

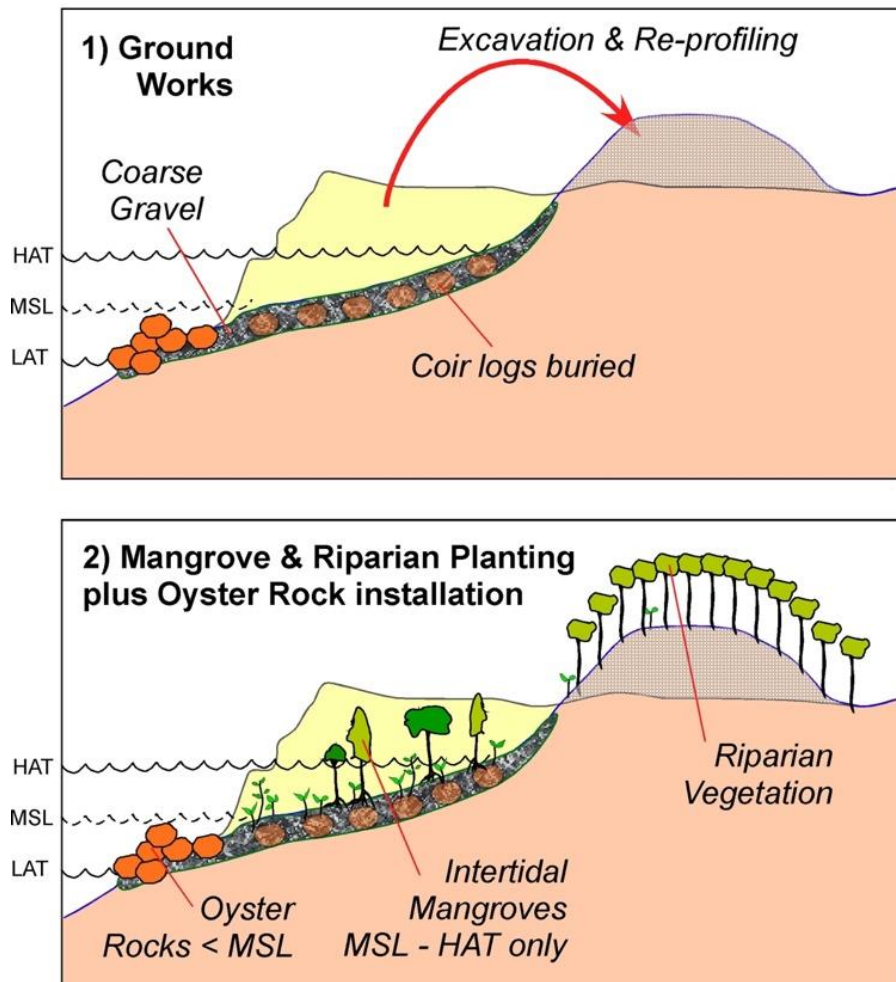


Figure 28: Profile views of planned rehabilitation works in the Kolan estuary. Tidal levels are marked for the location.

Operational works. Project tasks will be undertaken in three phases: pre-works; construction works; and post construction monitoring works.

The **pre-works phase** will collect baseline data on site physical and abiotic characteristics to inform on-ground works. Detailed site surveying of the site and adjacent mangrove and other habitat locations will be undertaken to inform planned ground works appropriate for establishment of living shoreline vegetation and substrate placement (Fig. 28). Historical water quality parameters (salinity, nutrients, pH) will be used to inform mangrove species suitability. Sediment nutrient and physical properties (grain size) of adjacent mangrove areas will be assessed to inform living shoreline construction. A near-site nursery, using only natural materials, will be established to assemble and raise mangrove seedlings. The nursery will be tended by Gidarjil Rangers and junior school-based trainees. Mangrove propagules of the key suitable local common mangrove species will be collected during the different fruiting periods.

The installation of **on-ground works** will be based on pre-work assessments. These works will be undertaken in view of comparable shoreline stabilization works in the USA and southern Queensland. Reference will also be made to partner organizations like OceanWatch and TNC, who have incorporated mangroves as key components of living shorelines. These plans also follow design protocols developed by Dr Norm Duke and MangroveWatch, where works were undertaken successfully in South-East Queensland. For the proposed profile refer to Figure 27. The overall design will establish tiered levels of rock (using anchor rock and large gravel), river soil and imbedded buried coir logs positioned against the eroded face of the shoreline. Tiers will be levelled to promote suitable mangrove species establishment, dependent on baseline assessment. Direct planting of mangrove propagules and seedlings will be used to promote natural recruitment and provide initial stability. To ensure immediate vegetation cover, cuttings of *Sesuvium portulacastrum* and transplants of *Sporobolus virginicus* will be used to reduce sediment loss and scour. Oyster and mussel spat will be encouraged to aggregate at the toe of the bank for future protection against wave action and shoreline instability. Recent assessment of flood impacts along the Burnett River have shown that existing historical low relief rock wall structures within 10m of mangrove habitat provided substantial flood protection in the lower estuary. These structures will be replicated here to reduce risk of scour and provide additional suitable substrate for oyster colonization.

Post construction monitoring works will be undertaken to evaluate the success or otherwise of the project. Specific factors will be checked regularly after construction, including site hydrodynamics, water quality and mangrove establishment success, and possible fish habitat improvement. Installed probes and monitoring stations will be used to monitor site hydrodynamics and water quality. Mangrove establishment success monitoring will follow protocols developed by Duke (1992). Downstream and upstream locations will be included in monitoring to ensure there are no perverse ecological outcomes of these construction works.

Site post-works evaluations and assessment will be undertaken by Gidarjil Rangers, advised by JCU scientists with advice from Oceanwatch Australia, The Nature Conservancy (TNC) and other project advisors. Engaging local Traditional Owners in this site rehabilitation will ensure local stewardship of the site, which includes ongoing monitoring and evaluation in combination with a continuing existing partnership between key stakeholders - Gidarjil, MangroveWatch, JCU and Bundaberg Sugar.

4.6 Burnett River bank rehabilitation – a proposal in partnership with land owner Gladstone Ports Corporation



Figure 29: Burnett estuarine bank identified as in need of rehabilitation from the NESP Southern GBR project. The yellow arrow marks the location.

Proposal Title. Rehabilitation of estuarine living shorelines (mangroves, saltmarsh and shellfish) along the southern GBR coast: Burnett River

Project Overview. A development permit has been sought for a proposal to restore and rehabilitate living natural shoreline habitats along sections of the Burnett River estuary (Fig. 29). On-ground works will be used to stabilize a section of badly flood-eroded and retreating shoreline that threatens adjacent endangered sub-tropical saltmarsh, mangroves and riparian communities. On-ground works will involve placement of rock, soil and buried coir logs to modify and restore shoreline slope and create an environment that encourages long-term establishment of riparian plus intertidal saltmarsh and mangrove. These living structured-shorelines will supplement constructed river bank verges with planted riparian vegetation to help prevent further shoreline retreat and improve fish habitat value. This technique has previously been used in southern Queensland, as well as overseas in the southern USA, to protect tidal wetlands with the creation of additional fish habitat there. The current project proposed for central Queensland will be the first to combine the re-establishment of three key biologically structured living shoreline habitats, including riparian, mangrove-saltmarsh and limited exposed rock for oysters and mussels. These 'living shorelines' were present historically in the region, and they are expected to enhance and protect fish habitat values within this Queensland estuary. As the rehabilitation project involves construction of infrastructure within tidal areas, with few, if any, disturbances to existing marine plants (present along the eroded shoreline face), and local collection of mangrove and saltmarsh plant material

for planting, plus local shellfish, appropriate permits will be sought through Queensland DAF under the Fisheries Act 1994.



Figure 30: Proposed Burnett River Fish Habitat bank rehabilitation project in partnership with Bundaberg Port and Gladstone Ports Corporation.

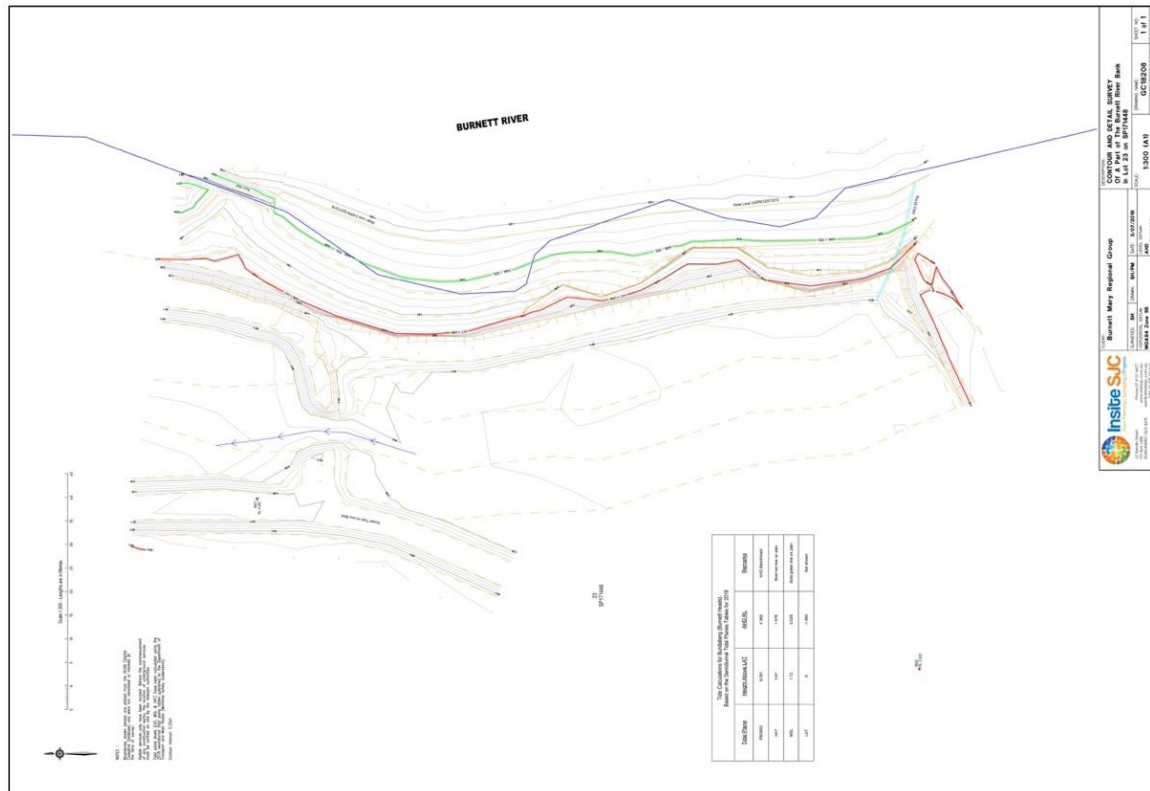


Figure 31: Plan view of planned rehabilitation works in the Burnett estuary.

Justification. The proposed works will be undertaken along a 618 m section of the Burnett River shoreline on land controlled by the Gladstone Ports Corporation Ltd (Figs. 30 and 31). We estimate the mitigation action will create and protect 7.4 ha of tidal wetland fish habitat and have indirect benefit to the remnant 49 ha of fish habitat on the site. The site is located in the Burnett River where there is an older river training wall. Construction works will extend shoreward from the rock structure with the express purpose of integrating bank stability across the entire intertidal profile. And, once living shorelines are re-established, these rehabilitation works are expected to enhance fish habitat values, increasing protection of shorelines while decreasing on-going maintenance of adjacent tidal wetland habitat, including the endangered sub-tropical saltmarsh communities. These rehabilitation works will mitigate previous historical fish habitat losses due to erosion (2.7 ha) and reclamation (8.8 ha) on the site. Without intervention the shoreline will continue to degrade and retreat. The current rate of shoreline retreat for the target shoreline is 1m/ yr, up to 1.5m/ yr loss in some parts. Since 1956 there has been an average total 60 m shoreline retreat, with some parts repeating nearly 100m in that time. This represents a 4% loss of habitat due to erosion. Current tidal wetland mapping layers from the Queensland Wetlands Mapping Program do not adequately represent the presence of tidal wetland vegetation and fish habitat at this site. To minimise the risk of failure, close attention to detail and multiple strategies will be employed to assess effectiveness, this includes both the level of shoreline infrastructure deployment, mangrove planting, and shellfish habitat structure installation. A detailed plan map of the site is shown in Figure 30 to compare with the Shoreline Video Assessment surveys conducted by Gidarjil Rangers during the NESP TWQ Hub project for the whole system in 2015-2017.

Specific points of justification include:

- 1) This tidal wetland area in the Burnett River estuary represents the largest continuous extent of high-intertidal sub-tropical saltmarsh having direct fish habitat connectivity to the river
- 2) The location is the last section of unmodified 'natural' shoreline sections in the lower Burnett River and has significant value for fish habitat connectivity along the estuary.
- 3) The lower Burnett estuary is still utilized by commercial beam-trawl operators, as well as being a popular area for recreational line fishing. Enhancement of fish habitat in this area will have direct benefit to commercial and recreational fisheries in the Burnett River estuary
- 4) The location within the lower estuary is suitable for a number of local mangrove and shellfish species. There is possibility enhance mangrove and shellfish biodiversity within the lower Burnett River.
- 5) The site location has high visibility from the estuary, with limited public access.
- 6) There is some risk that future flood events may result in loss of living shoreline assets once established. It is likely that construction of living shoreline infrastructure will minimize these risks and any future erosion at the site will be no greater than what would have occurred without intervention.

Shoreline Rehabilitation - Burnett River sites

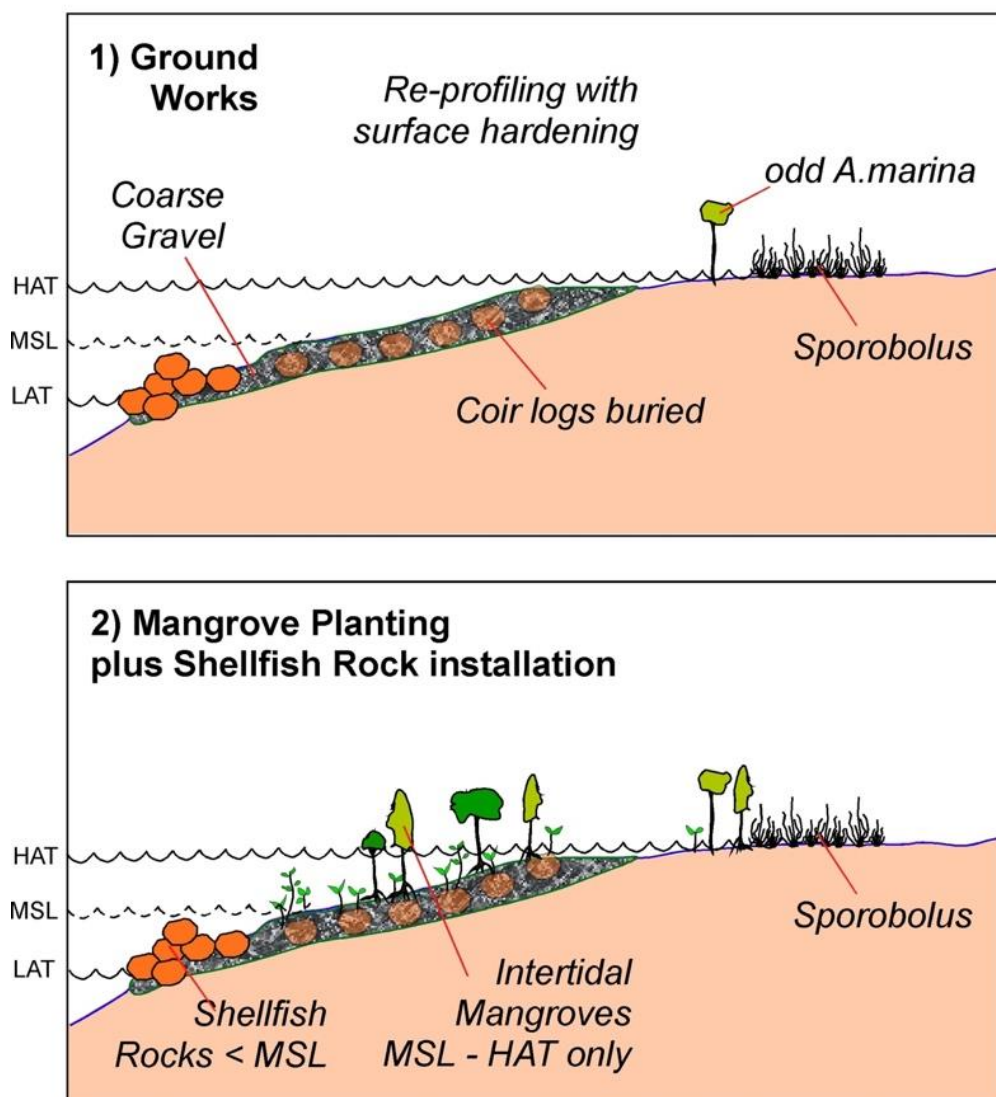


Figure 32: Profile views of planned rehabilitation works in the Burnett estuary. Tidal levels are marked for the location.

Operational works. Project tasks will be undertaken in three phases: pre-works; construction works; and post construction monitoring works.

The **pre-works** phase will collect baseline data on site physical and abiotic characteristics to inform on-ground works. Detailed site surveying of the site and adjacent mangrove and other habitat locations will be undertaken to inform planned ground works appropriate for establishment of living shoreline vegetation and substrate placement (Fig. 32). Historical water quality parameters (salinity, nutrients, pH) will be used to inform mangrove species suitability. Sediment nutrient and physical properties (grain size) of adjacent mangrove areas will be assessed to inform living shoreline construction. A near-site nursery, using only natural materials, will be established to assemble and raise mangrove seedlings. The nursery will be tended by Gidarjil Rangers and junior school-based trainees. Mangrove propagules of the key suitable local common mangrove species will be collected during the different fruiting periods.

The installation of **on-ground works** will be based on pre-work assessments. These works will be undertaken in view of comparable shoreline stabilization works in the USA and southern Queensland. Reference will also be made to partner organizations like OceanWatch and TNC, who have incorporated mangroves as key components of living shorelines. These plans also follow design protocols developed by Dr Norm Duke and MangroveWatch, where works were undertaken successfully in South-East Queensland. For the proposed profile design refer to Figure 1.31. The overall design will establish tiered levels of rock (using anchor rock and large gravel), river soil and imbedded buried coir logs positioned against the eroded face of the shoreline. Tiers will be levelled to promote suitable mangrove species establishment, dependent on baseline assessment. Direct planting of mangrove propagules and seedlings will be used to promote natural recruitment and provide initial stability. To ensure immediate vegetation cover, cuttings of *Sesuvium portulacastrum* and transplants of *Sporobolus virginicus* will be used to reduce sediment loss and scour. Oyster spat will be encouraged to aggregate at the toe of the bank for future protection against wave action and shoreline instability. Recent assessment of flood impacts along the Burnett River have shown that existing historical low relief rock wall structures within 10m of mangrove habitat provided substantial flood protection in the lower estuary. These structures will be replicated here to reduce risk of scour and provide additional suitable substrate for oyster colonization.

Post construction monitoring works will be undertaken to evaluate the success or otherwise of the project. Specific factors will be checked regularly after construction, including site hydrodynamics, water quality and mangrove establishment success, and possible fish habitat improvement. Installed probes and monitoring stations will be used to monitor site hydrodynamics and water quality. Mangrove establishment success monitoring will follow protocols developed by Duke (1992). Downstream and upstream locations will be included in monitoring to ensure there are no perverse ecological outcomes of these construction works. Site post-works evaluations and assessment will be undertaken by Gidarjil Rangers, advised by JCU scientists with advice from Oceanwatch Australia, TNC and other project advisors. Engaging local Traditional Owners in this site rehabilitation will ensure local stewardship of the site, which includes ongoing monitoring and evaluation in combination with a continuing existing partnership between key stakeholders - Gidarjil, MangroveWatch, JCU and Bundaberg Sugar.

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APPENDIX A: COMMUNITY FLYER INVITATION



Southern GBR CHAMP

(Coastal Habitat Archive & Monitoring Program)



YOUR INVITATION

to attend a workshop on developing a
Mangrove Management Plan for the Southern Great Barrier Reef

Do you have an interest in estuaries, waterways, mangroves, saltmarsh or fisheries in the Southern GBR region? We want your input!

Dr Norm Duke from TropWATER, JCU in partnership with Gidarjil Development Corporation, MangroveWatch, BMRG & FBA are working together to monitor and better manage tidal wetlands in the SGBR region.

Our project team **invite you to a workshop to discuss:**
Local tidal wetland values & threats,
Tidal wetland monitoring strategies,
Tidal Wetland restoration opportunities
A regional Mangrove Management Plan for the SGBR

This workshop is part of a **National Environmental Science Programme (NESP)** project to facilitate estuary repair that maximizes water quality outcomes for the SGBR.

Workshop Details

Date: Tuesday 19th April
Time: 8:30 am to 4:30 pm
Location: Gidarjil Marine Training Facility, 2 Marine Drive, Burnett Heads

Lunch & refreshments provided

Citizen-Science Tidal Wetland Monitoring Training

Keen to become a MangroveWatch citizen scientist? Join us following the workshop on the 20th & 21st April to attend hands-on training in tidal wetland monitoring methods.

For more information or to RSVP contact Sue Sargent: sue.sargent@bmrp.org.au







FITZROY BASIN ASSOCIATION


National Environmental Science Programme


Tropical Water Quality Hub


JAMES COOK UNIVERSITY AUSTRALIA


MangroveWatch

