Wet Tropics
Report Card 2022

Waterway Environments: **Methods**

REPORTING ON DATA **JULY 2020** TO **JUNE 2021**

MARCH 2022

Wet Tropics
Waterways

wettropicswaterways.org.au

This report was prepared by Richard Hunt, Wet Tropics Waterways Technical Officer, with significant support from the Regional Report Cards Technical Working Group, reviewed by the Reef Water Quality Protection Plan Independent Science Panel and endorsed by the Wet Tropics Waterways.

This report may be cited as: Wet Tropics Waterways 2022. Wet Tropics Report Card 2022 (reporting on data 2020-21). Waterway Environments: Methods. Wet Tropics Waterways and Terrain NRM, Cairns.

Report was compiled in March 2022.

EXECUTIVE SUMMARY

Wet Tropics Waterways was launched in July 2016 with the release of the 'Pilot Report Card' in December 2016 which reported on the 2014-15 year. Five annual report cards have been released since the pilot report card with the current 'Report Card 2022' reporting on the 2020-21 year (1 July to 30 June).

The purpose of this document is to provide detailed information on the methods used to produce assessments of condition and state for the freshwater, estuarine, inshore marine and offshore marine environments. Specifically, this document describes the following.

- The data collection methods
- The scoring methods
- The confidence rating method

The indicators for basins (freshwaters) are grouped within the water quality, habitat and hydrology and fish indices. The water quality index includes sediment (total suspended solids), nutrients (dissolved inorganic nitrogen and filterable reactive phosphorus) and pesticides (22 pesticide forms) as indicator categories. The habitat and hydrology index includes indicators relating to habitat modification (impoundment length and fish barriers), flow, riparian extent, wetland extent and invasive weeds. Of these indicators, fish barriers is still in development and is not reported in the Report Card 2022.

The indicators for estuaries are grouped within the water quality, habitat and hydrology and fish indices. The water quality index includes physical and chemical indicators (dissolved oxygen and turbidity), nutrient indicators (dissolved inorganic nitrogen and filterable reactive phosphorus) and pesticide indicators (as per basins). The habitat and hydrology index includes fish barriers, flow, riparian extent, mangrove and saltmarsh extent, shoreline mangrove habitat, and seagrass (above-ground biomass, meadow area and species composition) indicators. Seagrass condition is only reported for estuaries where it is known to be present.

The indicators for the inshore marine environment are grouped within the water quality, coral, seagrass and fish indices. The water quality index includes water clarity (total suspended solids and turbidity), nutrient (oxidised nitrogen, particulate nitrogen and particulate phosphorus) and pesticide (19 pesticide forms) indicators. The coral index includes coral cover, macroalgae cover, rate of coral cover increase, density of juvenile corals and community composition indicators. The seagrass index includes above-ground biomass, meadow area and species composition, and/or percentage cover and resilience indicators.

The indicators for the offshore marine environment are grouped within water quality (not available for 2020-21), coral, and fish indices. The coral index includes coral cover, rate of coral cover increase and density of juvenile corals indicators.

For the estuary, inshore marine and offshore marine environments the fish index is in development and is not currently reported in the Report Card.

The freshwater basin reporting was conducted for the nine freshwater reporting zones (Daintree, Mossman, Barron, Mulgrave, Russell, Johnstone, Tully, Murray and Herbert). Data for the water quality index was collected from Douglas Shire Council monitoring sites for the Mossman and Daintree Basin (base-flow) and by the Department of Environment and Science (DES) Great Barrier Reef

Catchment Loads Monitoring Program (GBR CLMP) sites for the Daintree, Barron, Mulgrave, Russell, Johnstone, Tully, Murray and Herbert basins. Data for the habitat and hydrology index (impoundment length, riparian extent, wetland extent and invasive weeds) was collected for all basins. Data for the habitat and hydrology flow indicator was collected for all basins except for the Daintree Basin. The fish index was reported for all basins except the Daintree.

The estuary reporting was conducted for the eight estuary reporting zones (Daintree, Dickson Inlet, Barron, Trinity Inlet, Russell-Mulgrave, Johnstone, Moresby and Hinchinbrook Channel). Data for the water quality index, excluding pesticides, was collected at DES monitoring sites (Daintree, Moresby and Hinchinbrook Channel), Douglas Shire Council monitoring sites (Dickson Inlet), Cairns Regional Council monitoring sites (Barron, Trinity Inlet and Russell-Mulgrave) and Cassowary Coast Regional Council monitoring sites (Johnstone). Data for pesticides was collected from the GBR CLMP site for the Daintree, Russell-Mulgrave and Johnstone estuaries. Data for the habitat and hydrology index (riparian extent, mangrove and saltmarsh extent and fish barriers) was collected for all eight estuary zones. Data for shoreline mangrove habitat was collected for the Daintree, Dickson Inlet, Barron, Trinity Inlet and Russell-Mulgrave estuaries. Data for the flow indicator was collected for the Barron, Russell-Mulgrave and Johnstone estuaries. Data for seagrass was collected by the Queensland Ports Seagrass Monitoring Program (QPSMP) for Trinity Inlet and Moresby estuary.

The inshore marine reporting was conducted for the four inshore reporting zones (North, Central, South and Palm Island). Data for the water quality index, excluding pesticides, was collected from the Marine Monitoring Program (MMP) water quality monitoring sites for each zone. Data for coral was collected from the MMP and Long-term Monitoring Program (LTMP) coral monitoring sites for each zone. Data for seagrass was collected from the MMP seagrass monitoring sites (North and South zones) and QPSMP sites (North zone).

The offshore marine reporting was conducted for the single offshore reporting zone. Data for the water quality index was not available for 2020-21. Data for coral was collected from the LTMP.

An overall condition grade was provided for each reporting zone within each environment (basin, estuary, inshore marine and offshore marine). Scores were averaged from the indicator level to generate indicator category scores. In some cases, for example estuary fish barriers and flow, multiple measures make up the indicator score. Where an indicator category is represented by a single indicator, the indicator category score is equal to the indicator score. Indicator categories were averaged to generate an index score, and indices were subsequently averaged to produce an overall score for an individual reporting zone in an environment. The levels of indicator aggregation and the terminology are presented in Figure i.

Scoring and aggregation was conducted by standardising all indicators into the Wet Tropics Report Card scoring range (0-100).

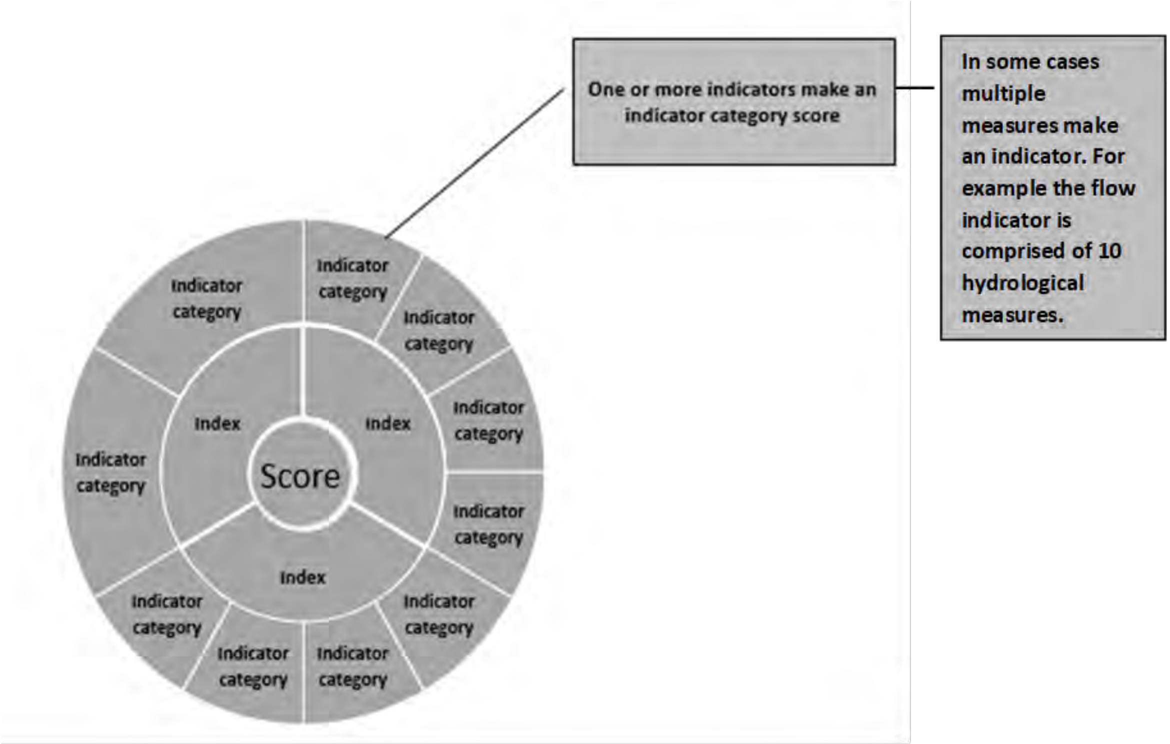

Figure i. Terminology used for defining the level of aggregation of indicators.

The assessment results in the Report Card were rated in terms of the confidence surrounding the data used for indicators. The Wet Tropics Report Card uses the method developed for the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program for the Great Barrier Reef Report Card for estimating confidence of indicators based on five criteria (updated in 2017). The method is applied to the Wet Tropics report card indicators using revised weightings for each criteria. The confidence ratings of indicators are aggregated to provide ratings for each indicator category and index.

Contents

FIGURES

TABLES

Terms and Acronyms

AIMS	Australian Institute of Marine Science
Basin	An area of land where surface water runs into smaller channels, creeks or rivers and discharges into a common point. A basin may include unconnected sub-basins which discharge at separate points.
Biomass	The total quantity or weight of organisms over a given area or volume.
CCRC	Cassowary Coast Regional Council
Chl-*a*	Chlorophyll-*a*: a measure used to estimate phytoplankton biomass. It is widely considered a useful proxy for measuring nutrient availability and the productivity of a system.
CRC	Cairns Regional Council
DDL	Declared Downstream Limit
DEHP	Department of Environment and Heritage Protection, Queensland. Now part of DES.
DES	Department of Environment and Science, Queensland
Diadromous	Of fish: species with life cycles that require migration between freshwater and saltwater environments.
DIN	Dissolved Inorganic Nitrogen
DO	Dissolved Oxygen
Driver	An overarching cause of change in the environment
Ecosystem	A dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit
Ecosystem health	An ecological system is healthy and free from distress if it is stable and sustainable - that is, if it is active and maintains its organisation and autonomy over time and is resilient to stress.
EC	Enclosed coastal marine water body
Estuary environment	The aquatic environment at the interface between freshwater and marine ecosystems and includes mid-estuary (ME) and lower-estuary (LE) waters (WTHWP 2018).
Fish (as an index)	Fish community health is evaluated, and included in the ecosystem health assessment (coasters). Inclusion in the Report Card will contribute to an understanding of the health of local fish communities.
Fish Barriers (as an indicator)	Fish barriers relate to any man-made barriers which prevent or delay connectivity between key habitats which has the potential to impact migratory fish populations, decrease the diversity of freshwater fish communities and reduce the condition of aquatic ecosystems (Moore, 2016)

Flow (as an indicator)	Flow relates to the degree that the natural river flows have been modified in the region's waterways. This is an important indicator due to its relevance to ecosystem and waterway health
FRP	Filterable Reactive Phosphorus
GBR	Great Barrier Reef
GBR CLMP	Great Barrier Reef Catchment Loads Monitoring Program
GBR Report Card	Great Barrier Reef Report Card developed under the Reef 2050 Water Quality Improvement Plan (2018).
GBRMPA	Great Barrier Reef Marine Park Authority
GV	Guideline Value
Impoundment length	An indicator used in the 'in-stream habitat modification' indicator for freshwater basins in the region. This index reports on the proportion (%) of the linear length of the main river channel when inundated at the Full Supply Level of an artificial in-stream structures such as dams and weirs
Index (for scoring)	Is generated by indicator categories (e.g. water quality made up of nutrients, water clarity, chlorophyll-*a* and pesticides)
Indicator	A measure of one component of an environmental dataset (e.g. particulate nitrogen)
Indicator category	Is generated by one or more indicators (e.g. water clarity made up of total suspended solids and turbidity)
Inshore marine environment	Includes enclosed coastal (EC), open coastal (OC) and mid-shelf (MS) waters, extending east to the boundary with the offshore waters (WTHWP 2018).
In-stream Habitat Modification (as an indicator)	This basin indicator category is made up of two indicators; fish barriers and impoundment length
IQQM	The Integrated Water Quantity and Quality Model – used to model pre-development flow for the flow tool score calculations.
JCU	James Cook University
LAT	Lowest astronomical tide
LTMP	Australian Institute of Marine Science Long-term Monitoring Program
Macroalgae (cover)	An indicator used in part to assess coral health. Macroalgae is a collective term used for large fleshy seaweeds and other benthic (attached to the bottom) marine algae that are generally visible to the naked eye.
Measure	A measured value that contributes to an indicator score for indicators that are comprised of multiple measurements (e.g. flow, estuary fish barriers).
MMP	Great Barrier Reef Marine Monitoring Program – A collaboration between Great Barrier Reef monitoring program, led by GBRMPA, JCU and AIMS. This provides water quality, coral and seagrass data for the inshore zones of the report card.

MoA	The mode of action is used to classify pesticides according to how they exert their effect on the target organism. The mode of action will be defined by its biochemical effects.
MS	Mid-shelf marine water body
ms-PAF	Multiple substances-potentially affected fraction derived using a concentration addition model which estimates the cumulative toxicity for contaminants with different modes of action. Referred to as the Pesticide Risk Metric.
MWQ	Marine water quality (MWQ) dashboard and data – Bureau of Meteorology.
NATA	National Association of Testing Authorities, Australia.
NO_x	Oxidised nitrogen (nitrate and nitrite)
OC	Open coastal marine water body
Offshore environment	Includes all offshore waters within the Wet Tropics NRM marine region
Overall Score	The overall scores for each reporting zone used in the report card are generated by an index or an averaging of indices
Palustrine wetlands	Primarily vegetated non-channel environments of less than eight hectares. Examples of palustrine wetlands include billabongs, swamps, bogs, springs, etc.
Pesticides (as an indicator)	Incorporating up to 22 herbicides and insecticides with different modes of action. A list of the relevant chemical components is provided in the methods report.
Pesticide Risk Metric	Refers to the methodology for estimation of ecological risk associated with pesticide pollution.
Phys-chem	The physical-chemical indicator category that includes two indicators: dissolved oxygen (DO) and turbidity
PN	Particulate nitrogen
POISE	Proportion of indigenous fish species expected
PONI	Proportion of non-indigenous fish
PP	Particulate phosphorus
Pre-clearing	Pre-clearing vegetation is defined as the vegetation or regional ecosystem present before clearing. This generally equates to terms such as 'pre-1750' or 'pre-European' used elsewhere (Neldner *et al*., 2019).
Pre-development flow	The pattern of waterflows, during the simulation period, using the IQQM computer program as if there were no dams or other water infrastructure in the plan area, and no water was taken under authorisations in the plan area (Queensland Government 2016).
PRM	Pesticide Risk Metric
PSII herbicides	Photosystem II inhibiting herbicides

PSII-HEq	Photosystem II herbicide equivalent concentrations, derived using relative potency factors for each individual PSII herbicide with respect to a reference PSII herbicide, diuron (Gallen *et al.* 2014)
QPSMP	Queensland Ports Seagrass Monitoring Program
Queensland Government	The Queensland Government includes several departments that provide data sources and support for the report card. Key departments for the report card are the Department of Environment and Sciences (includes management of the GBR CLMP), the Department of Regional Development, Manufacturing and Water (includes management of water monitoring), and the Department of Resources (includes management of Queensland Spatial).
RE	Regional Ecosystem
REMP	Receiving Environment Monitoring Plan
Resilience (MMP seagrass indicator)	Measure of the capacity of seagrass to cope with disturbances.
RIMReP	Reef 2050 Integrated Monitoring and Reporting Program
Riparian Extent (as an indicator)	An indicator used in the assessments of both basin and estuarine zones. This indicator uses mapping resources to determine the extent of the vegetated interface between land and waterways in the region
RPF	Relative potency factors
SF	Scaling factor. A value used to set scoring range limits for indicators.
SOP	Standard operating procedure
S-VAM	Shoreline-Video Assessment Method
TSS	Total Suspended Solids
UTL	Upper tidal limit
Waterway	All freshwater, estuarine and marine bodies of water, including storm drains, channels and other human-made structures in the Wet Tropics Region.
Water quality guideline	For purposes of waterway assessment, the term water quality guideline refers to values for condition assessment of water quality drawn from a range sources including water quality objectives scheduled under the Environmental Protection (Water) Policy 2009, and water quality guideline values obtained from the Queensland Water Quality Guidelines (DEHP 2009), the GBRMPA Guidelines (GBRMPA 2010) and the ANZG (2018)
Water quality objective (WQO)	Water quality objective refers to values for condition assessment of water quality scheduled under the Environmental Protection (Water) Policy 2009.
WWTP	Waste-water treatment plant

1. INTRODUCTION

1.1. General

Wet Tropics Waterways was launched in July 2016 with the release of the 'Pilot Report Card' in December 2016 which reported on the 2014-15 year. Six annual report cards have been released since the pilot report card with the current 'Report Card 2022' reporting on the 2020-21 year (1 July to 30 June).

The Report Card includes water quality and ecosystem condition and state assessments for freshwater, estuarine, inshore marine and offshore marine environments. For more detail on the Wet Tropics Report Card including reporting zones for the waterway environments refer to the Wet Tropics Report Card Program Design: Five-year plan 2018 - 2022 (WTHWP 2018).

1.2. Purpose of this Document

The purpose of this document is to provide detailed information on the methods used to produce condition and state assessments of the freshwater, estuarine, inshore marine and offshore marine environments. Specifically, this document describes the following.

- The data collection methods
- The scoring methods
- The confidence rating method.

A log of the updates applied to the 2020-21 methods technical report is presented in Appendix H.

1.3. Terminology

The Report Card assesses different indicators of waterway health to report on overall state and condition. Scores for indicators are aggregated together depending on the aspect of the environment they are assessing, such as water quality, coral or fish. The terminology used in this document for defining the level of aggregation of indicators is as follows.

- An indicator is a measured variable (e.g. particulate nitrogen) or generated from more than one measure, for example the flow indicator is generated from multiple hydrological measures.
- Indicator categories (e.g. nutrients) are generated by averaging indicators.
- Where an indicator category is represented by a single indicator the indicator category score is equal to the indicator score.
- Indices (e.g. water quality) are generated by averaging indicator categories.
- Overall score is generated by the averaging of indices or by a single index score.

Overall scores and scores for indices are represented in the report card and website by a circle diagram (Figure 1). Presentation of the circle diagrams can be without the indicator category outer ring as in the case of the Report Card publication. The overall scores are produced from a high level of aggregation which means these scores will be slow to change. It is important to take notice of the scores for indicators and indicator categories which can change more over time than overall scores.

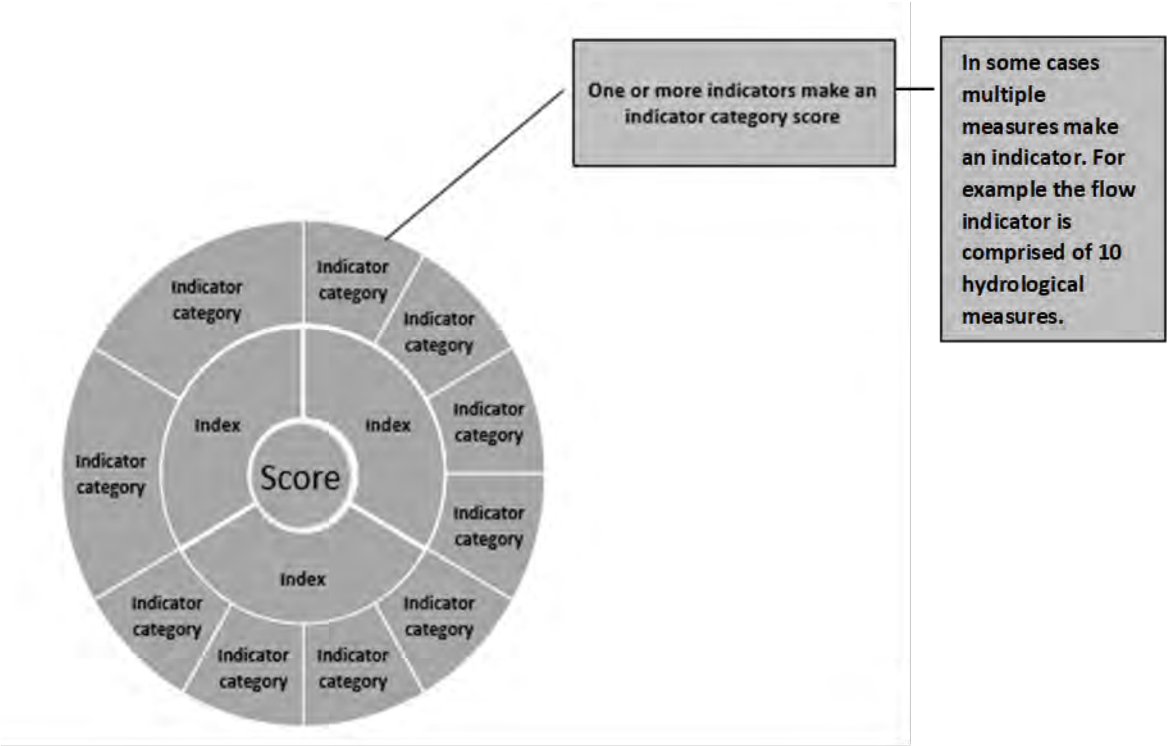

Figure 1 Terminology used for defining the level of aggregation of indicators.

1.4. Indicators for waterway environments

The Report Card provides scores for each reporting zone within each waterway environment. The indicators, indicator categories and indices selected for reporting state and condition are presented in Table 1 for each waterway environment. The table presents the nesting of indicators and indicator categories within indices.

Table 1 Indices, indicator categories and indicators used for scoring environmental state and condition of the four waterway environments (basins, estuaries, inshore marine and offshore marine).

Environment	Index	Indicator category	Indicator
Basins	Water quality	Sediment	Total suspended solids
		Nutrients	Dissolved inorganic nitrogen
			Filterable reactive phosphorus
		Pesticides	Pesticide risk metric
	Habitat & hydrology	Habitat modification	Impoundment length
			Fish barriers
		Flow	30th Percentile of 10 flow metrics
		Riparian vegetation	Extent
		Wetlands	Extent
		Invasive weeds	Extent, diversity and impact
	Fish	Native fish	Proportion of observed vs. expected species
		Introduced fish	Proportion of translocated fish
			Proportion of non-Australian fish
Estuaries	Water quality	Physical-chemical	Turbidity
			Dissolved oxygen
		Nutrients	Dissolved inorganic nitrogen
			Filterable reactive phosphorus
		Chlorophyll *a*	Chlorophyll *a*

Environment	Index	Indicator category	Indicator
		Pesticides	Pesticide risk metric
	Habitat & hydrology	Mangroves and salt marsh#	Extent
			Shoreline mangrove habitat
		Riparian vegetation	Extent
		Fish barriers (between freshwater and marine environments)	Barrier density
			Distance to first barrier
			Distance to first low passability barrier
		Flow	30th Percentile of 10 flow metrics
		Seagrass (Dickson Inlet, Trinity Inlet, Moresby, and Hinchinbrook Channel only)	Biomass
			Area
			Species composition
	Fish	In development	In development
Inshore marine	Water quality	Water clarity	Total suspended solids
			Turbidity
		Nutrients	Oxidised nitrogen
			Particulate nitrogen
			Particulate phosphorus
		Pesticides	Pesticide risk metric
		Chlorophyll *a*	Chlorophyll *a*
	Coral	Change in coral cover	Change in coral cover
		Juvenile density	Juvenile density
		Macroalgae cover	Macroalgae cover
		Coral cover	Coral cover
		Composition	Composition
	Seagrass	Biomass	Biomass
		Area	Area
		Species composition	Species composition
		Tissue nutrients	Tissue nutrients
		% cover	% cover
		Reproduction	Reproduction
	Fish	In development	In development
Offshore marine	Water quality	Water clarity	Total suspended solids
		Chlorophyll *a*	Chlorophyll- *a*
	Coral	Change in coral cover	Change in coral cover
		Juvenile density	Juvenile density
		Coral cover	Coral cover
	Fish	In development	In development

#The Mangroves and saltmarsh indicator category for estuaries has been updated to include shoreline mangrove habitat as from 2020-21. This update was recommended in the Five Year Program Design (WTHWP 2018) to address monitoring gaps for habitat condition.

Note that whilst the water clarity indicator category for inshore marine is aggregated from total suspended solids and turbidity, other measures such as Secchi depth and coloured dissolved organic matter are also effective indicators for water clarity and could be used for future reporting. The use of additional indicators for water clarity depend on availability of appropriate guideline values and monitoring data. The procedure for adding indicators for waterway reporting is presented in the Program Design (WTHWP 2018).

2. METHODS FOR DATA COLLECTION

2.1. Introduction

The sections below provide an overview of the data collection methods for the environmental indicator categories and indicators reported on in the Wet Tropics Report Card. The indicator selection procedure and descriptions of selected indicators is provided in the Program Design (WTHWP 2018). The methods used for data collection are provided in the sections below.

2.2. Freshwater Basins Data Collection

The freshwater basin reporting zones and the water quality monitoring site locations are shown in Figure 2. An additional site located in the upper catchment of the Tully Basin is shown which is used to reference the quality of water from undisturbed forest but not included in the Report Card condition assessment.

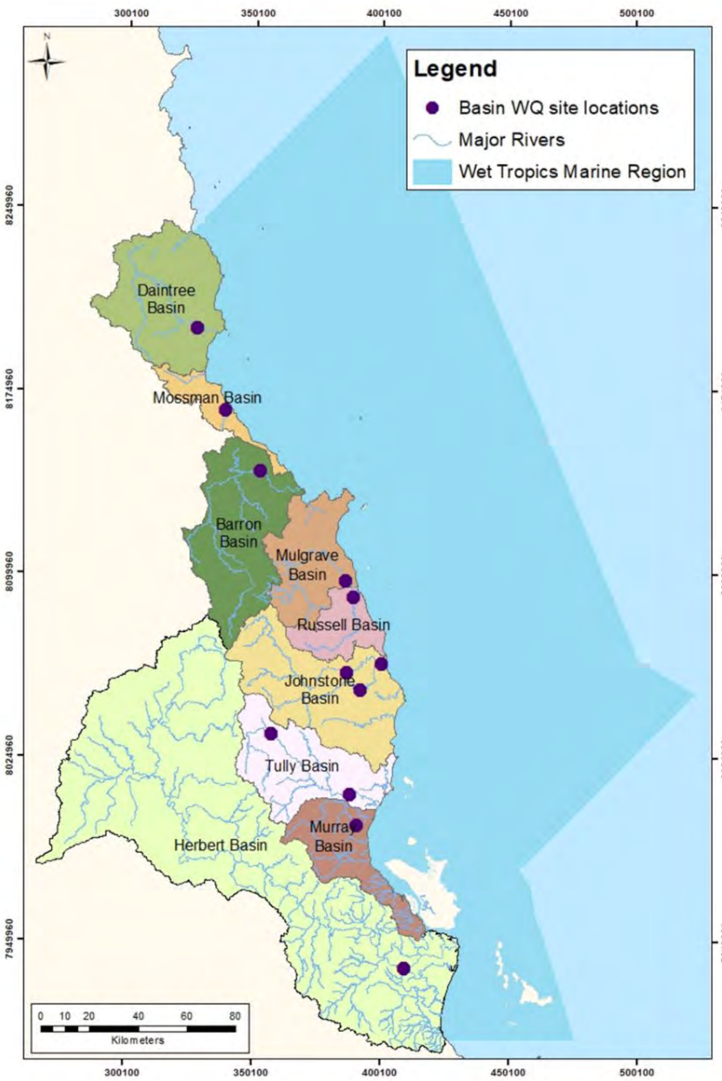

Figure 2 Freshwater basin reporting zones and water quality monitoring site locations for the Report Card.

2.2.1. Water Quality

The freshwater basin water quality data used in the Report Card were collected through the DES (Department of Environment and Science) GBR CLMP (Great Barrier Reef Catchment Loads Monitoring Program) and Queensland Government gauging station network and through Douglas Shire Council (DSC) for their Environmental Impact Monitoring Program (EIMP) with additional water quality monitoring conducted by the DES. Water quality indicators (total suspended solids (TSS), dissolved inorganic nitrogen (DIN), filterable reactive phosphorus (FRP), and river flow (discharge)) were collected at the GBR CLMP and DSC sites (Table 2). Sampling for pesticides was expanded to all basins in 2017-18 and 2018-19 in order to populate the Pesticide Risk Baseline, and from 2019-20 was dropped back to a more routine sampling regime at eight sites (Table 2) with the loss of monitoring for the Mossman Basin (previously monitored at Bonnie Doon) and for the Barron Basin (previously monitored at Rink's Close Jutty).

Table 2 Water quality monitoring sites, the variables measured at each site that are used for Wet Tropics Report Card scoring and the percent (%) of basin upstream of the sites.

Basin	Sites	TSS	DIN	FRP	Pesticides	Discharge	% of basin*
Daintree	Lower Daintree, DSC$	•	•	•	•	•	93
Mossman	MR2, MR4, MR 4.1$	•	•	•			45
	SMR1$	•	•	•			41
	MR5$	•	•	•			86
Barron	Myola#	•	•	•		•	89
Mulgrave	Deeral#	•	•	•	•	•	60
Russell	East Russell#	•	•	•	•	•	78
Johnstone	Goondi# (N. Johnstone)	•	•	•	•	•	41
	Upstream Central Mill# (S. Johnstone)	•	•	•		•	17
	Coquette Point# (Johnstone)				•		70
Tully	Euramo#	•	•	•	•	•	86
Murray	Bilyana#	•	•	•	•	•	tbc
Herbert	Ingham#	•	•	•	•	•	87

#Great Barrier Reef Catchment Loads Monitoring Program (GBR CLMP) sites. $Douglas Shire Council (DSC) water quality monitoring sites. *% of basin was sourced from Huggins *et al.* (2017) except for Mossman Basin sites which was sourced from drainage basin sub-area Queensland spatial mapping (DNRM 2009), and the Daintree Basin site which was sourced from the Queensland Department of Environment and Science.

The Daintree GBR CLMP site (Figure 3) was operational from 2017-18. This site is located in the mid-estuary water type in the main channel of the Daintree River. Analysis of daily electrical conductivity, water level and discharge data indicated that during base-flow the site was tidally influenced, whilst at higher discharge electrical conductivity was typical of freshwaters for the catchment. Consequently, data for freshwater basin condition assessment was restricted to high flows (> 25m^3/s) when event sampling occurred. Water quality monitoring during the dry season commenced in the latter half of 2019 at freshwater sites in the Daintree and provided data for reporting of water quality during base-flow periods. in future report cards.

Figure 3 Daintree water quality monitoring sites showing location of GBRCLMP site used for high flow monitoring and DSC (Douglas Shire Council) site used for base-flow monitoring.

The Mossman water quality monitoring was conducted at sites MR3, MR4 and MR4.1 which are located on the Mossman River upstream of the confluence with South Mossman River, site SMR1 which is located on the South Mossman River, and site MR5 is located on the Mossman River downstream of the confluence with the South Mossman River (Figure 4).

Figure 4 Mossman Basin water quality monitoring sites. Sites were monitored by the Douglas Shire Council as part of their Environmental Impact Monitoring Program and additional water quality monitoring was also conducted by the Department of Environment and Science.

All monitoring included in the Report Card was undertaken at these sites between 1 July 2020 and 30 June 2021. Sampling was conducted in accordance with the Environmental Protection (Water) Policy Monitoring and Sampling Manual (DES 2018).

At GBR CLMP sites, a combination of manual grab and automatic sampling was used. Daily river flows (mean m^3/s) from the Queensland Government were collected for each GBR CLMP site and used to separate water quality data into those associated with high flow and base-flow periods. Intensive sampling at GBR CLMP sites (up to hourly) occurred during high flow events and monthly sampling was undertaken during ambient (low or base-flow) conditions. Samples for TSS, nutrients and pesticide analysis were collected concurrently (Garzon-Garcia *et al.* 2015).

Samples from GBR CLMP sites were stored and transported in accordance with the Environmental Protection (Water) Policy Monitoring and Sampling Manual (DES 2018) and Wallace *et al.* (2015). Analyses for TSS and nutrients were undertaken by the Science Division Chemistry Centre (Dutton Park, Queensland), and the analyses for the PSII herbicides were conducted by Queensland Health Forensic and Scientific Services (Coopers Plains, Queensland) (Garzon-Garcia *et al.* 2015). Both laboratories are accredited by the National Association of Testing Authorities (NATA). Further information on the water quality data collection and analysis is provided in Garzon-Garcia *et al.* (2015).

At the Mossman Basin sites manual grab sampling was used. Samples were stored and transported in accordance with the Environmental Protection (Water) Policy Monitoring and Sampling Manual (DES 2018). Analyses of samples collected by Douglas Shire Council for TSS and Nutrients were undertaken by SGS Environmental Services, Portsmith, Qld, which is a NATA accredited laboratory. Analyses of samples collected by DES for TSS and Nutrients were undertaken at Queensland Health laboratories, Brisbane, Queensland. Where sampling at a given site was conducted by both Douglas Shire Council and DES on the same date, the DES sample was included in preference to the Douglas Shire Council sample because the Queensland Health laboratory provided higher accuracy of limit of reporting for the analyses.

Pesticide condition in freshwater catchments for 2020-21 was based on the monitored concentrations of up to 22 pesticides (Table 3). All pesticide concentration data and calculated pesticide risk metric data were provided by the Queensland Government's Great Barrier Reef Catchment Loads Monitoring Program.

Table 3 Pesticides, their type and mode of action (MoA) that are included in pesticide mixture risk metric. Not all of the listed pesticides were necessarily detected in all collected water samples.

Name of pesticide	Type	MoA
Chlorpyrifos	Insecticide	Acetylcholine esterase (AChE) inhibitor
Fipronil	Insecticide	Gamma-aminobutyric acid (GABA) gated chloride channel blocker
Imidacloprid	Insecticide	Nicotinic receptor agonist
Haloxyfop	Herbicide	Acetyl-coenzyme A carboxylase (ACCase) inhibitor
Imazapic	Herbicide	Group 1 Acetolactate synthase (ALS) inhibitor
Metsulfuron-methyl	Herbicide	Group 2 Acetolactate synthase (ALS) inhibitor
Pendimethalin	Herbicide	Microtubule synthesis inhibitor
Metolachlor	Herbicide	Inhib of VLCFA
2,4-D	Herbicide	Phenoxy-carboxylic acid auxin
MCPA	Herbicide	Phenoxy-carboxylic acid auxin
Fluroxypyr	Herbicide	Pyridine-carboxylic acid auxin
Triclopyr	Herbicide	Pyridine-carboxylic acid auxin

Name of pesticide	Type	MoA
Isoxaflutole	Herbicide	4-hydroxyphenylpyruvate dioxygenase (4-HPPD) inhibitor
Ametryn	Herbicide	PSII inhibitor
Atrazine	Herbicide	PSII inhibitor
Prometryn	Herbicide	PSII inhibitor
Terbuthylazine	Herbicide	PSII inhibitor
Tebuthiuron	Herbicide	PSII inhibitor
Simazine	Herbicide	PSII inhibitor
Diuron	Herbicide	PSII inhibitor
Hexazinone	Herbicide	PSII inhibitor
Metribuzin	Herbicide	PSII inhibitor

2.2.2. Habitat and Hydrology

Data collection methods for the habitat and hydrology index for the Report Card (habitat modification, flow, riparian extent, invasive weeds and wetland extent) are described below.

2.2.2.1. Habitat Modification

Impoundment Length

The impoundment length indicator reports on the proportion (%) of the linear length of non-tidal streams of order three or higher that are inundated at the full supply level of artificial in-stream structures, such as dams and weirs.

Impoundment locations and estimates of impounded lengths were derived from the Queensland Government 1:100,000 ordered drainage network, Google Earth imagery, Queensland Globe spatial layers (Dams, Weirs and Barrages, Referable Dams and Reservoirs) and local knowledge including Queensland Government regional hydrographic staff. The proportion of impoundment length was calculated as a percentage of the total linear length of the river channel as measured from Google Earth satellite imagery. All streams of order three or higher within the freshwater basin were included in the assessment. Impoundment length is updated every four years. Impoundment length data was updated for the 2018-19 period from a Queensland Government record search covering the last four years of works affecting existing impoundments or development for new impoundments on waterways of stream order 3 or greater in the Wet Tropics region. The impoundments were also visually assessed by Queensland Government staff from recent satellite imagery to verify their state.

Fish Barriers

The indicators and measures for freshwater fish barriers are currently being developed for review.

2.2.2.2. Flow

The flow indicator follows a reference condition approach where a waterway with a highly modified flow regime, resulting in large deviations from an unregulated reference condition, will score poorly and a waterway with an unmodified flow regime, resulting in a similar flow regime to reference condition, will score well. The indicator was applied to all available flow assessment sites within each basin. A flow assessment site requires: i) an operational stream gauging station that provides daily stream flow data; and ii) time series modelled pre-development daily flows, which provide the reference condition. Observed daily flows (ML/day) were obtained from the Queensland Government water monitoring information portal (water-monitoring.information.qld.gov.au) and were all stream gauging stations managed by Queensland Government. Pre-development time series (100+ years, typically 1890 – 2008) of daily flows (ML/day) were obtained from Queensland Government hydrologic models (IQQM - Integrated Water Quantity and Quality Model), which were developed for Queensland basin Water Plans. The flow measures used to score the flow indicator assesses deviations of the observed flow data from the reference pre-development flow data. The flow assessment sites used for the flow indicator within each basin are presented in Table 4, along with the Queensland Government gauging station number.

The hydrologic models for the Wet Tropics and Barron Water Plans, developed by Queensland Hydrology Unit, Science and Technology Division, Department of Environment and Science, have been externally reviewed. The pre-development flow data is based on those models, and the developers have a good level of confidence about the pre-development scenarios (A. Loy, Pers. Comm. Email 7/7/2021).

Table 4 Flow assessment sites with Queensland Government gauging station number (GS no.) used for the flow indicator within each basin.

Basin and flow assessment site	GS no.	Basin and flow assessment site	GS no.
Mossman		**Tully**	
Mossman River at Mossman	109001A	Tully River at Euramo	113004A
Barron		Cochable Creek at Powerline	113004A
Barron River at Myola	110001D	**Murray**	
Barron River at Mareeba	110002D	Murray River at Upper Murray	114001A
Barron River at Picnic Crossing	110003A	Meunga Creek at Sing's	114002A
Mazlin Creek at Railway Bridge	110018A	**Herbert**	
Barron River at Bilwon	110020A	Herbert River at Ingham	116001F
Barron River at Goonara Creek	110021A	Herbert River at Glen Eagle	116004C
Freshwater Creek at Redlynch Estate	110104A	Herbert River at Abergowrie	116006B
Mulgrave		Gowrie Creek at Abergowrie	116008B
Mulgrave River at The Fisheries	111005A	Blencoe Creek at Blencoe Falls	116010A
Mulgrave River at Peets Bridge	111007A	Millstream at Ravenshoe	116011A
Russell		Cameron Creek at 8.7km	116012A
Russell River at Bucklands	111101D	Millstream at Archer Creek	116013A
Babinda Creek at The Boulders	111105A	Wild River at Silver Valley	116014A
Johnstone		Blunder Creek at Wooroora	116015A
Fisher Creek at Nerada	112002A	Rudd Creek@Gunnawarra	116016A
North Johnstone River at Glen Allyn	112003A	Stone River at Running Creek	116017A
North Johnstone River at Tung Oil	112004A		
South Johnstone River at Upstream Central Mill	112101B		
Liverpool Creek at Upper Japoonvale	112102A		

The annual flow pattern in any given river will vary naturally with the prevailing rainfall conditions. For example, in a free-flowing river, total annual discharge will naturally be lower in a drought year than a wet year. To account for differences of rainfall between years, historical daily rainfall data (100+ years) was obtained from the Queensland Government SILO program for each catchment (legacy.longpaddock.qld.gov.au/silo/). The SILO rainfall record covers the entire hydrological modelling period (1890 – 2008) and continues to the present day. Sites used to provide rainfall data from either station (S) or point (P) locations from the SILO website for each basin are presented in Table 5.

Table 5 Rainfall data site details.

Basin & data type	Location	Latitude	Longitude	Elevation (m)
Mossman P2	Lower catchment	-16.45	145.4	18
Mossman P1	Mid catchment	-16.4	145.35	76
Barron P1	Upper Barron	-17.35	145.5	788
Barron P2	Tinaroo Falls Dam	-17.15	145.55	796
Barron S3	Walkamin	-17.08	145.43	594
Barron P3	Biboohra	-16.9	145.4	386
Barron P4	Kuranda Railway	-16.8	145.65	325
Barron P5	Clohesy	-16.9	145.55	406
Barron P6	Upper Freshwater	-16.95	145.7	249
Mulgrave P3	Mulgrave Mill	-17.10	145.8	52
Mulgrave P4	Mt Sophia	-17.15	145.9	8
Mulgrave P5	Deeral	-17.2	145.9	131
Mulgrave P1	Behana Creek	-17.2	145.8	705
Mulgrave P2	Upper-mid Mulgrave	-17.2	145.75	471
Russell P2	Happy Valley	-17.35	145.9	99
Russell P3	Babinda PO	-17.35	145.95	14
Russell P4	Bellenden Kerr bottom	-17.25	145.9	291
Russell P1	Upper-mid Russell	-17.45	145.85	172
Johnstone N P2	Topaz - Towalla	-17.45	145.7	602
Johnstone S S2	Exp Station	-17.61	146.0	18
Johnstone P3	Innisfail	-17.5	146.0	10
Johnstone P1	mid upper Johnstone	-17.6	145.75	474
Tully P2	Koombooloomba	-17.85	145.6	792
Tully P3	Kareeya	-17.75	145.6	469
Tully P4	Sugar Mill	-17.95	145.95	122
Tully P1	Mid Tully	-17.9	145.75	58
Herbert P2	Evelyn State Forest	-17.55	145.5	1056
Herbert P3	Mt. Garnet PO	-17.7	145.1	664
Herbert P4	Gunnawarra	-17.95	145.15	638
Herbert P5	Gleneagle	-18.15	145.35	601
Herbert P6	Elphinstone Pocket	-18.5	146.0	47
Herbert P7	Victoria Sugar Mill	-18.65	146.2	12
Herbert P1	Lower mid Herbert	-18.3	145.7	618
Murray P1	Upper Murray	-18.1	145.8	69
Murray P2	Meunga Creek at Sings	-18.2	145.9	199
Murray P3	US Murray and Meunga	-18.15	145.85	812

Note: Sites are either station (S) or point (P) locations on the SILO website (www.longpaddock.qld.gov.au/silo/).

Historical daily rainfall data was averaged from all rainfall sites within each basin and was used to define years within rainfall types using quartiles as follows.

- Drought: Annual rainfall ≤ 25th percentile year.
- Dry: 25th percentile year < Annual rainfall ≤ 50th percentile year.
- Average: 50th percentile year <Annual rainfall ≤ 75th percentile year.
- Wet: Annual rainfall>75th percentile year.

For a given basin, each year of the hydrological record was then ascribed a 'rainfall type'. As such, the flow measures used to produce the indicator scores each have reference distribution for each climatic type at each flow assessment site. The rainfall type for reporting year (2019-20) was determined by comparing the rainfall record to the historical rainfall data. Generation of rainfall types and determining rainfall type of the reporting year were conducted using the flow indicator tool developed for the Report Cards Flow Indicator Project (Stewart-Koster *et al*. 2018).

The methods used to generate flow indicator scores are presented in section 3.2.3.2, while the complete report for the Report Cards Flow Indicator Project (Stewart-Koster *et al*. 2018) is available on the WTW website here.

2.2.2.3. Riparian Extent

The assessment of riparian extent follows the same methodology used for the Reef Plan Great Barrier Reef Report Card (Queensland Government 2014). This methodology first defines riparian areas using topographic drainage data and riverine wetlands derived from the 2009 Queensland Wetland Mapping Programme data. The present extent of riparian forest is defined by those areas with a foliage projective cover of at least 11 % using the 2013 Landsat foliage projective cover data. This was then compared against the pre-clearing extent of riparian forest regional ecosystems (based on regional ecosystem mapping version 9) to estimate the amount of riparian forest remaining in the Daintree, Mossman, Barron, Mulgrave, Russell, Johnstone, Tully, Murray and Herbert basins. The method assumes that the pre-clearing riparian forest regional ecosystems were 100 % forested.

2.2.2.4. Wetland Extent

The assessment of wetland extent uses data from Queensland Regional Ecosystem (RE) Version 5 and Queensland Wetland Data Version 5 mapping supplied through Queensland Herbarium and is the same source of data used for the Reef Plan report card to report wetland extent. The Report Card wetland extent assessment only includes data for palustrine wetlands in the nine basins of the Wet Tropics (Daintree, Mossman, Barron, Mulgrave, Russell, Johnstone, Tully, Murray and Herbert basins). The current condition (2017) of wetland extent was conducted through a comparison of current extent against pre-clearing extent of vegetated freshwater swamp (palustrine) systems with more than 30 percent emergent vegetation cover. The updated pre-clearing wetland extent values version 5 replace the previous values reported for 2013.

2.2.2.5. Invasive Weeds

An established pest and weeds planning and prioritisation process operates throughout Far North Queensland and includes all of the basins within the Wet Tropics region (FNQROC 2015). The process involves the collation of information by an expert panel composed of officers and stakeholders from the Local Government's Pest Working/Advisory Groups (PWGs). The process was used for identification of the species included in the invasive weed indicator, mapping the distribution of aquatic weed species and defining impact scores for each aquatic weed species and was conducted for the 2019-20 reporting period.

Weed species that are distributed within Wet Tropics basins and which meet the following criteria were included in the invasive weeds indicator.

1. Priority species from Regional Pest Management Strategies or Local Government Biosecurity Plans.
2. Species with aquatic (in stream) habitat requirement and impact.

3. Able to be mapped (or are already mapped) at 1 kilometre grid resolution across the entire reporting region.
4. Management objectives, involving active management, in place across all jurisdictions.

Spatial analysis and assessments were conducted using ArcMap (10.0) and Community Viz (4.1.62.0). Spatial distribution data for each weed species is derived from a regional pest mapping project, which has been in development and use in the Wet Tropics region since 2005. The mapping project underpins Local Governments statutory Pest/Biosecurity Management Plans. The grid mapping is updated in each revision of the Local Plans and generated from a combination of management/survey data intersected with a 1 km^2 grid to create a presence/absence field for each species. Basin names and target species are captured in a single feature class and a short integer field (columns) is used to define presence [1] or absence [0] of each species in each grid cell (rows).

The distribution grid generated for each species is validated by local weed experts including members of the PWG from aerial imagery and local expert knowledge. Additional occurrences of weed species were added to the distribution grid as part of this process.

The weed distribution grid was intersected with the freshwater basin reporting zones to assign a basin name to each grid cell (partial grid cells were counted as whole grid cells if dissected by a basin boundary). The distribution grid for all species was then intersected with a single waterway habitat mapping layer compiled from merged polygons from Queensland Wetland Mapping representing lacustrine, palustrine, riparian and estuarine wetland types; and from Queensland Government 1:100,000 ordered drainage network Stream order ≥3. The polygons were then used to create a single feature representing waterway habitat.

Each weed species was scored from low (1) to high (5) according to its impact upon waterways based upon the impact scores developed by the PWGs. The score provided the impact rating for the species for use in the indicator.

The mapping procedure provided a record of the presence or absence of each weed species intersecting with the waterway habitat layer for all grid cells within each basin. The data was then exported from ArcMap into an Excel pivot table for processing into scores (see section 3.2.3.5).

For the 2019-20 a new species of invasive weed was added into the indicator due to an outbreak in the Barron Basin. The detection of the invasive weed Amazon frogbit (*Limnobium laevigatum*) has been accompanied by mapping of its distribution following implementation of the invasive weed indicator in 2015-16, and the mapping has revealed rapid spread of the species in the Barron Basin. The Amazon frogbit is now considered to be a priority species for management and control in the Wet Tropics.

A full description of the method including diagrams of key procedures is provided in Sydes and Hunt (2017). It is expected that the invasive weeds assessment for the Report Card will be conducted at least every four years.

2.2.3. Fish

All the field monitoring surveys, data collection and analysis, and fish indicator and index calculations were conducted by the Department of Environment and Science (DES).

The fish index (last updated in 2019-20) was assessed for all basins except for the Daintree and compared observed data to modelled data to report on the following two indicators.

- The Proportion Observed Indigenous Species compared to Expected (POISE): the number of naturally-occurring native Australian fish species caught as a proportion of the number predicted to occur at the site (in a single sample, using a standardised method) by a quantitative statistical model.
- The proportion of non-indigenous fish (PONI): the number of non-Australian and translocated native Australian fish caught expressed as a proportion of the total fish catch at the site. The PONI indicator consisted of the following two measures summed for each site.
    - Proportion Alien Fish: the number of non-Australian fish caught expressed as a proportion of the total fish catch at the site and calculated as 'number alien fish caught / total number fish caught'.
    - Proportion Translocated Fish: the number of translocated native Australian fish caught expressed as a proportion of the total fish catch at the site and calculated as 'number translocated fish caught / total number fish caught'.

Values for all indicators and measures were calculated at the site level. For each indicator, the basin score was the median of the site indicator values.

A model was used to produce a Maximum Species Richness Line (MSRL) which predicts the 90th percentile of fish species richness across the landscape, based on catches at sites with varying degrees of disturbance. Data used for the model included multiple landscape-scale predictors (catchment area, elevation and stream bed slope) and fish species distribution data from 370 fish sampling events on 252 different stream segments across the Wet Tropics, Dry Tropics and Mackay-Whitsunday regions. The model was partitioned into 'species richness zones' to account for catchments with restricted fish movement due to natural barriers such as major waterfalls. The zones were the Upper Barron, being major streams on the escarpment forming Barron River Falls, the Upper Herbert, being major streams on the escarpment forming Herbert River Falls, the Upper Johnstone, and unrestricted coastal streams (coastal waterways without major natural barriers to fish movement) being all other major streams.

The landscape predictors were based upon a digital elevation model (DEM) derived by the Department of Environment and Science to produce hydrologically-correct 12.5 m cell-size based on the latest 1 second (≈30 m) SRTM-derived DEM-S elevation data (https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/72759) and State 1:25,000 waterway mapping (qldspatial.information.qld.gov.au).

The model applied for the non-indigenous fish indicator to derive scores and grades was developed for South East Queensland (EHMP 2008). This approach allows for direct comparison of Wet Tropics results with those from other regions of Queensland which also apply the model. Since the model is not limited to data from the Wet Tropics but includes regions that have higher numbers of alien fish species it is important to note that the scores are relative to other regions of Queensland.

Non-indigenous fish may affect aquatic plants and animals through direct competition for food and space, predation, driving habitat changes and the introduction of exotic diseases and parasites. For this reason, it is important to prevent the introduction of non-indigenous fish into local waterways and eradicate new incursions of alien fish wherever possible. Managing populations of existing alien fish such as Tilapia through management and eradication programs promotes the health of native fish communities and waterways.

Fish survey sites were randomly identified using Generalized Random-Tessellation Stratified (GRTS) selection. Site selection was determined according to sites that could actually be accessed for the survey operations. The number of sites used for calculating indicator scores and the months of the surveys for each basin are presented in Table 6. The survey site and date, and site locations for each basin are presented in Appendix G Table 59 and Figure 38 to Figure 45. Fish surveys were conducted using backpack and boat-mounted electrofishing. Backpack electrofishing was undertaken until the operator was confident that a site had been adequately sampled and at least 300 'power-on' seconds had elapsed since capture of the last new species at the site. Boat electrofishing was undertaken until six 300 second 'power-on' time shots had been completed and no new species were captured during the last shot.

Table 6 The number of fish assessment sites used for calculating the indicator scores and the month and year of the fish surveys.

Basin	Number of sites	Month and year of survey
Mossman	13	September 2019
Barron	11	September 2019
Mulgrave	13	July - August 2019
Russell	14	July - August 2019
Johnstone	11	September 2019
Tully	11	August 2019
Murray	13	August 2019
Herbert	28	August 2020

The stocking of native Australian fish species under permits in the Wet Tropics region has been conducted in lower river reaches of the Barron, Mulgrave, Russell, Johnstone, Tully, Murray and Herbert and also in the impoundments of Tinaroo Falls Dam (Barron River), Copperlode Dam (Freshwater Creek, Barron Basin) and Koombooloomba Dam (Tully River). Stocked fish can potentially be captured during fish surveys and contribute to measures of species richness and to the measure of translocated fish numbers when stocked in locations outside their natural distributions. Data of recent fish stocking activity including basin, location, date, fish species and number was sourced from the Queensland freshwater fish stocking records (https://www.data.qld.gov.au/dataset/queensland-freshwater-fish-stocking-records) and presented in the results of the freshwater fish assessments to inform on possible influence of fish stocking on survey results.

2.3. Estuaries Data Collection

The location of the estuary reporting zones are shown in Figure 5. Monitoring and assessment of estuarine indicators is conducted at the reporting zone locations.

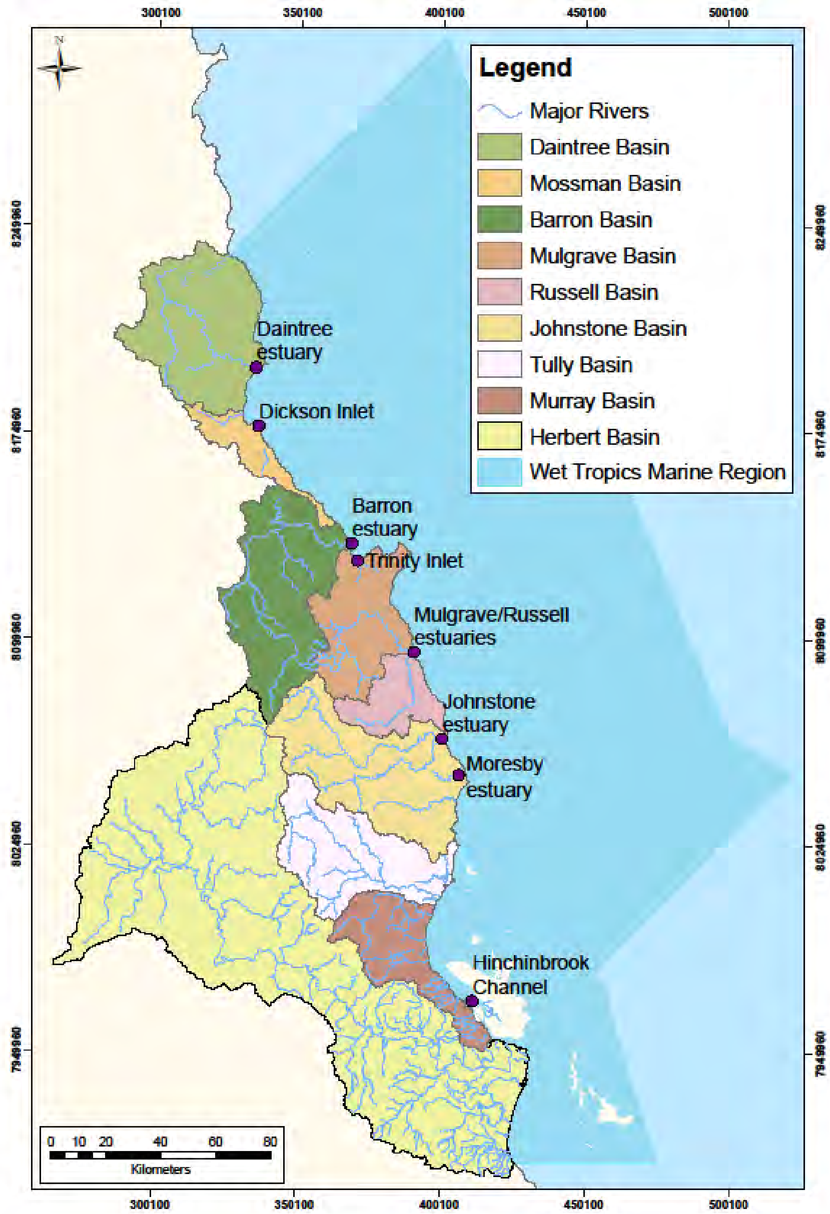

Figure 5 Location of estuary reporting zones.

2.3.1. Water quality

Water quality data for the Report Card was collected during the reporting period (1/7/20 to 30/6/21) by DES, Douglas Shire Council (DSC), Cairns Regional Council (CRC) and Cassowary Coast Regional Council (CCRC) monitoring programs at all of the eight estuary reporting zones (Table 7). The two sites from the Marine Monitoring Program for Inshore Water Quality located in the Russell-Mulgrave (RM11 and RM12) used for previous reporting years were discontinued in 2019. The estuary water quality monitoring site locations for each reporting zone are shown in Appendix A (Figure 10 to Figure 17). Of the selected water quality indicators for estuaries, turbidity was not monitored at the Johnstone estuary. Additional monitoring of DIN and FRP for the Johnstone estuary was provided from the GBR CLMP site at Coquette Point (Figure 15). The months for which monitoring was conducted (excluding pesticides) for each estuary are presented in Table 8. Pesticides were not monitored as part of the estuary water quality monitoring programs. Pesticide monitoring conducted for the GBR CLMP which is used for the basins was also used for estuaries at the estuary reporting zones where the monitoring sites are located (Daintree, Russel-Mulgrave at Deeral and East Russell (Appendix A, Figure 14) and Johnstone at Coquette Point (Appendix A, Figure 15)). The GBR CLMP sites are located in the mid-estuary water type of the estuary zones.

Table 7 Estuary monitoring programs with indicators, sample frequency, site numbers and water type for 2020-21.

Reporting zone	Program	Turbidity	DO	DIN	FRP	Chl-*a*	*n*/ year	Number of sites and water type
Daintree	DES WTW estuary monitoring	•	•	•	•	•	10	3 mid-estuary, 1 enclosed coastal
Dickson Inlet	DSC Port Douglas WWTP – monitoring plan	•	•	•		•	6	3 mid-estuary (sites 1, 3 & 4), 1 lower estuary (sites 5), 1 enclosed coastal (site 7)
Barron	CRC Northern WWTP plan	•	•	•	•	•	6	4 mid-estuary (sites 2 - 5) 1 lower estuary (site 6)
Trinity Inlet	CRC Edmonton/Southern WWTP - monitoring plan.	•	•	•	•	•	6	8 mid-estuary (sites 1 – 8)
Russell-Mulgrave	CRC Gordonvale WWTP - monitoring plan.	•	•	•	•	•	3 (Site 7), 6 (Site 6)	1 lower estuary (site 6), 1 mid-estuary (site 7)
Johnstone	CCRC Ninds CK REMP, DES GBR CLMP		•	•	•	•	10 (EHP1-3), 11 (CLMP)	4 mid-estuary (EHP1 – 3, CLMP[#])
Moresby	DES WTW estuary monitoring	•	•	•	•	•	10 (sites 1 to 5), 5 (site 6).	5 mid-estuary, 1 lower estuary (site 6)
Hinchin-brook	DES WTW estuary monitoring	•	•	•	•	•	11 (site 1), 10 (sites 2	3 enclosed coastal

[#]GBR CLMP (GBR Catchment Loads Monitoring Program) site samples nutrients (DIN and FRP) only. Water type is defined by the Environmental Protection (Water) Policy (EPP) 2009 Wet Tropics Map Series. Note: DES is Queensland Department of Environment and Science, DSC is Douglas Shire Council, CRC is Cairns Regional Council, CCRC is Cassowary Coast Regional Council, WTW is Wet Tropics Waterways, and WWTP is waste water treatment plant.

Table 8 Months that water quality monitoring was conducted for each estuary during 2020-21

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Daintree		•	•	•	•	•		•	•	•	•	•
Dickson Inlet	•		•		•		•		•			•
Barron	•	•	•	•	•							•
Trinity Inlet		•		•		•		•		•		•
Russell-Mulgrave		•		•		•		•		•		•
Johnstone	•	•	•	•	•	•		•	•	•	•	
Moresby		•	•	•		•	•	•	•			
Hinchinbrook Channel		•	•	•	•	•	•	•	•	•	•	•

Monitoring for the Russell-Mulgrave did not occur at all sites for each month. For the Johnstone estuary the table shows monitoring at CCRC sites; monitoring at GBR CLMP site (Coquette point) for DIN and FRP occurred for all months except September. For the Moresby site 6 (lower estuary) monthly sampling commenced in January. For Hinchinbrook Channel only site 1 was monitored in September. Pesticide monitoring is not included in the table.

Sampling and analysis of the water quality indicators (DO, DIN, FRP and Chl-*a*) was conducted at all monitoring sites in accordance with the Environmental Protection (Water) Policy Monitoring and Sampling Manual (DES 2018). To address the influence of tides on water quality indicators, monitoring at sites was conducted on the ebbing (outgoing) tide as recommended (DES 2018). Whilst dissolved oxygen concentrations in estuarine waters typically vary with the time of day as a result of biological processes, the influence of tide can substantially exceed that of time of day on dissolved oxygen concentrations, for example see Fortune and Mauraud (2015). Laboratory analyses of water samples were conducted by various laboratories accredited by NATA. This monitoring is a collaboration between, DES, DSC, CRC, CCRC and the WTHWP.

Sampling and analysis of pesticides for the Daintree estuary, Russell-Mulgrave estuary at Deeral and East Russell, and Johnstone estuary at Coquette Point are as per freshwater basins and described in section 2.2.1.

2.3.2. Habitat and Hydrology Indicators

Data collection details and methods for the habitat and hydrology indicators (riparian extent, mangrove and saltmarsh extent, flow and fish barriers) for the Report Card are described below.

2.3.2.1. Estuarine riparian vegetation extent

The assessment of riparian vegetation extent in the estuarine environment was conducted on the most recent Regional Ecosystem data set (2017, Version 5) by reviewing the proportion of riparian area that has been cleared of natural vegetation. In the case of estuaries, riparian vegetation is assessed on waterway banks upstream to the tidal limit and also includes vegetation communities that extend from river mouths along coastal shorelines that face estuary waters within the estuary zone. Thus, the term estuarine riparian vegetation includes vegetation communities occurring on river banks and coastal shorelines. The riparian area was determined to be any vegetation within 50 m of the bank of the estuarine environment. The area assessed was from the estuary mouth, upstream to the tidal limit. The tidal limit was determined based on vegetation species distribution observed *in situ* and expert opinion relating to these species. The actual spatial area assessed along the length of each estuary was recorded so that the same spatial layer for each assessment could be used in subsequent assessments allowing for comparability of Report Cards over time. Maps of the riparian extent assessment area for each estuary reporting zone are provided in Figure 18 to Figure 25 (Appendix B).

The data were obtained through Google Earth, and the Queensland Herbarium's Regional Ecosystem (version 5) mapping, and prepared by DES. The extent of riparian area within the 50 m buffer was compared to pre-clearing extent to determine the percentage of loss.

The following procedure was used for the spatial estimation of the proportion of the estuary area where natural vegetation (of any sort) has been cleared within 50 m of the water's edge.

1. Start from the upstream point that was considered by signs (vegetation) to be the tidal limit.
2. Construct lines for both the left and right sides of the stream, following the outermost waterline.
3. Construct areas 50 m wide as 'buffer strips' on the outside of the sides of each estuary.
4. Select all data within these defined areas to extract the latest Herbarium data (2017 Remnant Regional Ecosystems of Queensland, Version 5.0).
5. Using just the non-ocean data within the selected data, calculate the proportional area of non-remnant as the estimation result of the proportional area of natural vegetation (of any sort) that has been cleared within 50 m of the water's edge.
6. Determine riparian area loss by comparing extent layers for pre-clear to 2017, 2013 to 2017 and 1997 (first year of mapping) to 2017.

2.3.2.2. Mangrove and Saltmarsh Extent

The assessment of mangrove and saltmarsh extent uses data from Queensland Regional Ecosystem (RE) Version 5 and Queensland Wetlands Data Version 5 mapping supplied through Queensland Herbarium. The data layers for 2017, 2013 and the estimated pre-clearing areal extent of intertidal habitat categories (mangrove and saltmarsh) were compared and the proportion of extent loss since pre-clearing was determined.

Spatial estimation of the percentage loss from pre-clearing to 2017 and from 2013 to 2017 for important and dominant intertidal vegetation categories, including mangrove, samphire and melaleuca (REs 7.1.1, 7.1.2, 7.1.3 and 7.1.5) selected from Regional Ecosystem data were conducted as follows.

1. Start with the defined area of each estuary.
2. Select all the dominant Regional Ecosystem (RE1) data for the proportion of the selected intertidal important categories of vegetation including mangrove, samphire and melaleuca (7.1.1, 7.1.2, 7.1.3 and 7.1.5) with these defined areas used as a 'cookie cutter' to extract from the three Herbarium data sets of pre-clearing, 2013 and 2017 Remnant Regional Ecosystems of Queensland.
3. Calculate the percentage loss from the difference of combined area of the vegetation categories from the dominant Regional Ecosystem data for pre-clearing to 2017, and for 2013 to 2017.

Maps of the mangrove and saltmarsh extent assessment areas and the pre-cleared regional ecosystem vegetation layer for each estuary reporting zone are provided in Figure 26 to Figure 33 (Appendix C).

2.3.2.3. Shoreline mangrove habitat

The shoreline mangrove habitat indicator incorporates shoreline monitoring data of mangrove habitat structure, canopy cover and impacts which quantifies both physical and anthropogenic drivers of change at the estuary scale. The indicator has been developed to provide a repeatable and verifiable assessment of estuarine habitat that is sensitive to environmental change and human disturbance. The indicator adds to the assessment of habitat extent from the mangrove and saltmarsh indicator by providing measures of mangrove habitat quality.

The shoreline assessments underpinning the indicator are spatially restricted to the observable seaward fringe of the mangrove habitat. This section of the mangrove community informs on the habitat condition at the interface between land and water which is a key aspect of mangrove habitat health. Mangrove habitat extending from the coastline to the landward fringe is also an important aspect of condition which can inform upon pressures including land management and land use changes. The shoreline mangrove habitat indicator can be integrated with assessments that include more extensive habitat condition monitoring as and when they are developed.

Monitoring data for the shoreline mangrove habitat indicator is sourced from the Cairns and Far North Queensland MangroveWatch program coordinated by the Cairns and Far North Environment Centre (CAFNEC), which is a citizen science approach to mangrove habitat monitoring. The program has been conducting mangrove assessments at estuaries in the Wet Tropics region following the Shoreline-Video Assessment Method (S-VAM) protocol (Mackenzie *et al.* 2016). The S-VAM protocol is a standardised peer-review method that has been used for mangrove assessments across Queensland. The method of data collection and process is outlined below and the full description is available in Mackenzie (2021).

Shoreline surveys

Citizen scientists collected continuous video of estuary shorelines from a boat travelling between 6-10 kts speed, parallel to shoreline contours at a distance of up to 200 m from shore. The video camera was held at 90 degrees to the direction of boat travel at all times. A continuous 1-second GPS track was recorded. GPS waypoints and geotagged photos of special interest (for example wildlife, marine debris, dead mangroves, mangrove seedling banks, mangrove disturbance and places of local importance) were recorded. Voice recording while filming captured citizen science on-board observations to record local knowledge. Where possible, video data collection was captured on a low to mid tide during a neap tide period to ensure tidal waters were not obscuring shoreline features whilst maintaining safe navigation.

S-VAM surveys were undertaken to ensure whole-of-system capture of the main estuary channel shorelines from the mouth to upstream estuary limits or where practicably navigable. The S-VAM surveys provide a permanent visual record of estuary shoreline habitat that can be used to assess change over time.

To ensure data quality control, data was only accepted where at least one person on the S-VAM survey had participated in a MangroveWatch training event. Each survey team was provided with additional instruction sheets on the day to ensure video image data quality and time synchronisation between data streams.

Data was collected between April and November, and where possible was collected twice annually during the end-of-wet season period (Apr-May) and end-of-dry season period (Aug-Nov). Some surveys were missed in 2020 and 2021 due to COVID-19 pandemic limitations. Surveys have been conducted in all estuary reporting zones except for the Moresby (Table 9). Surveys for the Johnstone and Hinchinbrook have commenced but have not progressed to a stage that allows completion of the assessment for reporting.

Table 9 Shoreline mangrove habitat surveys and assessments for estuary reporting zones.

Estuary	Survey dates	Length of shoreline surveyed (km)	Percentage of estuary surveyed	Completed assessment for 2020-21
Daintree	May and September 2019	56.3	75%	✓
Dickson Inlet	September 2019	14.4	64%	✓
Barron	August to November 2019	32.2	75%	✓
Trinity Inlet	May to July 2019	32	80%	✓
Russell-Mulgrave	September 2019	28	50%	✓
Johnstone	April 2021			×
Moresby	-	-	-	-
Hinchinbrook Channel	October 2021			×

Post-survey Data Processing

The data streams collected from shoreline surveys were sent to MangroveWatch scientists for processing and assessment. Estuary video streams were converted to time stamped 1-second still image frames and shoreline shapefiles (.shp) were generated for each estuary in ArcMap 10.8 using existing estuary outlines from the Wetlands Mapping Program. A point-shapefile was generated for each estuary shoreline, with points representing 10-metre shoreline intervals creating a point-intercept transect line for each estuary shoreline. Analysis of data sets was conducted with R-studio to match video and still image video to 10 m shoreline points along the surveyed shoreline.

Estuary assessments

Five estuaries (Daintree, Dickson Inlet, Barron, Trinity Inlet and Russell-Mulgrave) have had surveys and data processing completed meaning that they have been fully assessed and have been scored and graded for the mangrove habitat indicator (Table 9). Only the lower 40% of estuaries was used for scoring. This was to provide standardisation of estuary habitat type for comparison between zones because the percentage of estuary assessed differed between estuaries. The methods used to generate mangrove habitat indicator scores are presented in Section 3.2.3.4,

2.3.2.4. Flow

Data collection for the estuary flow indicator follows that described for the basins (Section 2.2.2.2). The flow assessment sites used for the flow indicator for estuaries are presented in Table 10 along with the Queensland Government gauging station number. Flow assessment sites for estuaries only include the nearest upstream flow assessment sites on the waterways that discharge into the estuary.

Table 10 Estuary zone and flow assessment sites with Queensland Government gauging station number (GS no.) used for the flow indicator within each estuary.

Estuary and flow assessment site	GS no.
Barron estuary	
Barron River at Myola	110001D
Freshwater Creek at Redlynch Estate	110101A
Russell-Mulgrave estuary	
Mulgrave River at Peets Bridge	111007A
Russell River at Bucklands	111101D
Babinda Creek at The Boulders	111105A
Johnstone estuary	
North Johnstone River at Tung Oil	112004A
South Johnstone River at Upstream Central Mill	112101B

For estuaries, the rainfall data from the basin at which the estuary is located is used to determine the rainfall type of the reporting year (as per methods for the freshwater zone described in section 2.2.2.2). Details of the sites used to produce the rainfall records for the basins where estuaries are located are presented in Table 5.

2.3.2.5. Seagrass

Seagrass is monitored at two estuary reporting zones in the Wet Tropics (Trinity Inlet and Moresby) by the Queensland Ports Seagrass Monitoring Program (QPSMP). Seagrass is also present at the Hinchinbrook Channel and Dickson Inlet estuary reporting zones but is not currently monitored there. The location and habitat of seagrass meadows monitored in the Wet Tropics estuary reporting zones that were assessed for the 2021-22 reporting period are listed in Table 11. The QPSMP monitoring methods for Trinity Inlet and Moresby are the same as used by the QPSMP for inshore marine zones and an outline of the methods is provided in the Inshore Marine section 2.4.4 (Seagrass Data Collection) with more details provided in QPSMP reports for Cairns (e.g. York *et al.* 2016) and Mourilyan (e.g. Reason *et al.* 2016).

Table 11 QPSMP seagrass monitoring meadows by habitat and location for estuarine reporting zones.

Estuary zone	Habitat	Location	Meadow
Trinity Inlet	Estuary intertidal	Trinity Inlet	CN20
	Estuary subtidal	Trinity Inlet	CN19
			CN33
Moresby	Estuary intertidal	Mourilyan Harbour	MH1
			MH2
			MH3
			MH4
	Estuary subtidal	Mourilyan Harbour	MH5

2.3.2.6. Fish Barriers

Data for the fish barrier indicator category were collected in July 2017 by WTW for all eight estuary reporting zones. Data for the Hinchinbrook estuary zone was updated in 2021 from barrier mapping and field surveys conducted for the Fish Homes and Highways project managed by Terrain NRM in the Murray and Herbert basins. In addition to the Fish Homes and Highways project, the Regional Lands Partnership fish barriers project managed by Terrain NRM is conducting mapping and surveying of fish barriers in the Daintree, Mossman (including the Dickson Inlet estuary) and Barron basins during 2022 and will provide data for updates of these estuary zones over the 2021-22 reporting period. The funding and delivery of projects that include mapping and surveying fish barriers in the Wet Tropics region have provided opportunities for the estuary fish barrier assessment to be updated in greater detail from these projects and, for these four estuary zones, have aligned reasonably well with the recommended four-year cycle for fish barrier reporting updates. The assessment of estuary fish barriers for the Wet Tropics was conducted based upon the method developed for Mackay-Whitsunday (Moore 2016) with modifications appropriate for the Wet Tropics region.

The assessment was conducted upon the waterway network connected to the estuary mouth for each estuary zone. Given that the focus of the indicator is assessing physical impacts upon the movement and migration of diadromous fish species the spatial extent of the waterway network was limited to the area in which the species would be naturally distributed in the absence of artificial barriers. The area excluded waterways at elevations above which natural species distributions of diadromous fish occur. To determine the spatial extent for the assessment, the location of upper tidal limits (UTL) was determined for each waterway network from the Coastal Management District and the Wet Tropics riparian extent spatial layers (DES). The average upper tidal limit was identified as 10 m above sea level based upon the elevation of upper tidal limit locations using Google Earth Pro (accuracy of +/- 2.3 m standard deviations (Wang *et al*. 2017)). Expert opinion on the distribution of diadromous fish in relation to elevation was obtained for the Wet Tropics basins (Brendan Ebner JCU and CSIRO) and an elevation of 90 m above the upper tidal limit of 10m was identified. The elevation of 100 m above sea level is correlated with a separation between lowland fish communities and escarpment communities in the Wet Tropics region (Ebner pers. comm.). A boundary of 100 m elevation was mapped from the Queensland Government digital elevation model (25 metre Wet Tropics) data package (https://data.qld.gov.au/dataset/digital-elevation-models-25metre-by-catchment-areas-series/resource/f2cec980-5bdb-4e8e-b2d7-2fde284ae717) around the stream and estuary network layer (Queensland waterways for waterway barrier works, Queensland Fisheries 2013) for each estuary zone using Arc GIS to determine the spatial extent of the estuary assessment areas.

2017 Fish Barrier Assessment (reporting for 2015-16).

A desktop analysis was conducted on each assessment area by intersecting the Wet Tropics fish barrier spatial data layer developed by Lawson *et al*. (2010) and Kroon and Phillips (2015) with priority 3, 4 and 5 waterways of the stream and estuary network layer. Priority 3, 4 and 5 waterways only include waterways classified as ‘estuarine’ (priority 5), and waterways with ‘major’ (Strahler stream orders 4-7) and ‘high’ (Strahler stream orders 2-3 with low gradient; Strahler stream order 3 with medium gradient) risk categories. The analysis was performed on Google Earth Pro and used satellite imagery to identify precise locations of all potential barriers on priority 3, 4 and 5 waterways to produce a refined spatial layer of potential fish barriers for each estuary assessment area.

Field verification assessments were conducted on potential fish barriers for each estuary assessment area. Over 300 potential fish barriers were identified for field assessment and of these 87 were verified as fish barriers, whilst most of the remaining potential fish barriers were identified in the field as bridge structures. Of the 85 verified fish barriers, 62 were assessed directly in the field. For the remaining 23 barriers access was not possible and the assessment was conducted from Google Earth imagery and from local knowledge, including landholders and Terrain NRM staff who verified the presence of the fish barrier and the structural characteristics.

2021 Fish Barrier Update (reporting for 2020-21)

The fish barriers verified by the Fish Homes and Highways project were selected for the fish barrier assessment if they occurred in the Hinchinbrook estuary zone and if they were located on priority 3, 4 and 5 waterways. All selected barriers that had not previously been captured in the 2017 assessment were added into the 2020-21 update. A total of 15 additional barriers were added to the 18 fish barriers identified in 2017 for the Hinchinbrook estuary zone.

Fish Barrier Analysis

Verified fish barriers were assessed according to transparency/passability criteria to identify low transparency structures (Moore 2016). A spatial file of the locations of the verified fish barriers was created and for each estuary the following actions were performed on ArcGIS.

- The waterway layer was edited to show priority 3 and 4 waterways and estuaries (priority 5 waterways) whilst priority 1 and 2 waterways were removed. The waterways were intersected with the 100 m elevation boundary from a digital elevation model spatial file (Queensland Government 2005), removing waterways above 100 m elevation.
- The intersected waterway layer was selected, and lengths were determined using ArcGIS functions to calculate total stream length.
- The number of barriers was counted.
- Low transparency barriers were identified on the map. Only those that were located on waterways that could affect fish movement through freshwaters were used for the low transparency measure. Those that were located on waterways that did not extend beyond estuary habitat and could not affect fish movement to freshwaters were not used for the measure.
- The first upstream barrier for each waterway branch was identified and the length of each waterway downstream of the barrier to the estuary mouth was calculated using ArcGIS functions.

From these procedures the following measures were calculated and used for scoring the estuary fish barrier indicator.

The **‘barrier density**’ indicator was assessed by calculating the total waterway length (km) of priority 3, 4 and 5 waterways in the estuary assessment area and dividing the total waterway length by the total number of barriers in the estuary assessment area (Figure 6).

The **‘proportion of waterway length to the first barrier’** indicator was assessed by quantifying the distance (waterway length) downstream of the first barrier to the estuary mouth on all priority 3 and 4 waterways in the estuary assessment area (Figure 6). The total waterway length was divided by the overall connected waterway length to determine the proportion of waterway length of estuary waterways not impacted by barriers.

The **‘proportion of waterway length to the first low/no transparency/passability barrier’** indicator was assessed by quantifying the distance (waterway length) upstream to the first low/no transparency/passability barrier for priority 4 waterways only (Figure 6). The total waterway length was divided by the overall connected waterway length in the estuary assessment area to determine the proportion of waterway length upstream of the estuary waterways not impacted by low/no transparency/passability barriers. A low transparency/passability barrier was defined as a barrier that never or rarely drowns out (<1 flow event per year), a dam or weir with >2 m head loss, a causeway >2m high with pipe/culvert configuration <10 % and/or bankfull stream width and head loss >1 m.

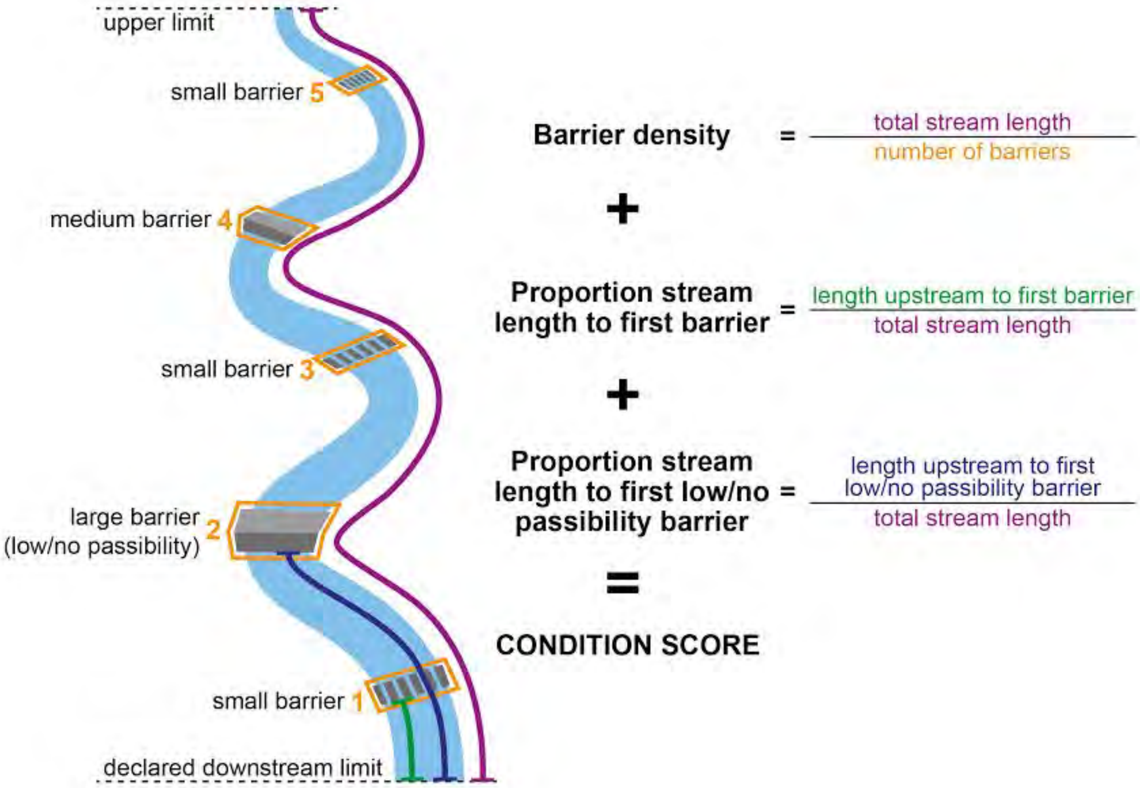

Figure 6 Diagram of the three fish barrier indicators and how they are calculated.

For purposes of the diagram the declared downstream limit is equivalent to the upper tidal limit. The fish barriers indicator category comprises of three indicators, barrier density, percent of stream length to the first barrier, and percent of stream length to the first impassable barrier. Each indicator is scored separately and then the scores for these three indicators are summed together to produce the overall score for the fish barriers index (Section 3.2.3.1).

2.3.3. Fish

Estuarine fish methodology is being developed and will be determined in collaboration with the Reef 2050 Integrated Monitoring, Modelling and Reporting Program (RIMReP) and other regional report card partnerships.

2.4. Inshore and Offshore Data Collection

The location of the inshore and offshore marine reporting zones, the inshore water quality, coral and seagrass monitoring sites, and the location of the offshore coral monitoring sites are shown in Figure 7. Long-term Monitoring Program (LTMP) sites provide data on coral communities. Close up maps of inshore monitoring sites for each of the four inshore zones including updates to pesticide passive sampling are in Appendix D Figure 34 to Figure 37.

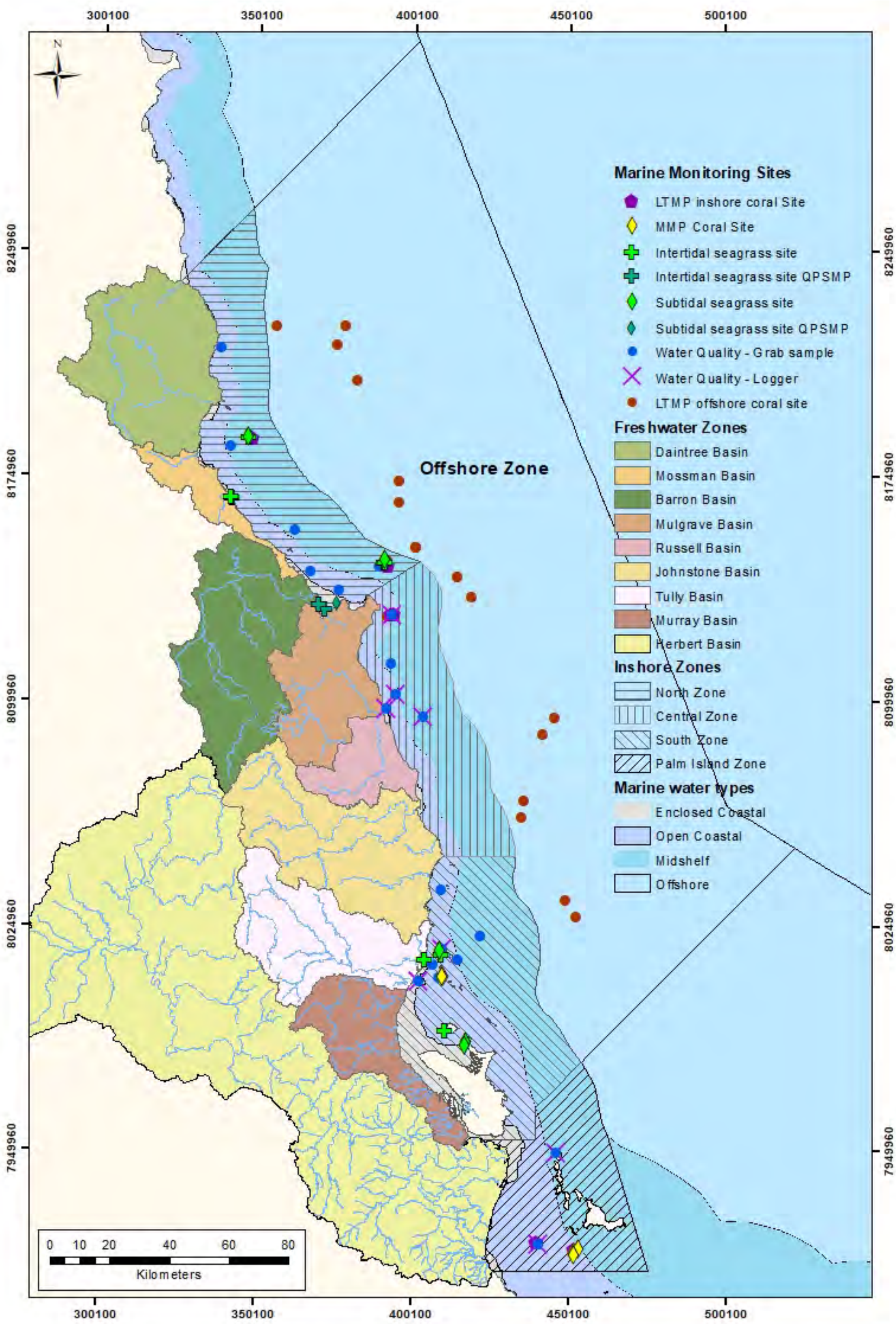

Figure 7 Reporting zones and monitoring sites for the inshore and offshore marine environments.

Note: Some monitoring sites are obscured, more detailed maps for each inshore zone are available in Figure 34 to Figure 37.

The inshore reporting zone includes enclosed coastal, open coastal and mid-shelf marine water types (see section 2.4.1 for more details on marine water type definitions), extending east to the boundary with the offshore waters (Figure 7). The inclusion of enclosed coastal, open coastal and mid-shelf waters for the inshore zone is consistent with the inshore zoning used by the Great Barrier Reef Marine Monitoring Program (MMP) in the Wet Tropics region for their annual inshore monitoring reports (for example see Gruber *et al.* (2020)).

2.4.1. Inshore Water Quality

Inshore water quality data for the Wet Tropics Region was collected for the MMP by the Australian Institute for Marine Science (AIMS) and James Cook University (JCU) (Table 12) over the reporting period. All water quality data were collected in accordance with the methods outlined in Gruber *et al.* (2020). The water type at each monitoring location is defined by the Environmental Protection (Water) Policy 2009 Wet Tropics Map Series and by delineation of marine waterbodies (GBRMPA 2010). Guideline values are set for the different water types in the Queensland Water Quality guidelines (DEHP 2009), the Environmental Protection (Water) Policy 2009 Wet Tropics (DEHP 2013) and the Water Quality Guidelines for the Great Barrier Reef Marine Park (GBRMPA 2010). The guideline values for inshore marine waters (enclosed coastal (EC), open coastal (OC) and mid-shelf (MS)) are listed in Table 41.

Table 12 MMP water quality monitoring sites for the Wet Tropics (2020-21) showing data source, water type for application of guideline values (GVs): mid-shelf (MS), open coastal (OC), enclosed coastal (EC), reporting zones, site name and code, and sample type.

AIMS data	JCU data	Water Type GV	Inshore zones and water quality monitoring sites	Sample type
North Zone				
√		OC	Cape Tribulation (C1)	Grab
√		MS	Port Douglas (C4)	Grab
√		MS	Double Island (C5)	Grab
√		OC	Yorkey's Knob (C6)	Grab
√		OC	Fairlead Buoy (C8)	Grab
√		MS	Green Island (C11)	Grab
Central zone				
√		OC	Fitzroy Island West (RM1)	Grab and logger
√	√	MS	RM3	Grab
√	√	MS	Frankland Group West (RM7)	Grab and logger
√	√	OC	High Island West (RM8)	Grab and logger
√	√	OC	Russell-Mulgrave River mouth mooring (RM10)	Grab and logger
South zone				
√	√	MS	East Clump Point (TUL2)	Grab
√	√	OC	Dunk Island North (TUL3)	Grab and logger
√	√	OC	Dunk Island South East (TUL5)	Grab
√	√	OC	Between Tam O'Shanter and Timana (TUL6)	Grab
√	√	OC	Bedarra Island (TUL8)	Grab
√	√	EC	Tully River mouth mooring (TUL10)	Grab and logger

AIMS data	JCU data	Water Type GV	Inshore zones and water quality monitoring sites	Sample type
Palm Island Zone				
√	√	OC	Pelorus and Orpheus Island West (BUR1)	Grab and logger
√	√	OC	Pandora Reef (BUR2)	Grab and logger

The monitoring sites for 'grab' water samples (suspended solids, nutrients and chlorophyll *a*) and deployment of water quality loggers (chlorophyll *a* and turbidity) for the MMP routine water quality sampling, from which the report card sources water quality data for the inshore zone, are listed in Table 12 and their locations are shown on the inshore zone maps (Figure 34 to Figure 37). From 2020-21 a rationalisation of the MMP has reduced the number of sites monitored as part of routine water quality sampling. Five sites (RM2, RM4, RM5, RM6 and RM9) in the Central zone, and three sites (TUL4, TUL7 and TUL9) in the South zone were ceased for routine monitoring and now are monitored only during selected high rainfall events. The AIMS and JCU MMP water quality sampling and analysis were conducted as per the methods of Gruber *et al.* (2020). Particulate nitrogen (PN), particulate phosphorus (PP), nitrogen oxides (NO_x), chlorophyll-a (Chl-*a*), total suspended solids (TSS), and turbidity (NTU) were selected as indicators for the report card inshore water quality (WTHWP 2018).

As part of the rationalisation of the MMP the monitoring of pesticides in inshore waters using passive samplers has been suspended. The report card used data from the passive samplers to report on pesticide risk for inshore zones. Up until 2018-19, data from passive loggers for reporting of pesticides for all four inshore zones was available. The sites with passive samplers were reduced for 2019-20 and pesticides were only reportable for the Central and South zones. As from 2020-21 pesticide data from passive samplers is no longer available for inshore zones.

2.4.2. Offshore Water Quality Data Collection

There is no data available for reporting offshore water quality for 2020-21.

Up until 2019-20, the data for the offshore assessment of water quality was extracted from the marine water quality (MWQ) Bureau of Meteorology dashboard based on remotely sensed analysis of reflectance. For 2019-20 there were notifications of limitations in data quality. In early 2021 the Bureau of Meteorology advised that the MWQ dashboard and underlying data preparation workflow was to be discontinued. Alternative data sources for offshore water quality reporting have been identified, in particular services and products produced by CSIRO for eReefs. Whilst data for 2020-21 for offshore water quality is not available it is expected that services from eReefs will provide data as from 2021-22.

2.4.3. Inshore and Offshore Coral Data Collection

Coral monitoring for the Wet Tropics region is conducted by AIMS through the MMP and the LTMP. The coral monitoring sites for each inshore zone are provided in Appendix E (Table 55) and the monitoring plan, which until 2021 sampled in alternate years, is provided in Table 13. The coral monitoring reefs for the offshore zone are provided in Table 14 and shows the LTMP sites sampled on odd years and even years. The inshore environment includes open coastal and mid-shelf waters, and coral monitoring for inshore zones, therefore, included MMP and some LTMP sites (Figure 7, Table 55), whilst offshore coral monitoring included LTMP sites only (Figure 7, Table 14). The MMP

2020-21 coral sampling occurred on the survey dates presented in Table 13. The LTMP coral sampling occurred in February 2020 and January 2021. Since the LTMP coral monitoring program conducts sampling of sites in alternating years data from the previous year is rolled forward for sites not monitored in the reporting year. For the 2020-21 reporting year, the 2019-20 data was rolled forward for reefs not monitored in 2021 (Table 13 and Table 14). Prior to 2021, the MMP also sampled reefs in alternating years, with additional unscheduled coral surveys (even year scheduled reefs sampled in odd years and vice versa) undertaken to fill gaps when disturbances were suspected.

Table 13 Inshore coral sampling locations. Black dots mark reefs surveyed as per sampling design, the "+" symbol indicates reefs surveyed out of schedule to assess disturbance.

Inshore zone	Reef	Program	2020	2021	Latest Survey
North	Snapper North	MMP	+	●	15/06/2021
	Snapper South	MMP	●	●	16/06/2021
	Low Isles	LTMP		●	13/01/2021
	Green	LTMP		●	7/11/2020
Central	Fitzroy West	LTMP		●	17/01/2021
	Fitzroy West	MMP	+	●	25/06/2021
	Fitzroy East	MMP	●	●	25/06/2021
	High East	MMP	+	●	9/07/2021
	High West	MMP	●	●	8/07/2021
	Frankland East	MMP	+	●	24/06/2021
	Frankland West	MMP	●	●	24/06/2021
South	Barnards	MMP	+	●	8/06/2021
	Dunk North	MMP	●	●	26/06/2021
	Dunk South	MMP	●	●	9/06/2021
	Bedarra	MMP	+	●	8/06/2021
Palm Island	Palms West	MMP	+	●	14/05/2021
	Palms East	MMP	●	●	15/05/2021
	Lady Elliot	MMP	●	●	12/05/2021
	Pandora North	LTMP		●	6/04/2021
	Pandora	MMP	●	●	12/05/2021
	Havannah North	LTMP		●	6/04/2021
	Havannah	MMP	+	●	13/05/2021

Table 14 Offshore reporting zone coral monitoring reefs.

Reef	2019-20	2020-21
Agincourt Reef (NO 1)	●	●
Mackay Reef		●
St Crispin Reef	●	●
Opal Reef (2)		●
Hastings Reef	●	●
Michaelmas Reef		●
Thetford Reef	●	●
Arlington Reef	●	
Moore Reef	●	●
Hedley Reef	●	
McCulloch Reef	●	
Peart Reef	●	
Feather Reef	●	●
Farquharson Reef (NO 1)	●	
Taylor Reef	●	

Inshore coral data from the MMP and LTMP were collected from permanently marked sites within the Wet Tropics region by AIMS. The MMP consisted of five 20 m (each 5 m apart) transects along the 5 m or 2 m depth contour. Digital depth gauges and electronic tide charts (produced by the Australian Hydrographic Service) were used to determine the desired depths of 5 m and 2 m below lowest astronomical tide (LAT).

LTMP core reefs are currently surveyed every second financial year (ending in an odd-numbered year) while a second set of reefs chosen to assess the effect of the 2004 Great Barrier Reef Marine Park re-zoning plan is surveyed in the alternate (ending in an even-number) financial year. Some reefs are common to both programs and so surveyed annually. Details of the LTMP survey methods are provided online by AIMS in their Standard Operating Procedures (SOPs).

The data collection methods of the MMP and LTMP are largely comparable. The following Standard Operational Procedure from the AIMS Long-term Monitoring Program were used for both MMP and LTMP.

- #9: (sic.) Coral surveys using the manta tow and SCUBA search techniques.
- #10: Surveys of benthic reef communities using underwater digital photography and counts of juvenile corals.

The data collection methods for the density of juveniles (juveniles per square metre of unoccupied suitable space) differs slightly between monitoring programs. Juveniles up to 5cm diameter are counted along the first 5 m of LTMP transects and the entire 20 m length of MMP transects. For both programs juvenile counts are converted to densities per area of substrate occupied by algae (considered potentially available for coral colonisation) as estimated from photo transects.

The MMP coral data for coral cover, macroalgal cover, rate of coral cover increase (change in coral), density of juvenile corals and community composition were sampled and analysed as per Thompson *et al.* (2016). For further detail on the MMP and LTMP methods, refer to Thompson *et al*. (2016) and Sweatman *et al.* (2007), respectively and to the AIMS Reef Monitoring website and SOPs.

2.4.4. Inshore Seagrass Data Collection

Marine Monitoring Program

The MMP seagrass sampling design was developed to detect change in inshore seagrass meadows in response to improvements in water quality parameters associated with specific catchments or regions and in context of disturbance events (McKenzie *et al*. 2015). The meadows monitored within the MMP were selected by the GBRMPA.

Mapping surveys were conducted to select representative meadows, which match the dominant community type, and average abundances (McKenzie *et al.* 2015). Sampled meadows were lower littoral (rarely exposed to air) and sub littoral (permanently covered with water) (McKenzie *et al.* 2015). Two sites were selected at each location to account for spatial heterogeneity (McKenzie *et al.* 2015). Additionally, minimum detectable difference (MDD) had to be no more than 20 % (McKenzie *et al.* 2015).

Monitoring timing was determined by GBRMPA for the MMP, with advice from experts. Monitoring for the reporting period occurred during the late dry (growing) season and late wet season, in order to obtain information on the seagrass communities' status pre- and post- wet. The MMP seagrass monitoring locations, sites and habitat type for the inshore zones are provided in Table 15.

Table 15 MMP seagrass monitoring locations sites and habitat for inshore zones.

Inshore zone	Habitat	Location	Site
North	Reef intertidal	Low Isles	LI1
		Green Is	GI1 & GI2
	Reef subtidal	Low Isles	LI2
		Green Is	GI3
	Coastal intertidal	Yule Pt	YP1 & YP2
South	Reef intertidal	Dunk Is	DI1 & DI2
	Reef subtidal	Dunk Is	DI3
	Coastal intertidal	Lugger Bay	LB1 & LB2
	Coastal subtidal	Missionary Bay	MS1 & MS2

Report card update

As from 2020-21 the MMP seagrass index is comprised of two indicators: seagrass abundance (percent cover) and seagrass resilience. Up until 2020-21, the seagrass index was comprised of three indicators: seagrass abundance (McKenzie, 2009; McKenzie et al., 2003), tissue nutrient status (carbon:nitrogen ratio) (McKenzie et al., 2015) and reproductive effort (production of spathes, flowers and fruits per unit area) (McKenzie et al., 2015). From 2020-21 the seagrass indicators have changed with the removal of tissue nutrient status and the replacement of the reproductive effort with a more holistic resilience indicator. The resilience indicator uses a multivariate approach to measure the capacity of seagrass to cope with disturbances and accommodates differences in recovery strategies between species. Species differ in their abilities to resist disturbances through physiological processes and modifications to morphology as well as recovering following loss by regeneration from seed and through plant growth. More information on the resilience indicator is provided in Collier et al. (2021).

For further information on site selection, methods and analysis, refer to the latest 'Marine Monitoring Program: Annual Report for inshore seagrass monitoring' available at https://elibrary.gbrmpa.gov.au/jspui/.

From the 2018-19 reporting year onwards, treating MMP transects as different sites has been discarded. For the MMP monitoring locations there are generally two transect blocks close to one another in the same meadow. It was decided in 2019 that these should not be counted as separate sites when being averaged within a zone and are now treated as replicates within a site.

Queensland Ports Seagrass Monitoring Program

The objective of the QPSMP is to report on the condition of seagrass in the highest risk areas of Queensland and use this information to assist in the planning and management of anthropogenic activities. The QPSMP assesses seagrass condition at 50 individual meadows located within 7 port locations along the Great Barrier Reef (Carter *et al*. 2016a). In contrast to the MMP which monitors smaller scale transect sites within individual meadows, the QPSMP monitors and reports on seagrass condition for entire individual meadows and sampling occurs annually during the peak of the seagrass growing season in late spring/early summer at the end of the dry season (Carter *et al.* 2016a). Meadow selection is based on their representation of the range of meadow types found in each location (dominant species, intertidal/subtidal, meadow size and mean biomass). Condition indicators reported for each meadow are mean above-ground biomass, meadow area and species composition (Carter *et al*. 2016a). The program and approach has had independent review on several occasions and results are regularly published in peer reviewed journals (Carter *et al.* 2016). For further information on site selection and methods in the Wet Tropics refer to previous QPSMP reports for Cairns (York *et al.* 2016). The location and habitat of seagrass meadows monitored in the Wet Tropics inshore marine zones for 2016-17 are listed in Table 16.

Table 16 QPSMP seagrass monitoring meadows by water body, habitat and location for the inshore zones.

Inshore zone	Habitat	Location	Meadow
North	coastal intertidal	Cairns Harbour	CN13
			CN34
	coastal subtidal	Cairns Harbour	CN11

The QPSMP report card approach was developed in consultation with the Gladstone Healthy Harbours Partnership (GHHP) to report on seagrass condition for the Gladstone region (Carter *et al*., 2015) and was implemented across the QPSMP Ports in 2014. The methods for setting baseline conditions, score calculation and indicator assessment (Bryant *et al.,* 2014; Carter *et al*., 2015, Carter *et al.* 2019) have received independent analysis and review through the GHHP Independent Science Panel.

2.4.5. Inshore and Offshore Fish Data

The development of marine (inshore and offshore) fish indicators and sampling methods is in progress with the view for inclusion in the Report Card once confirmed.

3. CONDITION AND STATE ASSESSMENT SCORING METHODS

3.1. General Scoring for Condition and State Assessments

The indicators are used to assess the different pressures on each of the environments in the region. The process of indicator selection, along with detail on the drivers and pressures in the Wet Tropics region, can be found in the Program Design (WTHWP 2018).

Ordinal categories are used to describe the scores for condition of indicators, indicator categories, indices and the overall grade. This follows a five-point grading system:

Very Good (A), Good (B), Moderate (C), Poor (D), Very Poor (E).

An overall condition grade was provided for separate reporting zones within each environment (freshwater basin, estuary, inshore marine and offshore marine). Scores were averaged from the indicator level to generate indicator category scores. Where an indicator category is represented by a single indicator the indicator category score is equal to the indicator score. Indicator categories were averaged to generate an index score, and indices were subsequently averaged to produce an overall score for an individual reporting zone in an environment.

Decision rules were developed for the minimum proportion of information required to generate the aggregated scores, as follows.

≥ 50 % of indicators to generate the indicator category score
≥ 60 % of indicator categories to generate the index score

Overall scores for reporting zones are presented in the Report Card, even if not all indicator categories and indices are available. However, the circle diagram presenting the data visually shows which indices contribute to the overall grade.

The common scoring range used for reporting is based on that used by the Great Barrier Reef Report Card, as shown in Table 17. Where required, indicator scores were standardised into the standardised scoring range by linear interpolation (scaling) within bandwidths. In the following sections, individual indicator scoring and associated formula for scaling are presented. Once standardised, relevant scores were averaged to aggregate into the higher category.

Table 17. Standardised scoring ranges and corresponding condition grades.

Scoring range	Condition grade and colour code
81-100	Very Good
61 to <81	Good
41 to <61	Moderate
21 to <41	Poor
0 to <21	Very Poor

Values for condition assessment of water quality are drawn from a range of sources including water quality objectives scheduled under the Environmental Protection (Water) Policy 2009, and water quality guideline values obtained from the Queensland Water Quality Guidelines (DEHP 2009), the GBRMPA Guidelines (GBRMPA 2010) and the ANZG (2018). For the purposes of the waterway assessment and to simplify terminology, all values obtained from these sources will be referred to as water quality guideline values.

3.2. Freshwater Basins and Estuaries

Basin and estuary environments share several indicators, indicator categories and indices and also apply the same or similar methods for determining scores of state and condition. To minimise repetitions this section combines the assessment and scoring methods for basins and estuaries, describing similarities and differences where they occur. The results technical report provides all results separately for basin and estuaries. Table 18 shows the similarities between scoring and assessment methods for estuaries and basins.

Table 18 Shared and similar scoring and assessment methods for indicators of the basin and estuarine environments.

Index	Indicator category	Indicator	Basins	Estuaries	Shared scoring method	Similar scoring method
Water quality	Sediment	Total suspended solids	●			
	Phys-chem	Turbidity		●		
		DO		●		●
	Chlorophyll *a*	Chlorophyll *a*		●		
	Nutrients	Dissolved inorganic nitrogen	●	●		
		Filterable reactive phosphorus	●	●		
	Pesticides	Pesticide risk metric	●	●	●	
Habitat & hydrology	Habitat modification	Impoundment length	●			
		Fish barriers		●		
	Flow	30th Percentile of 10 flow metrics	●	●	●	
	Riparian	Extent	●	●		
	Wetlands	Extent	●			●
	Mangroves and salt marsh	Extent		●		
	Invasive weeds	Extent, diversity and impact	●			
	Seagrass	Biomass, cover, species composition		●		

3.2.1. Water Quality – nutrient, sediment and physical-chemical indicators

The water quality condition assessments of basins and estuaries were conducted using monthly medians calculated for the reporting period (1/7/2020– 30/6/2021) for all water quality indicators excluding pesticides (TSS, DIN, FRP, Chl-*a*, turbidity and dissolved oxygen). Pesticides were assessed separately as outlined below. For data values recorded as below detection limit (BTL), a value of half the detection limit was applied.

To calculate a condition score (ranging from 0 – 100) for each water quality indicator, the medians from high flow periods and base-flow periods for freshwater basins and the annual medians for estuaries for sites within each estuary water type (all calculated from monthly values) are compared to scheduled guideline values. Only medians that meet or are better than the guideline value achieve a good or a very good score (Figure 8). This approach is very similar to the MMP system used in the marine zones, where the cut-off between "Good" and "Moderate" is where the indicator mean is equal to the guideline value.

Medians that do not meet the guidelines are scaled between the guideline and a scaling factor (SF). The approach to calculating a condition grade and translating this to the report card five-point grading is outlined in Table 19 and Table 20.

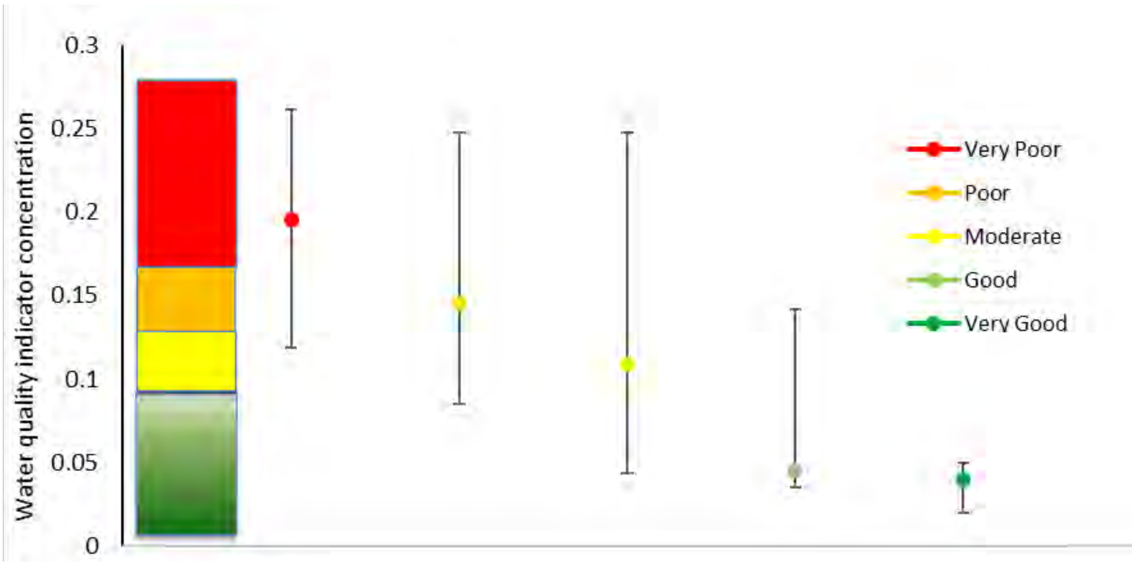

Figure 8. An example of how water quality grades are assigned. Where the middle point represents the annual median, the top whisker the 80th percentile and the bottom whisker the 20th percentile of the data. Only when the median meets or is better than the guideline (in this case below the guideline) can good or very good be scored. Scores for moderate, poor and very poor are equally scaled between the guideline and scaling factor.

The following steps are used to calculate condition scores for the water quality indicators.

- Derive DIN values from data where required (oxidised N + ammonia).
- For freshwater basins, excluding Mossman, separate the data according to high flow and base flow conditions.
- For the Mossman Basin separate the data to each of the five sites (data is all sampled during base-flows).
- For estuaries with more than one water type (enclosed coastal/lower estuary or mid-estuary), separate data according to water type (guideline values differ between water types).
- Determine monthly values for each site (for months with more than one data point monthly medians are calculated.
- For freshwater basins, excluding Mossman, calculate median for the high flow period and the base-flow period.
- For the Mossman Basin calculate median for each of the five sites.
- For estuaries calculate annual median for each water type (enclosed coastal, lower estuary or mid-estuary).
- Compare median to guideline values.
- Calculate condition score (0 – 100) following rules and formula in Table 19 and Table 20.

Water quality guideline values for nutrients provided in the water quality objectives (WQOs) for the Wet Tropics Basins (DEHP 2014) do not include concentrations values for DIN. DIN is comprised of oxidised nitrogen (NO_x) and ammonia nitrogen (NH_3) forms, and water quality objectives for both are specified for freshwater and estuary water types for the Wet Tropics (DEHP 2014). To derive guideline values for DIN (DIN-N) the WQO concentration values for oxidised nitrogen (NO_x-N) and ammonia nitrogen (NH_3-N) were summed for each water type. Further information about this approach is presented in the Program Design (WTHWP 2018).

Table 19 Rules, formula and scoring ranges and associated grades for nutrients, sediments and physico-chemical indicators in freshwater basins and estuaries of the Report Card when to meet a guideline values must be lower than the guideline.

Rule	Formula	Scoring range	Grade
Median meets GV and 80th percentile of data meets GV	Assigned 90.0[1]	81 to 100	Very Good
Median meets GV, but 80th percentile data does not meet GV	80.9-(19.9*(ABS((80th-GV)/(80th-median))))	61 to <81	Good
Median does not meet GV	60.9-(60.9*(ABS((median-GV)/(SF-GV))))	41 to <61	Moderate
		21 to <41	Poor
		0 to <21	Very Poor

Note: 80th means 80th percentile of the data; GV means guideline value; median is the annual median of the data; ABS means the absolute value/positive value; SF means scaling factor based on 90th percentile of available data).

Table 20 Rules, formula and scoring ranges and associated grades for nutrients, sediments and physico-chemical indicators in freshwater basins and estuaries when to meet a guideline values must be higher than the guideline (lower DO).

Rule	Formula	Scoring range	Grade
Median meets GV and 20th percentile of data meets GV	Assigned 90.0[1]	81 to 100	Very Good
Median meets GV, but 20th percentile of data does not meet GV	80.9-(19.9*(ABS((20th-GV)/(20th-median))))	61 to <81	Good
Median does not meet GV	60.9-(60.9*(ABS((median -GV)/(SF-GV))))	41 to <61	Moderate
		21 to <41	Poor
		0 to <21	Very Poor

Note: 20th means 20th percentile of the data; GV means guideline value; median is the annual median of the data; ABS means the absolute value/positive value; SF means scaling factor based on 90th percentile of available data).

[1]QLD Water quality guidelines 2009 recommend protocols for testing against 20th, 50th (median) and 80th percentiles. There is no *a priori* knowledge or guidelines regarding the entire distribution of water quality parameters in our systems, so assumptions/decisions regarding the other 20% of the data (between 80-100%) and how it should be distributed around the GV cannot be made. The middle (i.e. 90) of the Very Good range (Table 19) is assigned to scores for Very Good. SF for DO is based on the 99th percentile of all values.

3.2.1.1. Separation of high flow and base-flow water quality data

For freshwater basins excluding Mossman Basin, the water quality data were separated into high flow and base-flow periods using mean daily discharge data (Queensland Government) at each monitoring site and applying the mean daily base-flow (MDBF) cut off value (Orr *et al.* 2014), or an estimated cut off value (Table 21). This procedure allowed the separate scheduled guideline values for high flows and base-flows (Table 24) to be applied for calculation of the water quality scores. Base-flow is considered here to be flow that occurs in the absence of runoff due to rainfall events (Orr *et al*. 2014). For the MDBF cut off values, base-flow was calculated from the ratio of base-flow to total flow averaged across all years according to Grayson *et al*. (1996), using the River Analysis Package (eWater CRC 2012) as described by Orr *et al*. (2014). Base-flow was defined as all periods when mean daily discharge was less than or equal to the base-flow cut off value. Mean daily base-flow values have not been calculated for the Mulgrave and Russell CLMP sites, so base-flow cut off values were estimated and were set as the mean daily discharge, above which, high flow event sampling was initiated for DES loads monitoring. Monthly medians for basin water quality were calculated separately for high flow and base-flow conditions, and medians for high flow and base-flow periods were calculated from the monthly medians for each basin. For the purpose of calculating condition scores for the high flow and base-flow periods, the North Johnstone and the South Johnstone sub-basins were treated as separate basins. Note that the assessment of basin water quality will incorporate updated base-flow cut off values for separating high flow and base-flow conditions developed by Binns and Waters (2018) when scheduled. Examples of base-flow cut off values at sites for which data is currently available are presented in Table 21 and are lower than the values produced from the current method.

Table 21 Mean daily base-flow values for each GBR CLMP monitoring site.

Basin	GBR CLMP site	Base-flow cut off value (m^3/s)
Barron	Myola	8.2
Mulgrave	Deeral	30.0*
Russell	East Russell	39.5*
Johnstone	North Johnstone at Goondi	31.6
	South Johnstone at Central Mill	15.0 (12.1 – 13.7#)
Tully	Euramo	61.2 (51.1 – 53.4#)
Herbert	Ingham	44.2

Mean daily base-flow sourced from Orr *et al*. (2014) or by estimation (*). # Shows the base-flow cut off values from the method developed by Binns and Waters (2018) and are yet to be scheduled.

3.2.1.2. Mossman Basin base-flow water quality data

The Mossman Basin water quality was conducted as part of their Environmental Impact Monitoring Program and did not include monitoring during high-flow conditions. Monthly values for DIN, FRP and TSS were determined for the pooled data from the three sites MR3, MR4 and MR4.1 located on the Mossman River upstream of the confluence with South Mossman River (MR-US), the South Mossman River site SMR1 (SMR), and the Mossman River site MR5 located downstream of the confluence with the South Mossman River (MR-DS).

3.2.1.3. Scaling factors

Scaling factors for the freshwater nutrient and sediment indicators (DIN, FRP and TSS) were derived as follows. The historical GBR CLMP data were pooled from all basins (seven sites). The data were separated into high-flow and base-flow periods using an approximation method, where any 'event-flow' data (indicated by consecutive samples within a single day or over consecutive days) represented samples taken above the event-flow threshold, and that conversely, any discrete 'ambient' samples (approximately monthly) were taken below the event-flow threshold (and therefore represented base-flow). The 90th percentile was set as the SF and was calculated for each data set (Table 22). The advantage of this approach was that the SFs were derived from the largest sample size available for high flow and base-flow conditions and the number of SF values across the Report Card were minimised and provided consistency between basins.

Table 22 Scaling factors (SF) for calculating condition for basin water quality indicators.

Indicator category	Sediment	Nutrients			
Indicator	TSS	DIN		FRP	
Flow type	(mg/L)	(µg/L)	(mg/L)	(µg/L)	(mg/L)
High flow	191	306	0.306	16	0.016
Base-flow	74	261	0.261	13	0.013

For the estuarine indicators DO, turbidity, DIN, FRP and Chl-*a*, historical data were sourced for each estuary reporting zone from available data sets. Scaling factors were set by comparison of data sets with guideline values using expert knowledge, because there were too few historical data available to calculate sensible scaling factors from 90th percentiles. Guideline values for moderately disturbed waters are consistent across the estuary reporting zones for each water type (mid-estuary or lower estuary).

Table 23 Scaling factors for calculating condition for estuary water quality indicators.

Indicator category	Physico-chemical		Chlorophyll-*a*	Nutrients			
Indictor	Turbidity	DO	Chl *a*	DIN		FRP	
	(NTU)	(% saturation)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(mg/L)
	10	50 – 111	5	200	0.200	10	0.010

3.2.1.4. Guideline values

For freshwater basins, the water quality indicator guideline values (GVs) for moderately disturbed (MD) freshwaters (50th percentile) for base-flow conditions (DEHP 2014 (Barron, Mulgrave and Johnstone Basins) and 80th percentile for high flow conditions (DEHP (2014) and Orr *et al*. (2014)) were applied and are provided in Table 24. All GVs are sourced from the EPP (2009) for Wet Tropics Basins (DEHP 2014). The scheduled high flow GVs were set as the 80th percentile of historical data from the upper Tully Gorge reference site, which has naturally low FRP concentrations. Concentrations of FRP are diluted during rainfall run-off events, as it takes longer to become soluble than other nutrients (for example DIN). Consequently, the FRP GVs are lower for high flows than for base-flows. The moderately disturbed values for base-flow conditions are derived from 50th percentiles of impacted end of system catchment sites, which drain agricultural areas where phosphorus is applied in the form of fertiliser.

Table 24 Scheduled water quality guideline values for Wet Tropics basins.

Guideline Values		TSS (mg/L)	DIN (µg/L)	FRP (µg/L)
Base-flows				
MD	All basins	8	60	8
High flows				
80th Percentile	All basins	52	114	4

Source EPP (2009) Wet Tropics Basins.

For estuaries, the guideline values for moderately disturbed mid estuary and moderately disturbed lower estuary/enclosed coastal waters (EPP 2009 Wet Tropics Basins) were applied. For estuary reporting zones where monitoring sites were located in both mid estuary and lower estuary water or enclosed coastal types (for example the Barron estuary, see Table 7) data were separated according to water type for the calculation of annual medians, and calculation of condition scores using the specified guideline values for each water type, as shown in Table 25 (EPP 2009 Wet Tropics Basins).

Table 25 Water quality guideline values for Wet Tropics moderately disturbed estuarine waters.

Guideline Values	Turbidity (NTU)	DO (% sat.)	Chl *a* (µg/L)	DIN (µg/L)	FRP (µg/L)
Mid estuary	10	80 – 105	3	45	5
Lower estuary/ enclosed coastal	10	85 - 105	2	25	5

The moderately disturbed guideline values for estuarine waters are the 80th percentiles of the reference data except for the lower DO values which are the 20th percentile of the reference data. Source EPP (2009) Wet Tropics Basins.

3.2.1.5. Calculation of annual condition scores for each indicator.

The following rules were applied to calculate the annual condition score for each indicator.

- For each basin, excluding the Mossman Basin, the condition scores for the high flow and base-flow period were multiplied by the proportion of days of the year they occurred and were then summed to provide the annual condition scores for each indicator.
- For the Johnstone Basin, the annual condition scores ware averaged from the annual condition scores of the North Johnstone and South Johnstone sub-basins.
- For estuary reporting zones, the condition scores for each indicator were multiplied by the proportion of data values within each water type within the reporting zone (enclosed coastal/lower estuary or mid estuary) and then condition scores were summed.

For the Mossman Basin, the condition score was calculated as follows.

- The total catchment area upstream of the each monitoring site was determined using a 12.5 m cell-size hydrologically-correct digital elevation model (DEM) derived by the Department of Environment and Science based on the latest 1 second (≈30 m) SRTM-derived DEM-S elevation data (https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/72759) and State 1:25,000 waterway mapping (qldspatial.information.qld.gov.au).
- The adjusted upstream catchment area for each assessment site was determined, which is all the catchment area up until the next upstream monitoring site if present (applicable to sites MR4.1 and MR5).
- The proportion of total catchment for each monitoring site was determined and multiplied by the standardised score for the monitoring site.
- All scores were summed to provide the final basin score.

The upstream catchment area, adjusted catchment area and proportion of total upstream catchment area is presented in Table 26.

Table 26 Mossman Basin monitoring sites adjusted catchment area and proportion of total upstream catchment area.

Site	Upstream catchment area (km^2)	Adjusted catchment area (km^2)	Proportion of total upstream catchment
MR2/MR4	104/106	104	0.536
MR4.1	106	1	0.005
MR5	196	1	0.004
SMR1	89	89	0.456

Condition scores for indicators are aggregated into indicator categories (as presented in Table 22 and Table 23) and the water quality index by averaging the scores following decision rules for minimum information.

3.2.2. Water quality - Pesticides

In regional report cards prior to the 2017-18 reporting period, the Pesticide Risk Metric (PRM; previously referred to as the ms-PAF method) had been used to calculate the mixture toxicity for photosystem II (PSII) herbicides only. PSII herbicides share a common mode of action (MoA), and therefore, the ms-PAF could be calculated using the concentration addition model of joint action (Bliss 1939; Plackett and Hewlett 1952; Könemann 1981). From the 2017-18 Report Card, the ms-PAF approach was applied to pesticides with multiple MoAs (Table 3). The ms-PAF for pesticides with different modes of action was calculated using the independent action model of joint action (Plackett and Hewlett 1952). Further details on how the Pesticide Risk Metric calculations were made are provided in Warne *et al*. (2020). The pesticide mixture toxicity was calculated for all samples collected over the standardised 182-day wet season, commencing when a rise in river water level and an increase in aqueous pesticide concentrations occurs. Where there was more than one sample per day a daily mean concentration was calculated.

The mixture toxicity data (i.e. ms-PAF values) for all water samples collected over the wet season were then summarised as a single PRM value. In order to do this it was necessary to estimate the daily average ms-PAF for days that weren't monitored during the wet season using a multiple imputation technique (Rubin 1996; Donders *et al*. 2006; Patrician 2002). This involved fitting a statistical distribution to the observed data for the wet season for the site. This distribution was then used to impute values to fill in the missing days in the 182-day period. The resultant 182 days of data were then divided by 182 to obtain the Pesticide Risk Metric, and ranked into five risk categories (Table 27). These categories are consistent with the ecological condition categories used in the Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters.

Table 27. Grading description for the pesticides risk assessments.

Risk categories (% species affected)	% species protected	Risk Level	Pesticides assessment	Scaling of scores for aggregation
≤1.0%	≥99%	Very low risk	Very good	VG = 81+ ABS((19 - ((score-0) *(19/1))))
>1 – 5%	95 – <99%	Low risk	Good	G= 61+ ABS((19.9 - ((score -1.01) *(19.9/3.99))))
>5 – 10%	90 – <95%	Moderate risk	Moderate	M=41+ ABS((19.9 - ((score -5.01) *(19.9/4.99))))
>10 – 20%	80 – <90%	High risk	Poor	P= 21+ ABS((19.9 - ((score -10.01) * (19.9/9.99))))
>20.0%	<80%	Very high risk	Very poor	VP=0+ABS((20.9 - ((score-20.01) *(20.9/79.99))))

All values were rounded to the nearest whole number. For Russell-Mulgrave, the mean of the pesticide scores for each river basin is used for the estuary. Pesticide condition scores were aggregated into the water quality index following the procedure for the other water quality indicator categories.

3.2.3. Habitat and Hydrology

3.2.3.1. Habitat Modification (instream)

Impoundment Length (Freshwater Basins)

The suggested rating scheme (Table 28) was derived from earlier work on Murray-Darling Basin rivers, which involved benchmarking the ecological condition of multiple rivers in relation to several ecological indicators, one of which was the proportion of river impounded by dams and weirs. The ecological condition of streams was assessed during benchmarking based on existing studies and the expert opinion of a panel of experienced aquatic ecologists (see DNR 2000 and Sheldon *et al*. 2000).

There are likely to be differences in the degree of ecological impact resulting from impoundment of stream segments in differing areas of the stream network, but currently it is not possible to account for such complex differences in any robust way. The rationale for including impoundment length as an indicator was to highlight the loss of natural habitat and ecological processes in the region, many of which are related to natural channel wetting and drying – something that is lost as a result of impoundment. An assumption of status quo is implied in the scoring for impoundment length (rather than cause-and-effect with ecological function), with additional impoundments lowering subsequent Report Card scores.

Table 28. Grading description for the impoundment length indicator for freshwater basins.

% of waterway impounded	Condition grade	Scaling of scores for aggregation
< 1.0%	Very Good	VG= 81+ ABS((19 - ((score-0) *(19/0.99))))
1.0-3.99%	Good	G= 61+ ABS((19.9 - ((score -1) *(19.9/2.99))))
4.0-6.99%	Moderate	M=41+ ABS((19.9 - ((score -4) *(19.9/2.99))))
7.0-9.99%	Poor	P=21+ ABS((19.9 - ((score -7) * (19.9/2.99))))
≥ 10.0%	Very Poor	VP=0+ABS((20.9 - ((score-10) *(20.9/90))))

Fish Barriers (Freshwater Basins)

Methods of calculating condition scores for fish barriers will be presented following development and the review of the measures and indicators

Fish Barriers (Estuaries)

To assess the condition of fish barriers a scoring range and subsequent score was applied for each of the three indicators (Table 29 to Table 31) following the method developed by Moore (2016) used for the Mackay Whitsunday report cards. Each estuary was allocated a score for each indicator based on these scoring ranges. The final aggregated fish barriers indicator score for each estuary was derived by adding these three scores together (Table 32).

Table 29 Scoring range and subsequent score assigned for the barrier density indicator.

Scoring Range (km/barrier)	Score	Condition grade
≥16.1	5	Very Good
8.1 - 16	4	Good
4.1 - 8	3	Moderate
2.1 - 4	2	Poor
0 - 2	1	Very Poor

Table 30 Scoring ranges and score assigned for 'stream length to the first barrier as a proportion (%) of total stream length'.

Scoring Range (%)	Score	Condition grade
No Barriers	5	Very Good
80% - 99.9%	4	Good
60% - 79%	3	Moderate
40% - 59.9%	2	Poor
0% - 39.9%	1	Very Poor

Table 31 Scoring ranges and score assigned for 'stream length to the first low/no transparency/passability barrier as a proportion (%) of total stream length'.

Scoring Range (%)	Score	Condition grade
no low pass barriers (100%)	5	Very Good
90.1% – 99.9%	4	Good
80.1% - 90%	3	Moderate
60.1% - 80%	2	Poor
0% - 60%	1	Very Poor

Table 32 Overall fish barrier condition scoring range and fish barrier condition rating.

Scoring Range	Overall Fish Barrier Condition Rating	Scaling of scores for aggregation
14-15	Very Good	VG = 81+ ABS((19 + ((score-15) *(19/1)))
11-13	Good	G= 61+ ABS((19.9 + ((score -13) *(19.9/2))))

8-10	Moderate	M=41+ ABS((19.9 + ((score -10) *(19.9/2))))
5-7	Poor	P= 21+ ABS((19.9+ ((score -7) * (19.9/2))))
3-4	Very Poor	VP=ABS((20.9 + ((score-4) *(20.9/1))))

3.2.3.2. Flow (Freshwater Basins and Estuaries)

The flow indicator scores the daily flow record for the reporting year at a given flow assessment site. There are 10 flow measures that contribute to the flow indicator score (Figure 9). Each measure assesses observed flow data against the reference distribution from the predevelopment modelled flow for the given flow assessment site. The reference distributions are selected for one of the four rainfall types (drought, dry, average or wet) to match the rainfall type of the reporting year. The 10 flow measures have been selected to represent key components of the natural flow regime that are required by a range of ecological assets with links to water resources that are sensitive to changed water allocation and management conditions. The key flow components and ecological assets are: cease to flow - amphibians, riffles and waterholes; low flows - low flow spawning fish species, reptiles, amphibians, riffles and waterholes; medium flows - riffles; and high flows - fisheries production in estuaries. Details of the flow requirements of the assets (including seasonal flow requirements), their links to the flow measures and a description of the flow measures are provided in Appendix F Table 56 to Table 58 and also presented in the Report Card Flow Indicator Project report (Stewart-Koster *et al*. 2018) available from the WTHWP website.

Note that due to landscape changes resulting from human activities, including vegetation clearing, removal of wetlands, levelling, modification of channel morphology and removal or addition of waterway channels, the characteristics of flood waters including their duration, extent and frequency may have been affected. Consequently, whilst flow volumes during flood events may be similar to predevelopment levels the actual hydrological characteristics of the flood and inundation events, and hence their ecological functioning, may be altered.

Table 33 The 10 flow measures used for the flow indicator, the season to which they apply and the hydrologic definition of the measure.

Low flow Duration	July-Jan	Total duration of flows which remain equal to or below a lower threshold for the reporting period (annual).
Low flow Frequency	July-Jan	Count of the number of occurrences during which the magnitude of flow falls to or below the threshold during the reporting period (annual).
Low flow variability	July-Dec	Coefficient of variation (standard deviation/mean) of daily flow for dry season.
Driest six Months	July-Dec	Proportion of annual discharge contributed during the months July-December.
Cease to flow Duration	All year	Total duration of where flow ceases during the reporting period (annual).
Cease to flow Frequency	All year	Count of the number of occurrences during which flow ceases during the reporting period (annual).

Medium flow Duration	All year	Total duration of flows which remain equal to or above a threshold for the reporting period (annual)
Medium flow Frequency	All year	Count of the number of occurrences during which the magnitude of flow passes from below to equal or above the threshold during the reporting period (annual).
High flow duration	All year	Total duration of flows which remain equal to or above a threshold for the reporting period (annual)
High flow Frequency	All year	Total count of flows which remain equal to or above a threshold for the reporting period (annual)

Source: Stewart-Koster *et al*. (2018).

The scoring for each flow measure is based upon the percentile range representative of standard deviations from the mean as presented in Table 34.

Table 34 The benchmark measures for all the flow measures expressed as standard deviations from the mean and approximate percentiles.

Score	Target standard deviations from mean	Rationale	Percentile range
5	1	within 68.27% observed range	15.87-84.13
4	2	within 95.45% observed range	2.28-15.87, 84.13-97.72
3	3	within 99.73% observed range	0.13-2.28, 97.72-99.87
2	4	within 99.99% observed range	0-0.13, 99.87-100
1	5	outside the observed range	<0, >100

The flow measures score the flow for the reporting year on a scale of 1 to 5. For each flow assessment site, the 30th percentile value of all 10 flow measures is used to provide a summary score. Several summary statistics were evaluated during the development of the flow indicator (Stewart-Koster *et al*. 2018) and the 30th percentile value was selected as the most appropriate summary statistic for representing the range of the 10 flow measures. The other summary statistics evaluated were the mean, the mode and the minimum score. The procedures required for producing flow measure scores and summary scores were conducted using the flow indicator tool developed for the Report Card Flow Indicator Project (Stewart-Koster *et al*. 2018). The summary scores from the flow assessment sites were converted from the 1 to 5 scale to the standardised scale of 0 to 100 for aggregation with other report card indicators.

For each flow assessment site, the following steps were applied to provide a standardised score from 0 to 100 from the output score of the flow assessment tool (1 to 5).

1. Determine the 30th percentile value from the 10 flow measures (each scored 1-5) for each flow assessment site.
2. Apply the following formula for scores of <2: (20.9 + ((30th percentile - 1.9)*(23.2))).
3. Apply the following formula for scores of 2 to <5: ((30th percentile x 20) - 19).
4. Apply the following formula for scores of 5: 80 + ((M_{min} - 1) x 5) where M_{min} is the lowest scoring measure (1 to 5) for the flow assessment site.

The 30th percentile score, standardisation formula and standardised scoring range with grade colour code are presented in Table 35.

Table 35 Standardisation formula for 30th percentile scores of flow assessment sites.

30th percentile score	Formula applied for standardisation	Standardised range
5	80 +((minimum flow measure score - 1) x 5)	81-100
4 - <5	(score x 20) - 19	61-80.9
3 - <4	(score x 20) - 19	41-60.9
2 - <3	(score x 20) - 19	21-40.9
1 - <2	20.9 + ((score - 1.9) x (23.2*))	0-20.9

*23.2 is a scaling factor to convert the 30th percentile score to within the very poor standardised scoring range (0-20.9)

Note: Step 2 is to provide a value of 0 to 20.9 for scores of less than two and graded 'very poor'. Step 3 is to provide a value of between 21 and 80 for scores between two and less than five and are graded 'poor', 'moderate' or 'good'. Step 4 is to provide a value of between 80 to 100 for scores of five using the lowest contributing flow measure score as a scale and also prevents a flow assessment site for which a flow measure is scored 1 (outside of the observed distribution) from receiving a grade of "very good". For the Report Card, grades of very good are defined in the Program Design as: "Conditions frequently meeting guidelines or reference values and the majority of critical habitats are intact" (WTHWP 2018).

For basins or estuaries with more than one flow assessment site, the following steps were applied for aggregating scores.

- The total catchment area upstream of the gauged flow assessment sites was determined.
- The adjusted upstream catchment for each assessment site (stream gauge) was determined, which is all the catchment area up until the next upstream assessment site(s) if present.
- The proportion of total catchment for each assessment site was determined and multiplied by the standardised score for the assessment site.
- All contributing scores are summed to provide the final basin score.

Seasonal assessment approach

Review of the flow indicator for 2018-19 identified occasions where some flow metrics were scoring considerably lower than expected based on observations of river flows. It was concluded that the issue occurred due to marked differences of monthly rainfall for 2018-19 compared to long-term monthly averages (in particular the Mulgrave River). The period of July to November included months with rainfall well below their long monthly term average whilst the period December to June included months with rainfall well above their long-term average. However, the flow indicator tool defines the rainfall type of a reporting year from its total rainfall, and compares observed flows to modelled pre-development flow from years of the same rainfall type. 2018-19 was defined as a 'wet' year and flow measures were calculated using 'wet' modelled pre-development flow data. The flow indicator tool was adjusted to assess the dry season months (July to November) and the months during and after the wet season (December to June) separately. Application of the adjusted flow season tool on the 2018-19 flow data resulted in the 'dry season' period classified as 'drought' (due to months with rainfall well below their long-term averages) and the 'wet season' classified as 'wet' (due to months with rainfall well above their long-term averages). The flow measure scores produced by the seasonally specific flow indicator tool were markedly more consistent with the observations of flow (based on results for the Mulgrave River). For reporting years which have high variation of monthly rainfall compared to long-term means the flow indicator may be applied seasonally to flow assessment sites on a case by case basis to correct for major differences of seasonal rainfall types.

Worked example of the flow indicator

The 2017 to 2018 rainfall for the Barron Basin and the annual flow records for Picnic Crossing and Mareeba flow assessment sites on the Barron River are presented in Figure 9. Picnic Crossing is upstream of Tinaroo Falls Dam and has a smaller catchment than Mareeba which is downstream of Tinaroo Falls Dam. Differences in the flow records between the sites include the effect of the impoundment on river flows. This example visually presents how assessment of flow records using the indicator differ between a site that has minimal alteration from predevelopment flows (Picnic Crossing) and one that has substantial alteration from predevelopment flows (Mareeba) for the 2017-18 reporting period.

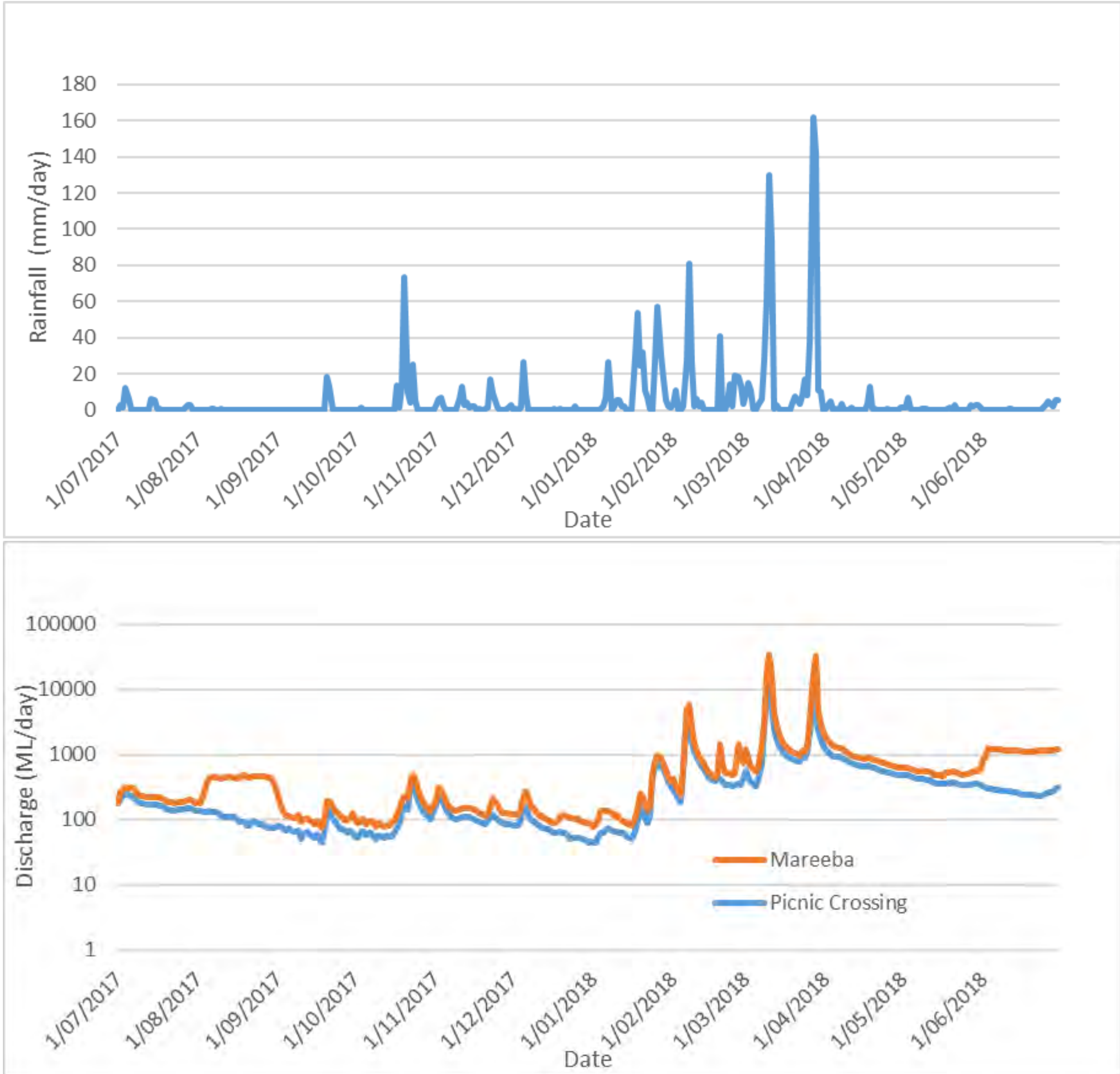

Figure 9 Rainfall for the Barron Basin and flow records for Mareeba and Picnic Crossing for 2017-18.

The flows at Picnic Crossing for 17-18 scored a maximum five for each of the 10 flow measures and flows were determined as being not substantially altered from pre-development flows. The flows at Mareeba were substantially altered from pre-development flows for the following four of the 10 flow measures: low flow duration (score = 1/5), low flow variability (score = 3/5), medium flow duration (1/5) and medium flow frequency (1/5). The flow record for Mareeba shows abrupt changes in flow during August 2017 and June 2018 as a results of flow regulation of Tinaroo Falls Dam. These changes in flow did not occur at Picnic Crossing and were not driven by rainfall. The flow measure scores for low and medium flows were affected by the alteration of flows at Mareeba. The overall flow indicator score for Mareeba was 2.4, as calculated as the 30th percentile of the 10 flow measure scores. The standardised value of this score was 29 (poor). The example demonstrates how the flow indicator assesses the degree of change from reference for different characteristics of the flow regime.

This example includes alterations to flow that are easy to visualise from an annual flow record. However, the 10 flow measures are able to assess and score aspects of the flow regime that may not be as clearly visualised from the flow record but may still be important to waterway health.

The potential impacts upon waterway health attributes linked to low flows include low flow spawning fish, critical hydraulic habitat, longitudinal connectivity and water quality, those linked to medium flows include riffle habitats and macrophyte beds, and those linked to high flows include fisheries production (Stewart-Koster *et al*. 2018). The results of the flow indicator for Mareeba identify that alteration of flows may be impacting on waterway health for the attributes linked to low flows and medium flows.

3.2.3.3. Riparian, Wetland and Mangrove/Saltmarsh Extent (Freshwater Basins and Estuaries)

For the habitat extent indicators riparian and wetland extent are applied to basins whilst riparian and mangrove/saltmarsh are applied to estuary environments. Note that mangrove and saltmarsh are separate habitats but have been grouped together as part of the mapping process. Data on the extent of saltmarsh and mangrove is presented separately for each zone in the results technical report.

The score for the extent of riparian vegetation was calculated as the percent loss of riparian vegetation since pre-development to current (2013) for each basin or estuary zone.

The score for wetland extent in freshwater basins was calculated as the percent loss of vegetated freshwater swamp (palustrine) systems with more than 30 per cent emergent vegetation cover. The score for the extent of mangroves and saltmarsh in estuaries was calculated as the per cent loss of mangroves and saltmarsh. For both habitat types, the current (2017) extent was calculated as a percentage of the pre-development extent for each zone, based on Queensland Regional Ecosystem (RE) Version 5.

For each zone (freshwater or estuarine) and applicable habitat type (riparian, wetland, or mangrove and saltmarsh), the percent loss of habitat extent score was assigned the appropriate grade and the corresponding standardisation formula was applied as per Table 36.

Table 36 Scoring ranges, grades and aggregation formula for the riparian, wetland and mangrove/saltmarsh habitat extent indicators in freshwater basin and estuary assessments.

Per cent loss of habitat extent score ranges	Grade	Standardisation of scores for aggregation
≤5.0%	Very Good	VG = 81+ ABS((19 - ((score-0) *(19/4.9))))
>5.0-15.0%	Good	G= 61+ ABS((19.9 - ((score -5.1) *(19.9/9.9))))
>15-30.0%	Moderate	M=41+ ABS((19.9 -((score -15.1) *(19.9/14.9))))
>30-50%	Poor	P= 21+ ABS((19.9- ((score -30.1) * (19.9/19.9))))
>50%	Very Poor	VP=ABS((20.9 - ((score-50.1) *(20.9/49.9))))

3.2.3.4. Shoreline mangrove habitat

Habitat features were identified and assessed from the processed post-survey data for each estuary. The features were scored using a criteria-based image analysis following Mackenzie et al. (2016). A description of the five features assessed, and the respective criteria used for assessments are detailed in Table 37. The scoring system for each feature was devised based on experience and knowledge of tropical shoreline estuary habitats. Scoring criteria used the most parsimonious approach that maintained relevance to spatial and temporal comparisons of features within and between estuaries. Image feature assessment was undertaken on images associated with 10-meter interval shoreline points. Mangrove presence and point features were scored every 10 m, whereas habitat features were scored every 50 m or 100 m depending on the estuary size and shoreline mangrove cover. The scoring interval was chosen after an initial assessment of shoreline mangrove percentage cover to ensure a minimum of 30 sampling points with mangroves present per estuary section. Estuaries were divided into 5 equal sections representing 20th percentiles of the distance from the estuary upstream limit to the estuary mouth along the main estuary channel.

Shoreline mangrove habitat features were grouped into three (3) measures: habitat structure, canopy cover and habitat impact. Each measure is designed to reflect ecosystem service provision potential and ecosystem resilience. The scores for the measures of shoreline mangrove habitat were calculated as the mean score of the features within each group. The shoreline mangrove habitat indicator score was calculated from the mean score of the three measures. Features were scored on a scale of 0 to 100 in accordance with the standardised scoring system of the report card (Table 37). For binary and discrete – nominal scores, the score was calculated relative to the proportional representation of classes within each feature. For features with a discrete-ordinal score, the score was based on the estuary mean score. A description of scoring and grading calculations is provided in Table 37 and further information on the method is provided in Mackenzie (2021).

Table 37 Descriptions and scoring procedures for the shoreline mangrove habitat indicator.

<table>
<tr><th colspan="7">Shoreline Mangrove Measure: Habitat Structure</th></tr>
<tr><td colspan="7">Shoreline Mangrove Habitat Structure Score =
<u>((Mangrove Cover Score (%C) + Mangrove Density Score (MD) + Mangrove Maturity Score (MM)))/3</u></td></tr>
<tr><th>Feature</th><th>Interval</th><th>Feature Descriptor</th><th>Assessment Criteria (Point sampling)</th><th colspan="3">Score Metrics (Estuary sampling)</th></tr>
<tr><td rowspan="7">Fringe Mangrove Cover</td><td rowspan="7">10 m</td><td rowspan="7">The percent cover of mangroves along the estuary shoreline.</td><td rowspan="7">0) Mangroves not directly present along shoreline

1) Mangroves present along shoreline</td><td colspan="3">Base Metric: % Cover (%C)
Percentage cover of mangroves represented as the number of shoreline points assessed with mangroves present (1) as a proportion of total number of shoreline points assessed.</td></tr>
<tr><th>Range</th><th>Grade</th><th>Standardisation</th></tr>
<tr><td>> 90%</td><td>Very Good</td><td>= 81+((19+((%C-100)*(19/9.9))))</td></tr>
<tr><td>> 80-90%</td><td>Good</td><td>= 61+((19.9+((%C-90)*(19.9/9.9))))</td></tr>
<tr><td>> 70-80%</td><td>Moderate</td><td>= 41+((19.9+((%C-80)*(19.9/9.9))))</td></tr>
<tr><td>≥ 50-70%</td><td>Poor</td><td>= 21+((19.9+((%C-70)*(19.9/20))))</td></tr>
<tr><td>< 50%</td><td>Very Poor</td><td>= ((20.9+((%C-49.9)*(20.9/49.9))))</td></tr>
<tr><td rowspan="7">Shoreline Mangrove Stand Density</td><td rowspan="7">Small estuary
50 m

Large estuary
100m</td><td rowspan="7">The density of mangrove stands along the shoreline</td><td rowspan="7">1) Sparse
Individual mangrove plants but with other isolated individuals in close proximity not forming a contiguous mangrove stand.
2) Isolated Stand/Patch
Multiple individual plants present at assessment point not forming part of contiguous forest extending >20m along the shoreline as determined by mangrove absence or isolated individuals in adjacent frames.
3) Open Continuous Forest
Mangrove visible at assessment point part of contiguous mangrove fringe (>20m along shoreline) but with large spaces between individuals and canopies not intermingling.
4) Closed Continuous Forest
Mangrove visible at assessment point part of contiguous mangrove fringe (>20m along</td><td colspan="3">Mangrove Density Score (MD) – 1 to 4
Mean Mangrove Density Score along shoreline with mangroves present.</td></tr>
<tr><th>Range</th><th>Grade</th><th>Standardisation</th></tr>
<tr><td>> 3.75</td><td>Very Good</td><td>= 81+((19+((MD-4)*(19/0.24))))</td></tr>
<tr><td>> 3.25-3.75</td><td>Good</td><td>= 61+((19.9+((MD-3.75)*(19.9/0.49))</td></tr>
<tr><td>> 2.5-3.25</td><td>Moderate</td><td>= 41+ ((19.9+((MD-3.25)*(19.9/0.49)</td></tr>
<tr><td>≥ 2-2.5</td><td>Poor</td><td>= 21+ ((19.9+((MD-2.5)*(19.9/0.49))</td></tr>
<tr><td><2</td><td>Very Poor</td><td>= ((20.9+((MD-1.99)*(20.9/1.99))))</td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td>shoreline) with no spaces between individuals and canopies intermingling.</td><td></td></tr>
<tr><td>Shoreline Mangrove Stand Maturity</td><td>Small estuary
50 m

Large estuary
100m</td><td>The estimated age class of mangroves along the shoreline as determined from expert visual assessment.</td><td>1) Seedlings
Only seedlings (< ~0.5m tall) present: <2 yrs old
2) Saplings
Only Immature plants <1.5m tall, 2-5 yrs old
3) Young Mature
Stand dominated young (~5-10 yrs) mature trees
4) Mature Established Trees
Stand dominated by established mature individuals >10 yrs old present.</td><td>Mangrove Maturity Score (MM) – 1 to 4
Mean mangrove maturity score along shoreline with mangroves present.
<table>
<tr><th>Range</th><th>Grade</th><th>Standardisation</th></tr>
<tr><td>> 3.75</td><td>Very Good</td><td>= 81+((19+((MM-4)*(19/0.24))))</td></tr>
<tr><td>> 3.25-3.75</td><td>Good</td><td>= 61+((19.9+((MM-3.75)*(19.9/0.49)))</td></tr>
<tr><td>> 2.5-3.25</td><td>Moderate</td><td>= 41+ ((19.9+((MM-3.25)*(19.9/0.49)))</td></tr>
<tr><td>≥ 2-2.5</td><td>Poor</td><td>= 21+ ((19.9+((MM-2.5)*(19.9/0.49)))</td></tr>
<tr><td><2</td><td>Very Poor</td><td>= ((20.9+((MM-1.99)*(20.9/1.99))))</td></tr>
</table></td></tr>
<tr><td colspan="5">Shoreline Mangrove Measure: Canopy Cover</td></tr>
<tr><td colspan="5">Shoreline Mangrove Canopy Cover Score = Mean Mangrove Condition Score</td></tr>
<tr><td>Shoreline Mangrove Condition</td><td>Small estuary
50 m

Large estuary
100m</td><td>The health of mangrove stands determined by canopy density related to leaf production, canopy retreat, exposed branches and twigs (dieback) and dead trees.</td><td>0) Dead or Almost Dead
<10% Canopy Cover
1) Very Poor Condition
10-30% Canopy Cover
2) Poor Condition
30-60% Canopy Cover
3) Moderate Condition
60-90% Canopy Cover
4) Healthy
>90% Canopy Cover</td><td>Mean Canopy Cover Score (CC) - 1 to 5
The mean canopy cover score along shoreline with mangroves present.
<table>
<tr><th>Range</th><th>Grade</th><th>Standardisation</th></tr>
<tr><td>> 3.5</td><td>Very Good</td><td>= 81+((19+((MC-4)*(19/0.49))))</td></tr>
<tr><td>> 3-3.5</td><td>Good</td><td>= 61+((19.9+((MC-3.5)*(19.9/0.49)))</td></tr>
<tr><td>> 2.5-3</td><td>Moderate</td><td>= 41+ ((19.9+((MC-3)*(19.9/0.49)))</td></tr>
<tr><td>≥ 2-2.5</td><td>Poor</td><td>= 21+ ((19.9+((MC-2.5)*(19.9/0.5)))</td></tr>
<tr><td><2</td><td>Very Poor</td><td>= ((20.9+((MC-1.99)*(20.9/1.99))))</td></tr>
</table></td></tr>
<tr><td colspan="5">Shoreline Mangrove Measure: Habitat Impact</td></tr>
<tr><td colspan="5">Shoreline Habitat Impact Score =
<u>(Mangrove Damage Score (D) + Shoreline Modification Score (SM))/2</u></td></tr>
<tr><td>Shoreline Mangrove Habitat Damage</td><td>10m</td><td>The presence of active or recent (<1 year) human-related shoreline mangrove removal and damage where mangroves are present.</td><td>1) Physical Damage to mangroves causing loss of mangrove condition not causing tree death or habitat loss
Physical damage to mangrove plants including access tracks, boat landings/tie points, cattle grazing.</td><td>Mangrove Damage Score (D)
The proportion of mangroves with modification evident, weighted for the level of damage where present

Damage Multipliers:
1 – x 1
2 – x 1.5
3 – x 2</td></tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td></td>
<td>2) Physical Damage to mangroves causing minor (<10m shoreline) death or minor habitat loss
Physical damage to mangrove plants including trimming and cutting, removal of individual plants and small gap creation.

3) Physical Damage to mangroves causing extensive (>10m shoreline) tree death or habitat loss
Damage to multiple mangrove plants causing plant death or removal of mangrove stands.</td>
<td>
<table>
<tr><th>Range</th><th>Grade</th><th>Standardisation</th></tr>
<tr><td>≤1</td><td>Very Good</td><td>= 81+ ((19 - (D*19))</td></tr>
<tr><td>> 1-3</td><td>Good</td><td>= 61+ ((19.9 - ((D-1.1) *(19.9/1.9)))</td></tr>
<tr><td>> 3-7</td><td>Moderate</td><td>= 41+ ((19.9 - ((D-3.1) *(19.9/3.9)))</td></tr>
<tr><td>> 7-15</td><td>Poor</td><td>= 21+ ((19.9 - ((D-7.1)*(19.9/7.9)))</td></tr>
<tr><td>>15</td><td>Very Poor</td><td>= ((20.9-((D-15.1)*(20.9/84.9))))</td></tr>
</table>
</td>
</tr>
<tr>
<td>Shoreline Modification</td>
<td>10m</td>
<td>The presence of human-related shoreline substrate modification (E.g. Rip-rap walls, concrete boat ramps, debris dumping).</td>
<td>0) Natural –
No substrate modification

1) Modified –
substrate modification with existing or potential for mangrove colonisation

2) Impervious –
substrate modification with no potential for mangrove colonisation</td>
<td>Shoreline Modification Score (SM)
The proportion of shoreline substrate modified weighted for the degree of modification.

Modification Multipliers:
1 – x 0.5
2 – x 1
<table>
<tr><th>Range</th><th>Grade</th><th>Standardisation</th></tr>
<tr><td>≤2</td><td>Very Good</td><td>= 81+ ((19 - ((SM *(19/1.9))))</td></tr>
<tr><td>> 2-6</td><td>Good</td><td>= 61+ ((19.9 - ((SM-2.1) *(19.9/3.9))</td></tr>
<tr><td>> 6-14</td><td>Moderate</td><td>= 41+ ((19.9 - ((SM-6.1) *(19.9/7.9))</td></tr>
<tr><td>> 14-30</td><td>Poor</td><td>= 21+ ((19.9 - ((SM-14.1)*(19.9/15.9)</td></tr>
<tr><td>>30</td><td>Very Poor</td><td>= ((20.9-((SM-30.1)*(20.9/69.9))))</td></tr>
</table>
</td>
</tr>
<tr>
<td colspan="5">Shoreline Mangrove Habitat Indicator Score =

<u>(Habitat Structure Score + Canopy Cover Score + Mangrove Habitat Impact Score)/3</u></td>
</tr>
</table>

3.2.3.5. Invasive Weeds (Freshwater Basins)

The invasive weeds mapping procedure provided a record of the presence or absence of each weed species intersecting with the waterway habitat layer for all grid cells within each basin. The data was then exported from ArcMap into an Excel pivot table for processing. Grid cells with at least one species of weed present were defined as occupied cells. The basin impact score was the sum of impact scores of weed species from all occupied cells within each basin. To determine the potential impact scores, the assumption was made that all weeds identified in the prioritisation process would be able to potentially occupy each and every grid cell given their aquatic lifeform. The potential impact score for each basin was calculated as the sum of the impact scores for all weeds potentially present in all occupied grid cells (grid cells where at least one weed species occurred). In the pivot table the potential impact score (the sum of all mean impact scores) and the actual impact score were calculated as a percentage per basin, as follows.

Percent impact score = (actual impact score/potential impact score) x 100

The 10th, 25th, 50th and 75th percentiles of the percent impact scores from all basins were used to set the scoring ranges for each grade and formulae were applied to generate standardised scores for aggregation, as shown in Table 38.

Table 38. Grading description for invasive weeds in the freshwater basin assessments 2019-20.

Percentile range	Percent impact score	Grade	Standardisation formula for aggregation
0 - 0.10	0-11.5	Very good	Very good = INT(81+((19-(score-0)*(19/11.5))))
>0.10-0.25	>11.5-12.8	Good	Good = INT(61+ ((19 - ((score-11.5) * (19/1.3)))))
>0.25-0.50	>12.8-15.2	Moderate	Moderate = INT(41+ ((19 - ((score-12.8) * (19/2.5)))))
>0.50-0.75	>15.2-16.8	Poor	Poor = INT(21+ ((19 - ((score-15.2) * (19/1.6)))))
>0.75	>16.8	Very poor	Very poor = INT(20 - ((score-16.8) * (20/83.2)))

Assessment of invasive weeds was conducted for 2019-20 and was the second assessment of weed distribution and scoring of the nine Wet Tropics basins since the indicator was introduced for 2015-16. The indicator scoring framework applies scores that are relative between all the basins by using percentile ranges for assigning grades that are generated from the data set of all the basins for the assessment year. This means that the percentile ranges will change for different assessments and that direct comparison of scores and grades for a given basin for different assessments is not feasible. However, comparisons between basins for a given assessment are appropriate. These first two assessments have provided data sets that can be used for generating benchmarks for future assessments. An update of the indicator is planned before the next assessment due for 2023-24 and will mean invasive weed condition for individual basins can be assessed for change overtime in comparison to fixed benchmarks and targets.

3.2.3.6. Estuarine Seagrass (Estuaries)

Calculation of estuarine seagrass condition using the QPSMP method is described in inshore seagrass (section 3.3.4).

3.2.4. Fish (Freshwater)

The scoring methods for the freshwater fish community condition are outlined in Table 39 and Table 40. A qualitative rating scheme for the proportion of indigenous fish species (POISE), which scores and grades native species richness, was developed (Table 39), where the 'very good' category was based on available fish survey data and the 'poor' was based on the 90th percentile of the results for recent times as predicted by the modelled Maximum Species Richness Line. Anything less than the 90th percentile is considered 'very poor'. The rating scheme for the proportion of non-indigenous fish species (PONI) is presented in Table 40 and used a model for the pest fish indicator developed for South East Queensland (EHMP 2008).

Table 39 Rating scheme for the proportion of indigenous fish species (POISE) indicator for freshwater fish communities.

POISE	Grade	Scaling of scores for aggregation
0.80 to 1	Very Good	VG = 81+ ABS((19 + ((score-1) *(19/0.2))))
0.67 to <0.80	Good	G= 61+ ABS((19.9 + ((score -0.7999) *(19.9/0.1329))))
0.53 to <0.67	Moderate	M=41+ ABS((19.9 + ((score -0.6669) *(19.9/0.1339))))
0.40 to <0.53	Poor	P= 21+ ABS((19.9+ ((score -0.5329) * (19.9/0.1329))))
0 to <0.40	Very Poor	VP=ABS((20.9 + ((score-0.3999) *(20.9/0.3999))))

Table 40 Rating scheme for the proportion of non-indigenous fish species (PONI) indicator for freshwater fish communities.

PONI	Grade	Scaling of scores for aggregation
0 to 0.03	Very Good	VG = 81+ ABS((19 - ((score-0) *(19/0.025))))
>0.03 to 0.05	Good	G= 61+ ABS((19.9 - ((score -0.0251) *(19.9/0.0249))))
>0.05 to 0.1	Moderate	M=41+ ABS((19.9- ((score -0.051) *(19.9/0.049))))
>0.1 to 0.2	Poor	P= 21+ ABS((19.9- ((score -0.101) * (19.9/0.099))))
>0.20 to 1	Very Poor	VP=ABS((20.9 - ((score-0.201) *(20.9/0.799))))

3.3. Inshore and Offshore Condition Assessment

3.3.1. Inshore Water Quality

3.3.1.1. Water clarity, nutrients and chlorophyll *a*

Water quality indicator guideline values for the Great Barrier Reef enclosed coastal waters, open coastal and mid-shelf waters of the inshore zones are listed in Table 41. The guideline values are those used for the MMP 2016 water quality report (Lønborg *et al.* 2016), which were based upon the Water Quality Guidelines for the Great Barrier Reef Marine Park (GBRMPA 2010) and Queensland Water Quality Guidelines (DEHP 2009). For the north, central and Palm Island reporting zones, all monitoring sites are located within open coastal and mid-shelf waters. The south reporting zone includes sites located in enclosed coastal waters (Table 12). Annual means were calculated for indicators at each site and condition scores were calculated using the relevant guideline value and the procedure below. Condition scores were aggregated for indicators and indicator categories (water clarity and nutrients) from all sites within each reporting zone.

Table 41 Water quality guidelines for inshore zone waters.

Indicator (unit)	**Inshore zone**		
	Enclosed coastal	**Open coastal**	**Mid-shelf**
TSS (mg/L)	nd	2.0	2.0
Turbidity (NTU)	10.0	1.5*	1.5*
Particulate nitrogen (µg/L)	nd	20.0	20.0
Particulate phosphorus (µg/L)	nd	2.8	2.8
NO_x (µg/L) ^{QLD}	10.0	2.0	2.0
Chlorophyll *a* (µg/L)	2.00	0.45	0.45

* The turbidity trigger value for opens coastal and mid-shelf water bodies (1.5 NTU) was derived for the MMP reporting by transforming the suspended solids trigger value in the Guidelines (2 mg/L) using an equation based on a comparison between direct water samples and instrumental turbidity readings (Lønborg *et al.* 2016). Note that the guideline values provided by DES, as indicated by QLD are 80th percentile guidelines. nd: no (or insufficient) data.

The following steps were used for the calculation of the indicator condition scores.

1. For indicators where non-compliance is defined as values being *higher* than guideline values (for example Chl-*a*):

   $$\text{Condition score} = \log_2 (GV/AM)$$

   Where:

   AM means annual mean of measured values
   GV means guideline value or target

2. Ratios exceeding -1 or 1 were capped to bind the water quality indicator to the range from 1- to 1, such that all indicators were on the same scale.
3. The nutrients indicator category score was calculated by averaging indicator values for NO_x, PP and PN (where available); the water clarity indicator category score was calculated by averaging indicator values for TSS and Turbidity (where available).
4. The indicator scores and indicator category scores for nutrients, water clarity, Chl-*a* are translated to the Report Card five-point grading scale using the ranges and grades shown in Table 42.

This formula and method is described in full in Lønborg *et al*. (2016).

Table 42. Inshore water quality scoring ranges, grades and scaling for aggregation.

Condition grade and colour code	Score Range	Scaling of scores for aggregation
Very Good	>0.5 to 1	100- (19 - ((score-0.51) * (19/0.49)))
Good	>0 to 0.5	80.99 - (19.99 - ((score -0.01) *(19.99/0.49)))
Moderate	<0 to -0.33	60.99- (19.99 - ((score -(-0.33)) *(19.99/0.32)))
Poor	<-0.33 to -0.66	40.99- (19.99 - ((score -(-0.66)) * (19.99/0.32)))
Very Poor	<-0.66 to -1	20.99- (20.99 - ((score -(-1)) *(20.99/0.34)))

The water quality guidelines for coastal and marine waters in the Wet Tropics region are currently being reviewed by the Queensland Department of Environment and Science. The draft water quality objectives have been released for consultation (http://www.ehp.qld.gov.au/water/policy/pdf/draft-wet-tropics-ev-wq-consultation.pdf) and provide more locally relevant guidelines values. The reporting is based upon guideline values coastal and marine waters that are currently scheduled. Future report cards will adopt the most up to date and relevant scheduled guidelines that apply to the inshore zones of the Wet Tropics region.

Note that on occasion indicators for water clarity, TSS and turbidity, can produce contrasting scores within a zone. This occurred for the South and Palm Island zones in 2017-18 (WTW 2019). Although TSS and turbidity are often correlated, they measure different properties of water and relationships between TSS and turbidity demonstrate considerable spatial and temporal variation. As well as temporal and spatial influences, the sampling frequency of TSS, which is manually sampled, and turbidity, which is sampled by continuous loggers, can influence data values averaged over the reporting year. The guideline values, which set the scoring ranges for water quality indicators, can also exacerbate contrasts between TSS and turbidity scores, especially when one of the indicators tends to slightly exceed guideline values whilst the other tends to meet guideline values. This issue is examined in more detail in section 5.1.1 of the 2017-18 results technical report (WTW 2019).

3.3.1.2. Pesticides

Pesticide monitoring for inshore zones was suspended in 2020-21. The following description is provided as reference for inshore pesticide results for previous reporting years.

In order to express the concentration data for all selected pesticides as a single number that represented the overall risk to aquatic ecosystems, it was necessary to convert all the concentration data into a numerical term that represented the toxicity of the mixture of pesticides in each passive sampler or water sample. The multi substance potentially affected fraction (ms-PAF) approach (Traas *et al*. 2002) was applied (as used for basins) and includes pesticides with multiple MoAs (Table 3). The ms-PAF for pesticides with different modes of action was calculated using the independent action model of joint action (Plackett and Hewlett 1952). Further details on how the pesticide risk metric calculations were made are provided in Warne *et al*. (2019).

The result of the ms-PAF analysis provides an estimate of the toxicity of the mixture of pesticides in each passive sampler device or water sample expressed as a percentage of species affected.

The corresponding per cent species protected (calculated for each passive sampler at each monitoring site) were then allocated to the risk categories presented in Table 27. These categories are consistent with the ecological condition categories used in the Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters (ANZ WQG 2018).

For the 2017-18 to 2019-20 reporting periods, ms-PAF values were used to determine pesticide grades. All values were rounded to the nearest whole number.

3.3.1.3. Water quality index

The water quality indicators and indicator categories were equally weighted to generate the index score. Table 43 shows the relationship of indicators, indicator categories and indices, and the associated weightings.

Table 43. Relationship of selected indices, indicator categories and indicators.

<table>
<tr><th>Index</th><th>Indicator category</th><th>Indicator</th><th>Weighting of indicator within indicator</th></tr>
<tr><td rowspan="8">Water Quality</td><td rowspan="3">Nutrients</td><td>PN</td><td rowspan="3">Equally, therefore 33 % each</td></tr>
<tr><td>PP</td></tr>
<tr><td>NO_x</td></tr>
<tr><td>Chl-a</td><td>Chl-a</td><td>Entire score</td></tr>
<tr><td rowspan="2">Water clarity</td><td>TSS</td><td rowspan="2">Equally, therefore 50 % each</td></tr>
<tr><td>Turbidity</td></tr>
<tr><td>Pesticides</td><td>Risk assessment</td><td>Entire score</td></tr>
</table>

3.3.2. Offshore Water Quality

Reporting for offshore quality was suspended in 2020-21 due to decommissioning of the BoM Marine Water Quality dashboard. A replacement offshore water quality assessment approach is being developed. The following description is provided as reference for reporting years prior to 2020-21.

The offshore water quality condition assessment used the percentage of area in the offshore zone that exceeds the relevant water quality guideline value (Table 44). The water quality guideline values for offshore waters were not set solely using percentiles of reference data, they were set using additional environmental and water quality considerations as explained in GBRMPA (2010).

Table 44. GBRMPA guideline values to assess the offshore water quality indicators.

Indicator category	Indicator	Guideline value
Water clarity	TSS	0.7 mg/L
Chlorophyll-*a*	Chlorophyll-*a*	0.4 µg/L

Each indicator score (chlorophyll-*a* and TSS) was calculated by subtracting the percentage of the water body that exceeded the guideline value from 100 %, with the resulting value being that percentage of area that did not exceed the water quality guideline value, within the reporting period. The score (from 0 – 100) was then directly translated to the standardised Report Card score and grade (Table 17). The TSS and chlorophyll-*a* results were weighted equally, so were averaged to provide the water quality indicator category result for the offshore zone.

3.3.3. Coral

Condition assessment of the different coral indicators for inshore and offshore coral monitoring followed the method of the MMP (Thompson *et al*. 2016). The following coral indicators were scored for each site and averaged for each inshore reporting zone.

- **Coral cover (inshore and offshore):** This indicator simply scores reefs based on the level of coral cover. For each reef the proportional cover of all genera of hard (order Scleractinia) and soft (subclass Octocorallia) corals are combined into two groups, 'HC' and 'SC' respectively. The resulting value for coral cover is scaled linearly from zero (when cover is 0 %) through to 1 (when cover is at or above the threshold of 75 %).
- **Macroalgae cover (inshore only):** For the inshore environment macroalgae was measured as the percentage cover of macroalgae as a proportion of the total cover of all algal forms.
- **Density of juvenile hard corals (inshore and offshore):** Counts of juvenile hard corals (colonies up to 5 cm in diameter) were converted to density per m^2 of space available to settlement.
- **Change in coral cover (inshore and offshore)**: The change in coral cover indicator was derived from the comparison of the observed change in coral cover between two visits and predicted change in cover derived from multi-species forms of a Gompertz growth equation. Due to differences in growth rates, models were run separately for the fast growing corals of the family Acroporidae and the slower growing combined grouping of all other hard corals.
- **Community composition (inshore only):** The basis of the indicator is the scaling of cover for constituent genera (subset to life forms for the abundant genera *Acropora* and *Porites*) by genus weightings that correspond to the distribution of each genus along a gradient of turbidity and chlorophyll concentration (see Thompson *et al*. 2016 for more explanation).

The condition of the inshore coral reefs is based upon data from MMP and LTMP sites and reports on all five coral indicators. The condition of offshore coral reefs is based on LTMP data, and the coral index for offshore reefs is based on coral cover, density of juvenile corals and the coral change index, but does not include the cover of macroalgae or the community composition indicators.

The indicators for both inshore and offshore regions were scored in a similar way. Methods for scoring condition of offshore reefs now include updates to align with the indices used by the Great Barrier Reef Report Card and with the coral index for inshore reporting zones. Observations for each indicator were scored on a continuous scale following Thompson *et al*. (2016) and can be seen in Table 45. The approach involves selecting bounding values for each indicator based on biology. These bounds become zero (very poor) and 1.0 (very good) on an approximately linear scale (see Section 6 of Thompson *et al*. 2016). This linear scale is then used to convert the value of each indicator from each reef to a value between zero and 1.0, and the values for the reefs in each reporting zone are averaged.

Note that different sets of reefs are surveyed in alternate years. For this reason, the indices for coral cover and the density of juveniles are based on the most recent surveys of each reef in the reporting zone. The most recent surveys for some of the reefs will have been made in the preceding year. The coral change index is based on estimates of rate of change over the interval between surveys, this is only possible during periods free from acute disturbances, such as cyclones or mass bleaching events. Estimates are averaged over valid observations over the four years, up to and including the reporting year.

All indicators are weighted equally, and the scores are then averaged to determine the overall coral index score for the reporting zone. The range between 0 and 1 is divided into five equal bands corresponding to ratings from very poor to very good (Table 46).

Table 45. Threshold values for the condition assessment of coral.

Community attribute	Thresholds	Score
Combined hard and soft coral cover: **'Cover'**	1 at 75% cover or greater	Continuous between 0-1
	0 at zero cover	
Rate of increase in hard coral cover (preceding 4 years): **'Change'**	Change > 2x upper 95% CI of predicted change	1
	Change between upper 95% CI and 2x upper 95% CI	Continuous between 0.6 and 0.9
	Change within 95% CI of the predicted change	Continuous between 0.4 and 0.6
	Change between lower 95% CI and 2x lower 95% CI	Continuous between 0.1 and 0.4
	change < 2x lower 95% CI of predicted change	0
Proportion of algae cover classified as Macroalgae: **'Macroalgae'** **(inshore only)**	≤ reef specific lower bound and ≥ reef specific upper bound	Continuous between 0-1
Density of hard coral juveniles (<5 cm diameter): **'Juvenile'**	> 13 juveniles per m^2 of available substrate	1
	4.6 to 13 juveniles per m^2 of available substrate	Continuous between 0.4 and 1
	0 to 4.6 juveniles per m^2 of available substrate	Continuous between 0 and 0.4
Composition of hard coral community: **'Composition'** **(inshore only)**	Beyond 95% CI of baseline condition in the direction of improved water quality	1
	Within 95% Confidence intervals of baseline composition	0.5
	Beyond 95% CI of baseline condition in the direction of declined water quality	0

Table 46. Scoring ranges for aggregated coral results.

Condition grade and colour code	Score Range	Scaling of scores aggregation
Very Good	> 0.8	'score' x 100
Good	> 0.6 – 0.8	'score' x 100
Moderate	> 0.4 – 0.6	'score' x 100
Poor	> 0.2 – 0.4	'score' x 100
Very Poor	0 – 0.2	'score' x 100

3.3.4. Inshore Seagrass

3.3.4.1. Marine Monitoring Program

Through the MMP seagrass monitoring, a method has been developed and documented (refer to McKenzie *et al*. 2015) to aggregate seagrass data results into the Great Barrier Reef Report Card scoring range (Table 17). Each set of seagrass indicator results are analysed to provide a relevant score and grade. These scores are translated to fit the Great Barrier Reef Report Card scoring range. The scoring thresholds and their relation to the Great Barrier Reef Report Card scoring ranges are provided for seagrass abundance (% cover) in Table 47, and for seagrass resilience in Table 48. Note that the resilience indicator is a multivariate metric and sources data from a range of seagrass measures which are converted into the linear scoring system.

An overall seagrass index is calculated from standardised scores (0 - 100) by averaging each indicator score from replicate transects within each site, averaging the two seagrass indicator scores for each site, and averaging site scores within the reporting zone. Indicators are equally weighted. For further detail on the seagrass scoring methods, refer to latest 'Marine Monitoring Program: Annual Report for inshore seagrass monitoring' available at https://elibrary.gbrmpa.gov.au/jspui/.

Table 47. Seagrass abundance (% cover) scoring thresholds in relation to condition grades (low = 10th or 20th percentile guideline). Source McKenzie *et al.* 2015.

Category	Score	Standardised scoring range	Condition grade
75 – 100	100	81 – 100	Very Good
50 – 75	75	61 – 80	Good
Low – 50	50	41 – 60	Moderate
< Low	25	21 – 40	Poor
< Low by > 20 %	0	1 – 20	Very Poor

Table 48. Seagrass sites grouped and graded according to resistance and reproductive qualities of resilience and the corresponding standardised scoring ranges and grades. Source Collier *et al.* 2021.

Resilience group	Scoring range	Resilience group grade	Scoring range	Standardised scoring range	Condition grade
Reproductive high resistance	70-100	Persistent reproductive and high resistance	85-100	81 – 100	Very Good
		Reproductive high resistance	70-100	61 – 80	Good
Non-reproductive high resistance	30-70	Reproductive history and high resistance	50-70	41 – 60	Moderate
		Non-reproductive history and high resistance	30-50	21 – 40	Poor
Low resistance sites	0-30	Reproductive and low resistance	5-30		
		Non-reproductive, low resistance	0-15	1 – 20	Very Poor

For further detail on the seagrass scoring methods for seagrass abundance, refer to McKenzie *et al.* (2015) and for seagrass resilience refer to Collier et al. (2021).

3.3.4.2. Queensland Ports Seagrass Monitoring Program

The QPSMP uses a condition index developed for seagrass monitoring meadows based on changes in mean above-ground biomass, total meadow area and species composition relative to a baseline (10-year average). The index provides a means of assessing current meadow condition and likely resilience to impacts against the baseline. Seagrass condition for each indicator is scored from 0 to 1 and assigned one of five grades: A (very good), B (good), C (satisfactory), D (poor) and E (very poor) (Table 49). A meadow classification system defines threshold ranges for the three condition indicators (e.g. stable, variable) in recognition that, for some seagrass meadows, these measures are historically stable, while in other meadows they are relatively variable (Table 49). Baseline conditions for species composition were determined based on the annual percentage contribution of each species to mean meadow biomass of the baseline years. Meadows are classified as either single species-dominated (one species comprising ≥80 % of baseline species), or mixed species (all species comprise <80 % of baseline species composition). Where species composition was determined to be anything less than in 'perfect' condition (i.e. a score <1), a decision tree was used to determine whether equivalent and/or more persistent species were driving this grade/score (Carter *et al*. 2016b).

Table 49 Threshold levels for grading seagrass indicators for various meadow classes relative to the baseline. Upwards/ downwards arrows are included where a change in condition has occurred in any of the three condition indicators (biomass, area, species composition) from the previous year (Source: Carter *et al.* 2016).

Seagrass condition indicators/ Meadow class		Seagrass grade				
		A Very good	B Good	C Satisfactory	D Poor	E Very Poor
Biomass	Stable	>20 % above	20 % above - 20 % below	20-50 % below	50-80 % below	>80 % below
	Variable	>40 % above	40 % above - 40 % below	40-70 % below	70-90 % below	>90 % below
Area	Highly stable	>5 % above	5 % above - 10 % below	10-20 % below	20-40 % below	>40 % below
	Stable	>10 % above	10 % above - 10 % below	10-30 % below	30-50 % below	>50 % below
	Variable	>20 % above	20 % above - 20 % below	20-50 % below	50-80 %	>80 % below
	Highly variable	> 40 % above	40 % above - 40 % below	40-70 % below	70-90 % below	>90 % below
Species composition	Stable and variable; Single species dominated	>0 % above	0-20 % below	20-50 % below	50-80 % below	>80 % below
	Stable; Mixed species	>20 % above	20 % above - 20 % below	20-50 % below	50-80 % below	>80 % below
	Variable; Mixed species	>20 % above	20 % above- 40 % below	40-70 % below	70-90 % below	>90 % below

Increase above threshold from previous year

Decrease below threshold from previous year

Each overall meadow grade/score is defined as the lowest grade/score of the three condition indicators within that meadow. The score range and grading colours used for QPSMP report cards are provided in Table 50. For further details on the scoring methods see Carter *et al.* (2016a).

Table 50 Score range and grading colours used for QPSMP report cards.

Grade	Description	Score Range	
		Lower bound	Upper bound
A	Very good	≥0.85	1.00
B	Good	≥0.65	<0.85
C	Satisfactory	≥0.50	<0.65
D	Poor	≥0.25	<0.50
E	Very poor	0.00	<0.25

3.3.4.3. Combined Display Approach for MMP and QPSMP Seagrass Indicators.

The combined display approach for seagrass indicators maintains the score calculation methods from each program. This ensures that the scores given in the regional report cards for a particular meadow/site remain consistent with MMP and QPSMP reporting. There is no overlap between the QPSMP and MMP locations in the Wet Tropics NRM regions.

Scores for each monitoring site that are generated (either by averaging across indicators for MMP sites, or using the lowest grade for QPSMP sites) are averaged to generate an overall score for a defined reporting zone. The combined display method adopts the Great Barrier Reef Report Card scaling, and the MMP terminology and score ranges. For this, the QPSMP scores were multiplied by 100 so both programs are reported on the 0-100 scale and the scores are graded based on the Great Barrier Reef Report Card scoring ranges (Table 17). For a full description and worked example of the combined display approach refer to Carter *et al*. (2016).

3.3.5. Inshore and Offshore Fish

As mentioned above, the development of marine fish indicators and methods is still in progress and therefore the fish indices are not included in the Report Card.

4. CONFIDENCE

4.1. Confidence Associated with Results

The Regional Report Cards use the 2015 Great Barrier Reef Water Quality Protection Plan Report Card method for communicating confidence (Australian Government and Queensland Government, 2015) developed through the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program. This is based on a multi-criteria analysis approach to qualitatively score the confidence for each key indicator used in the report card. The approach enables the use of expert opinion and measured data.

The multi-criteria analysis identifies the key components that contribute to confidence. These are known as criteria. Each criterion is then scored using a defined set of scoring attributes. The attributes are ranked from those that contribute weakly to the criteria to those that have a strong influence. If the criteria are seen to have different levels of importance for the problem being addressed, they can be weighted accordingly. The strengths of this approach are that it is repeatable, transparent and can include contributions from a range of sources. The weaknesses are that it can be subjective and open to manipulation.

The method was updated for the 2015-16 reporting period. The update involved revising the weighting of confidence for each criterion as described below.

4.1.1. Confidence Versus Uncertainty

Uncertainty and confidence are closely related; high uncertainty around a theme would lead to low confidence that the given theme is contributing to program outcomes. However, confidence does not eliminate the presence of uncertainty.

Each time an observation is made, or a score calculated, there is the potential that error may be introduced. Even if this potential error is miniscule, it can add up and be compounded by further calculations, extrapolation of results, changes in scale and many other processes. It is important to measure and report this potential error. This is done through the measurement of uncertainty.

In this instance, **uncertainty** relates to the state of knowledge (epistemic) relating to a theme and the potential for error in that knowledge. It is very rare (if not impossible) to know absolutely everything about a theme without any potential for error, and so there will always be some degree of uncertainty. Having a strong understanding of the knowledge gaps (uncertainty) for a theme is critically important for program theme leaders. An understanding of uncertainty allows for continuous improvement of program themes, filling knowledge gaps and reducing uncertainty. Uncertainty (by itself) is less useful at a whole of program level as it fails to convey the confidence managers have that the various themes are contributing to the program goals.

Confidence as reported by the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program is the state of mind (psychological) of managers relating to the contribution of the program theme output to the overarching program goals. Confidence incorporates the state of knowledge (uncertainty), but also considers other factors, such as the logic frameworks (conceptual models), scale of observation and the use of scientifically robust methods. The five key criteria used in reporting confidence for the Paddock to Reef Integrated Monitoring, Modelling and reporting program are outlined in the Methods section below.

4.1.2. Methods

The determination of confidence for the Report Card 2018 used five criteria.

- Maturity of methodology
- Validation
- Representativeness
- Directness
- Measured error

Maturity of methodology
The purpose of this criterion is to show the confidence that the method/s being used are tested and accepted broadly by the scientific community. Methods must be repeatable and well documented. Maturity of methodology is not a representation of the age of the method, but the stage of development. It is expected that all methods used would be robust, repeatable and defendable.
This score is weighted 0.36 for this criterion, so as not to outweigh the importance of the other criteria.

Validation
The purpose of this criterion is to show the proximity of the indicator being measured to the indicators reported. The use of proxies is scored lower than direct measures. The reason for this criterion is to minimise compounded error. This score is weighted 0.71 for this criterion, so as not to outweigh the importance of the representativeness criteria.

Representativeness
The purpose of this criterion is to show the confidence in the representativeness of monitoring/data to adequately report against relevant targets. This criterion takes into consideration the spatial and temporal resolution of the data, as well as the sample size. This criterion is considered most important when considering confidence for regional report cards, so the score for this criterion is weighted 2.

Directness
This criterion is similar to "validation", but instead of looking at the proximity of the indicator, the criterion looks at the confidence in the relationship between the monitoring and the indicators being reported against. This score is weighted 0.71 for this criterion, so as not to outweigh the importance of the representativeness criteria.

Measured error
The purpose of this criterion is to incorporate uncertainty (as defined above) into the measure and use any quantitative data where it exists. This score is weighted 0.71 for this criterion, so as not to outweigh the importance of the representativeness criteria.

4.1.3. Scoring

For all indicators where a condition score was reported, each criterion is scored 1 (lowest) to 3 (highest) as defined in Table 51. The score of each criterion is weighted accordingly and the total confidence score is calculated by adding all weighted scores for of the five criteria. The final score is assessed against a 1 to 5 qualitative confidence ranking (Table 52). When scoring confidence for indicators in the Wet Tropics region, confidence of an indicator was considered separately for the different reporting zones (i.e. for each of the nine freshwater basins, eight estuaries, four inshore marine zone and the one offshore marine zone). This was because, for some indicators, there were different sample sizes and programs contributing to the condition scores of an indicator depending on the reporting zone.

The representativeness criteria were considered at a spatial and temporal scale. Where confidence was lower at one scale, the conservative (lowest) score was applied to this criterion for that indicator. For example, if spatial representativeness was moderate (i.e. 2), but at the temporal scale representativeness was low (i.e. 1), the score used for representativeness was low (i.e. 1).

Table 51 Scoring matrix for each criterion used to assess confidence.

Maturity of methodology (weighting 0.36)	**Validation** (weighting 0.71)	**Representat-iveness** (weighting 2)	**Directness** (weighting 0.71)	**Measured error** (weighting 0.71)
Score = 1 **New** or experimental methodology	**Score = 1** **Limited** Remote sensed data with no or limited ground truthing or Modelling with no ground truthing or Survey with no ground truthing	**Score = 1** **Low** 1:1,000,000 or Less than 10% of population survey data	**Score = 1** **Conceptual** Measurement of data that have conceptual relationship to reported indicator	**Score = 1** Greater than 25% error or limited to no measurement of error or error not able to be quantified
Score = 2 **Developed** Peer reviewed method	**Score = 2** **Not comprehensive** Remote sensed data with regular ground truthing (not comprehensive) or Modelling with documented validation (not comprehensive) or Survey with ground-truthing (not comprehensive)	**Score = 2** **Moderate** 1:100,000 or 10%-30% of population survey data	**Score = 2** **Indirect** Measurement of data that have a quantifiable relationship to reported indicators	**Score = 2** Less than 25% error or some components do not have error quantified
Score = 3 **Established** methodology in published paper	**Score = 3** **Comprehensive** Remote sensed data with comprehensive validation program supporting (statistical error measured) or Modelling with comprehensive validation and supporting documentation or Survey with extensive on ground validation or directly measured data	**Score = 3** **High** 1:10,000 or 30-50% of population	**Score = 3** **Direct** Direct measurement of reported indicator with error	**Score = 3** 10% error and all components have errors quantified

Table 52 Confidence ranking.

Final confidence score range	Ranking	Display in report card
>11.7 to 13.5	Five	High ●●●●●
>9.9 to 11.7	Four	●●●●○
>8.1 to 9.9	Three	●●●○○
>6.3 to 8.1	Two	●●○○○
4.5 to 6.3	One	Low ●○○○○

4.1.4. Assessment of representativeness for the flow indicator

For the flow indicator, representativeness was assessed from the proportion of catchment monitored by gauging stations and, for basins only, the number of gauging stations (flow assessment sites) per unit area of catchment. The number of flow assessment sites within a basin was not considered relevant to estuaries since estuaries are downstream of all assessment sites and only assessed from the most downstream assessment site(s).

To assess the number of flow assessment sites per unit area, a fixed area of 100 km^2 was applied. This was selected to represent an optimal number of assessment sites for larger catchments (>500 km^2) based on catchments in South East Queensland (Table 53). River networks will differ between the optimal number of flow assessment sites per unit area, for example, the siting of gauging stations downstream of all major confluences will vary between systems. Queensland Government has commissioned a surface water network review, part of which will inform on optimal network monitoring, based on catchment area, rainfall and climate zone.

Table 53 Number of gauging station (GS) sites in South East Queensland catchments based on catchment area.

Catchment	Area (km^2)	Number of GS	GS sites/100km^2
Brisbane River	10170	28	0.3
Logan	2416	10	0.4
Mary	6845	15	0.2
Albert	544	4	0.7
Maroochy	307	6	2.0

For basins, representativeness values were generated from relating the proportion of monitored catchment to coverage by multiplying both terms, whilst for estuaries representativeness values were generated just from the proportion of monitored catchment (Table 54). The standard criteria for representativeness used for determining a score of 1 to 3 was then applied to these values where 0 < 10% = 1, 10 – 30% = 2 and > 30% = 3 (Table 51).

Table 54 Terms used for determining representativeness for basins and estuaries.

Basin/ estuary	Catchment area (km²)	Gauged catchment area (km²)	Proportion of catchment area monitored	Number of assessment sites	Coverage (sites per 100km²)	Coverage x proportion	Represent-ativeness
Basin							
Mossman	472.4	106	0.22	1	0.21	0.05	1
Barron	2188.8	2015	0.92	7	0.32	0.29	2
Mulgrave	1315	520	0.40	2	0.15	0.06	1
Russell	669	354	0.53	2	0.30	0.16	2
Johnstone	2323.9	1221	0.53	6	0.26	0.14	2
Tully	1683.5	1450	0.86	2	0.06	0.05	1
Murray	1108.4	309	0.28	2	0.18	0.05	1
Herbert	9845.9	8581	0.87	11	0.11	0.10	2
Estuary							
Barron	2188.8	2015	0.92	na	na	na	3
Russell-Mulgrave	1648	874	0.53	na	na	na	3
Johnstone	2246	1325	0.59	na	na	na	3

Note: The number of assessment sites is not applicable to estuaries since estuaries are downstream of all assessment sites and only assessed from the most downstream assessment site(s). The catchment area for the Russell-Mulgrave estuary excludes the Trinity Inlet sub-catchment which drains to the north, and the catchment area for the Johnstone estuary excludes Liverpool Creek sub-catchment which drains to the south. na is not applicable.

5. REFERENCES

Allen, G. R., Midgley, S. H., and Allen, M. 2003. Freshwater Fishes of Australia. (CSIRO Publishing: Melbourne, Vic., Australia.).

Altenburger R, Walter H, Grote M. 2004. What contributes to the combined effect of a complex mixture? Environ Sci & Technol, 38:6353–6362.

ANZ WQG 2018 the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. http://www.waterquality.gov.au/anz-guidelines/

Australian Government and Queensland Government. 2015. Scoring system, Great Barrier Reef Report Card 2014. Available to download from: http://www.reefplan.qld.gov.au/measuring-success/report-cards/2014/assets/gbrscoring-system-2014.pdf

Binns, P. and Waters, D. 2018. Baseflow separation. Refinement of the Lyne & Hollick baseflow separation methodology using historical water quality data from Great Barrier Reef catchments. , Resource Assessment & Information, Queensland Department of Natural Resources, Mines and Energy. Brisbane. https://trove.nla.gov.au/work/234290652?

Bliss CI. 1939. The toxicity of poisons applied jointly. Ann Appl Biol 26:585–615.

Bryant, C., Jarvis, J. C., York, P., & Rasheed, M. 2014. Gladstone Healthy Harbour Partnership Pilot Report Card; ISP011: Seagrass. (pp. 74). Cairns: Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 14/53, James Cook University.

Carter, A. B., Jarvis, J. C., Bryant, C. V., & Rasheed, M. A. 2015. Development of seagrass indicators for the Gladstone Healthy Harbour Partnership Report Card, ISP011: Seagrass (pp. 71). Cairns: Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 15/29, James Cook University.

Carter, A., Rasheed, M., McKenzie, L., & Coles, R. 2016a. An interim approach to integrate seagrass monitoring results for NRM regional report cards. A case study using the Wet Tropics NRM region. Seagrass Ecology Group- James Cook University. Centre for Tropical Water & Aquatic Ecosystem Research, Cairns.

Carter AB, Chartrand KM, Wells JN & Rasheed MA (2019). 'Gladstone Healthy Harbour Partnership 2019 Report Card, ISP011: Seagrass'. Centre for Tropical Water & Aquatic Ecosystem Research Publication 19/15, James Cook University, Cairns, 63 pp.

Collier, C.J., Langlois, L., Waycott, M., McKenzie, L.J. 2021, Resilience in practice: development of a seagrass resilience metric for the Great Barrier Reef Marine Monitoring Program, Great Barrier Reef Marine Park Authority, Townsville, 61pp.

Commonwealth of Australia 2015. Reef 2050 Long-Term Sustainability Plan. Australian Government, Canberra, Australia.

DEHP (Department of Environment and Heritage Protection) 2009. Queensland Water Quality Guidelines, Version 3, ISBN 978-0-9806986-0-2. Available at www.ehp.qld.gov.au/water/pdf/water-quality-guidelines.pdf

DEHP (Department of Environment and Heritage Protection) 2014. Environmental Protection (Water) Policy 2009 Wet Tropics Basins Environmental Values and Water Quality Objectives. Environmental Policy and Planning Division, Department of Environment and Heritage Protection.

DES 2018. Monitoring and Sampling Manual: Environmental Protection (Water) Policy. Brisbane: Department of Environment and Science Government.

Devlin, M. Lewis, S. Davis, A. Smith, R. Negri, A. Thompson, M. Poggio, M. 2015. Advancing our understanding of the source, management, transport and impacts of pesticides on the Great Barrier Reef 2011-2015. A report for the Queensland Department of Environment and Heritage Protection. Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication, James Cook University, Cairns, 134 pp.

De Zwart D, Posthuma L. 2005. Complex mixture toxicity for single and multiple species: Proposed methodologies. Environ Toxicol Chem 24:2665–2676.

DNR (Department of Natural Resources) 2000. Condamine-Balonne WAMP: environmental flows technical report. Water Resource Allocation and Management, Department of Natural Resources, Brisbane. 163 pp.

DNRM (Department of Natural Resources and Mines) 2009. Drainage basin sub-area Queensland. http://qldspatial.information.qld.gov.au/catalogue/custom/search.page?q=%22Drainage basin sub-area Queensland%22

DPC (Department of the Premier and Cabinet). 2013. Reef Water Quality Protection Plan 2013, Securing the health and resilience of the Great Barrier Reef World Heritage Area and adjacent catchments, Reef Water Quality Protection Plan Secretariat, Brisbane. Available from: www.reefplan.qld.gov.au. Downloaded: 20 May 2015.

EHMP 2008. Ecosystem Health Monitoring Program 2006–07 Annual Technical Report. Moreton Bay Waterways and Catchments Partnership, Brisbane.

eWater CRC 2012. Water Quality Analyser. eWater Limited Canberra, Australia, http://www.ewater.com.au/products/ewater-toolkit/eco-tools/water-quality-analyser/ Accessed March 2014.

FNQROC (Far North Queensland Regional Organisation of Councils) 2015. Pest Management Planning - Local Government Pest assessment, prioritisation and planning framework. Appendix to the Far North Queensland Local Government Regional Pest Management Strategy 2010-15. Version 1.6. Cape York edition (July 2015).

Fortune, J and Mauraud, N.(2015). Effect of tide on water quality of Jones Creek, Darwin Harbour. Report No. 02/2015D. Department of Land Resource Management, Aquatic Health Unit. Palmerston, NT.

Gallen C, Devlin M, Thompson K, Paxman C, Mueller J. 2014. Pesticide monitoring in inshore waters of the Great Barrier Reef using both time-integrated and event monitoring techniques (2013 - 2014). The University of Queensland, The National Research Centre for Environmental Toxicology (Entox).

Gallen, C., Thompson, K., Paxman, C., Devlin, M., Mueller, J. 2016. Marine Monitoring Program. Annual Report for inshore pesticide monitoring: 2014 to 2015. Report for the Great Barrier Reef

Marine Park Authority. The University of Queensland, The National Research Centre for Environmental Toxicology (Entox), Brisbane.

Garzon-Garcia, A., Wallace, R., Huggins, R., Smith, R. A., Turner, R. D. R., Warne, M. St. J. 2015. Total suspended solids, nutrient and pesticide loads (2013–2014) for rivers that discharge to the Great Barrier Reef – Great Barrier Reef Catchment Loads Monitoring Program. Department of Science, Information Technology and Innovation. Brisbane

GBRMPA (Great Barrier Reef Marine Park Authority) 2010. Water Quality Guidelines for the Great Barrier Reef Marine Park. Revised Edition 2010. Great Barrier Reef Marine Park Authority, Townsville. 100p

Grant S., Thompson K., Paxman C., Elisei G., Gallen C., Tracey D., Kaserzon S., Jiang H., Samanipour S. and Mueller J. 2018, Marine Monitoring Program: Annual report for inshore pesticide monitoring 2016-2017. Report for the Great Barrier Reef Marine Park Authority, Great Barrier Reef Marine Park Authority, Townsville, 128 pp.

Grayson, R.B., Argent, R.M., Nathan, R.J., McMahon, T.A., Mein, R. 1996. Hydrological Recipes: Estimation Techniques in Australian Hydrology. Cooperative Research Centre for Catchment Hydrology, Clayton, Victoria, Australia.

Gruber, R., Waterhouse, J., Logan, M., Petus, C., Howley, C., Lewis, S., Tracey, D., Langlois, L., Tonin, H., Skuza, M., Costello, P., Davidson, J., Gunn, K., Lefevre, C., Moran, D., Robson, B., Shanahan, M., Zagorskis, I., Shellberg, J. and Neilen, A. 2020. Marine Monitoring Program: Annual Report for Inshore Water Quality Monitoring 2018-19. Report for the Great Barrier Reef Marine Park Authority, Great Barrier Reef Marine Park Authority, Townsville.

Hamers, T, Aldenberg, T, van de Meent, D. 1996. Definition report—indicator effects for toxic substances (Itox). National Institute of Public Health and the Environment. Bilthoven (NL): RIVM. Report 607128 001. Available from: http://www.rivm.nl/bibliotheek/rapporten/607128001.html.

HRAC (Herbicide Resistance Action Committee). 2010. The world of herbicides. HRAC, CropLife. Available from: www.hracglobal.com . Downloaded: 5/01/2019.

Huggins, R., Wallace, R., Orr, D. N., Thomson, B., Smith, R. A., Taylor, C. King, O., Gardiner, R., Wallace, S., Ferguson, B., Preston, S., Simpson, S., Shanks, J., Warne, M. St. J., Turner, R. D. R., Mann, R. M. 2017. Total suspended solids, nutrient and pesticide loads (2015–2016) for rivers that discharge to the Great Barrier Reef – Great Barrier Reef Catchment Loads Monitoring Program. Department of Science, Information Technology and Innovation. Brisbane.

IRAC (Insecticide Resistance Action Committee). 2016. Mode of action classification. The key to resistance management. IRAC, CropLife. Available from: www.irac-online.org. Downloaded: 5/01/2019.

Junghans M. 2004. Studies on combination effects of environmentally relevant toxicants: Validation of prognostic concepts for assessing the algal toxicity of realistic aquatic pesticide mixtures. PhD thesis. Bremen (DE): Univ Bremen. Available from: http://deposit.ddb.de/cgi-bin/dokserv?idn¼975465317&dok_var¼d1&dok_ext¼pdf&filename¼975465317.pdf.

Könemann H. 1981. Fish toxicity tests with mixtures of more than two chemicals: A proposal for a quantitative approach and experimental results. Toxicology 19:229–238.

Kroon, F. J. and Phillips, S. 2015 Identification of human-made physical barriers to fish passage in the Wet Tropics region, Australia. Marine and Freshwater Research http://dx.doi.org/10.1071/MF14397.

Lawson, T., Kroon, F., Russell, J., Thuesen, P., and Fakes, A. 2010. Audit and prioritisation of physical barriers to fish passage in the Wet Tropics region. Milestone report, MTSRF project 2.6.2. (CSIRO Ecosystem Sciences: Atherton, Qld, Australia.).

Lønborg C, Devlin M, Waterhouse J, Brinkman R, Costello P, da Silva E, Davidson J, Gunn K, Logan M, Petus C, Schaffelke B, Skuza M, Tonin H, Tracey D, Wright M and Zagorskis I (2016). Marine Monitoring Program: Annual Report for inshore water quality monitoring: 2014 to 2015. Report for the Great Barrier Reef Marine Park Authority. Australian Institute of Marine Science and JCU TropWATER, Townsville 229pp.

Lorenzen, C. J. 1967. Determination of chlorophyll and phaeopigments: spectrophotometric equations, Limnology and Oceanography, 12: 343-346.

Mackay-Whitsunday Healthy Rivers to Reef Technical Working Group. 2015. Program Design: Pilot Report Card. Brisbane.

Mackenzie, J.R. 2021. Development of an Estuarine Mangrove Habitat Indicator from MangroveWatch Citizen-Science Data for use in the Wet Tropics Healthy Waterways Report Cards. Earthwatch Institute, Melbourne.

Mackenzie, J. R., Duke, N. C., & Wood, A. L. 2016. The Shoreline Video Assessment Method (S-VAM): Using dynamic hyperlapse image acquisition to evaluate shoreline mangrove forest structure, values, degradation and threats. Marine pollution bulletin, 109(2), 751-763.

McKenzie, L. J. 2009. MTSRF Milestone report for June 2009: Seagrass indicators, distribution and thresholds of potential concern. Available: http://www.rrrc.org.au/publications/downloads/113-QDPIF-McKenzie-L-2009-June-Milestone-Report.pdf.

McKenzie, L. J., Campbell, S. J. and Roder, C. A. 2003. Seagrass-Watch: Manual for Mapping & Monitoring Seagrass Resources by Community (citizen) volunteers. 2nd Edition. (QFS, NFC, Cairns) 100pp.

McKenzie, L. J., Collier, C. and Waycott, M. 2015. Reef Rescue Marine Monitoring Program - Inshore Seagrass, Annual Report for the sampling period 1st June 2012 – 31st May 2013. TropWATER, James Cook University, Cairns. 173pp.

McKenzie, L. J., Mellors, J., Waycott, M., Unsworth, R. and Collier, C. 2010. Intertidal seagrass monitoring. In RRRC Ltd. (Ed.), Reef Rescue Marine Monitoring Program: Quality Assurance/Quality Control Methods and Procedures Manual. Report prepared for the Great Barrier Reef Marine Park Authority. (pp. 42-56). Cairns: Reef & Rainforest Research Centre Ltd.

Moore, M. 2015. Mackay Whitsunday WQIP barriers to fish migration health metrics. Catchments solutions.

Moore, M. 2016. HR2R – Freshwater & Estuary Fish Barrier Metrics Report – Final Report for Healthy Rivers to Reef Partnership.

Orr, D., Turner, R.D.R., Huggins, R., Vardy, S., Warne, M. St. J. 2014. Wet Tropics water quality statistics for high and base flow conditions. Great Barrier Reef Catchment Loads Monitoring Program, Department of Science, Information Technology, Innovation and the Arts, Brisbane.

Plackett RL, Hewlett PS. 1952. Quantal responses to mixtures of poisons. J Roy Stat Soc B 14:141.

Pusey, B., Kennard, M., and Arthington, A. 2004. 'Freshwater Fishes of North-Eastern Australia.' (CSIRO Publishing: Melbourne.)

Queensland Government 2005. Digital elevation model - 25metre - Wet Tropics - data package http://qldspatial.information.qld.gov.au/catalogue/custom/search.page?q=%22Digital%20elevation%20model%20-%2025metre%20-%20Wet%20Tropics%20-%20data%20package%22 QSpatial, Department of Resources, Brisbane.

Queensland Government 2014. Riparian methods. Great Barrier Reef Report Card 2014. http://www.reefplan.qld.gov.au/about/assets/gbr-report-card-2014-riparian-methods.pdf

Reason, C., York, P., Scott, E., McKenna, S. and Rasheed, M. 2016. Seagrass habitat of Mourilyan Harbour: Annual Monitoring Report 2015. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication, James Cook University. Cairns, 39 pp.

Sheldon, F., Thoms, M., Berry, O., and Puckridge, J. 2000. Using disaster to prevent catastrophe: Referencing the impacts of flow changes in large dryland rivers. Regulated Rivers: Research and Management 16: 403-420.

Short, F.T. and S. Wyllie-Echeverria. 1996. Natural and human-induced disturbance of seagrasses. Environmental Conservation 23:17-27.

Smith *et al*. (in prep). Rationale and Revised Methods for Reporting Pesticides Using the Multisubstance – Potentially Affected Fraction (ms-PAF).

Stewart-Koster, B., Bofu Yu, B., Balcombe, S., Kennard, M., Marsh, N. 2018 Development of Report Card flow Indicators for the Mackay-Whitsunday and Wet Tropics regions. Australian Rivers Institute, Griffith University and Truii Pty Ltd. Brisbane.

Sweatman H, Thompson A, Delean S, Davidson J, Neale S. 2007. Status of inshore reefs of the Great Barrier Reef 2004. Australian Institute of Marine Science, Townsville.

Sydes, T. and Hunt R.J. 2017. A method for assessing invasive weeds of waterways in the Wet Tropics for the Wet Tropics Healthy Waterways Report Card. Wet Tropics Healthy Waterways Partnership.

Terrain NRM 2015. Wet Tropics Water Quality Improvement Plan 2015-2020. Terrain NRM, Innisfail.

Thompson A, Lønborg C, Logan M, Costello P, Davidson J, Furnas M, Gunn K, Liddy M, Skuza M, Uthicke S, Wright M, Zagorskis I, and Schaffelke B. 2014. Marine Monitoring Program. Annual Report of AIMS Activities 2013 to 2014– Inshore water quality and coral reef monitoring. Report for the Great Barrier Reef Marine Park Authority. Australian Institute of Marine Science, Townsville.160 pp.

Thompson A, Costello P, Davidson J, Logan M, Gunn K, Schaffelke B. 2016. Marine Monitoring Program. Annual Report for inshore coral reef monitoring: 2014 to 2015. Report for the Great Barrier Reef Marine Park Authority. Australian Institute of Marine Science, Townsville.133 pp.

Traas, T.P., Van de Meent, D., Posthuma, L., Hamers, T., Kater, B.J., De Zwart, D., Aldenberg, T. 2002. The potentially affected fraction as a measure of ecological risk. In: Posthuma, L., Suter, II G.W., Traas, T.P., editors. Species Sensitivity Distributions in Ecotoxicology. Boca Raton (FL), USA: Lewis Publishers. p 315-344.

Wallace, R., Huggins, R., Smith, R. A., Turner, R. D. R., Garzon-Garcia, A and Warne, M. St. J. 2015. Total suspended solids, nutrient and pesticide loads (2012–2013) for rivers that discharge to the Great Barrier Reef – Great Barrier Reef Catchment Loads Monitoring Program 2012–2013. Department of Science, Information Technology and Innovation. Brisbane.

Wang, Y., Zou, Y., Henrickson, K., Wang, Y. Tang, J., and Park, B-J. 2017 Google Earth elevation data extraction and accuracy assessment for transportation applications. PLoS ONE 12(4): e0175756. https://doi.org/10.1371/journal.pone.0175756

Warne, M.St.J., Batley, G.E., van Dam, R. A., Chapman, J. C., Fox D.R., Hickey, C.W., and Stauber, J.L. 2015. Deriving Australian and New Zealand water quality guideline values for toxicants. Department of Science, Information Technology, Innovation and the Arts, Brisbane, Queensland, 36 pp.

Warne M.St.J., Neelamraju, C., Strauss, J., Smith, R.A., Turner, R.D.R., Mann, R.M. 2020. Development of a method for estimating the toxicity of pesticide mixtures and a Pesticide Risk Baseline for the Reef 2050 Water Quality Improvement Plan. Brisbane: Department of Environment and Science, Queensland Government.

Worley Parsons. 2014. Abbot Point Baseline Water Quality Monitoring Report. 301001-01648-00-MA-REP-0002. Brisbane.

WTHWP (Wet Tropics Healthy Waterways Partnership) 2018. Wet Tropics Report Card Program Design: Five year plan 2018 - 2022. Wet Tropics Health Waterways Partnership and Terrain NRM, Cairns.

WTW (Wet Tropics Waterways) 2019. Wet Tropics Report Card 2019 (reporting on data 2017-18). Waterway Environments: Results. Wet Tropics Waterways and Terrain NRM, Cairns.

York, P.H., Davies, J.N. & Rasheed, M.A. 2014. Long-term seagrass monitoring in the Port of Mourilyan – 2013', JCU Publication, Centre for Tropical Water & Aquatic Ecosystem Research, Cairns, 36 pp.

York, P. H., Reason, C., Scott, E. L., Sankey, T., & Rasheed, M. A. (2016). Seagrass habitat of Cairns Harbour and Trinity Inlet: Annual Monitoring Report 2015 (pp. 58). JCU Publication, Centre for Tropical Water & Aquatic Ecosystem Research Report 16/13, Cairns.

APPENDIX A Estuarine Water Quality Monitoring Site Maps

Figure 10 DES estuary water quality monitoring sites and the DES GBR CLMP monitoring site for pesticides in the Daintree estuary.

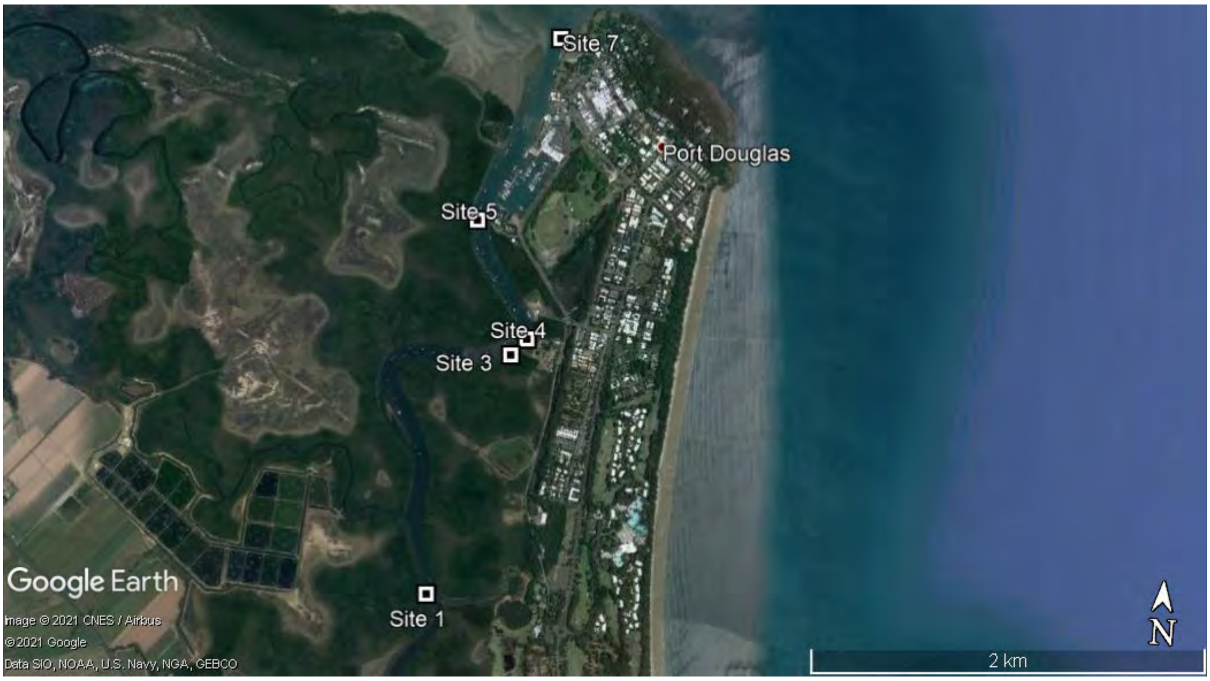

Figure 11 Douglas Shire Council water quality monitoring sites in the Dickson Inlet estuary.

Figure 12 Cairns Regional Council water quality monitoring sites at the Barron estuary.

Figure 13 Cairns Regional Council water quality monitoring sites at the Trinity Inlet estuary.

Figure 14 Cairns Regional Council water quality monitoring sites (Mulgrave Site 6 and Babinda Ck Site 7) and DES GBR CLMP monitoring sites for pesticides (Mulgrave River at Deeral and Russell River at East Russell)) at the Russell-Mulgrave estuary.

Figure 15. Cassowary Coast Regional Council water quality monitoring sites and the DES GBR CLMP Coquette Point site (CLMP) at the Johnstone estuary.

Figure 16 DES water quality monitoring sites in the Moresby estuary.

Figure 17 DES water quality monitoring sites in the Hinchinbrook Chanel.

APPENDIX B Estuarine Riparian Extent Assessment Area Maps

Figure 18 Daintree estuary riparian extent assessment area.

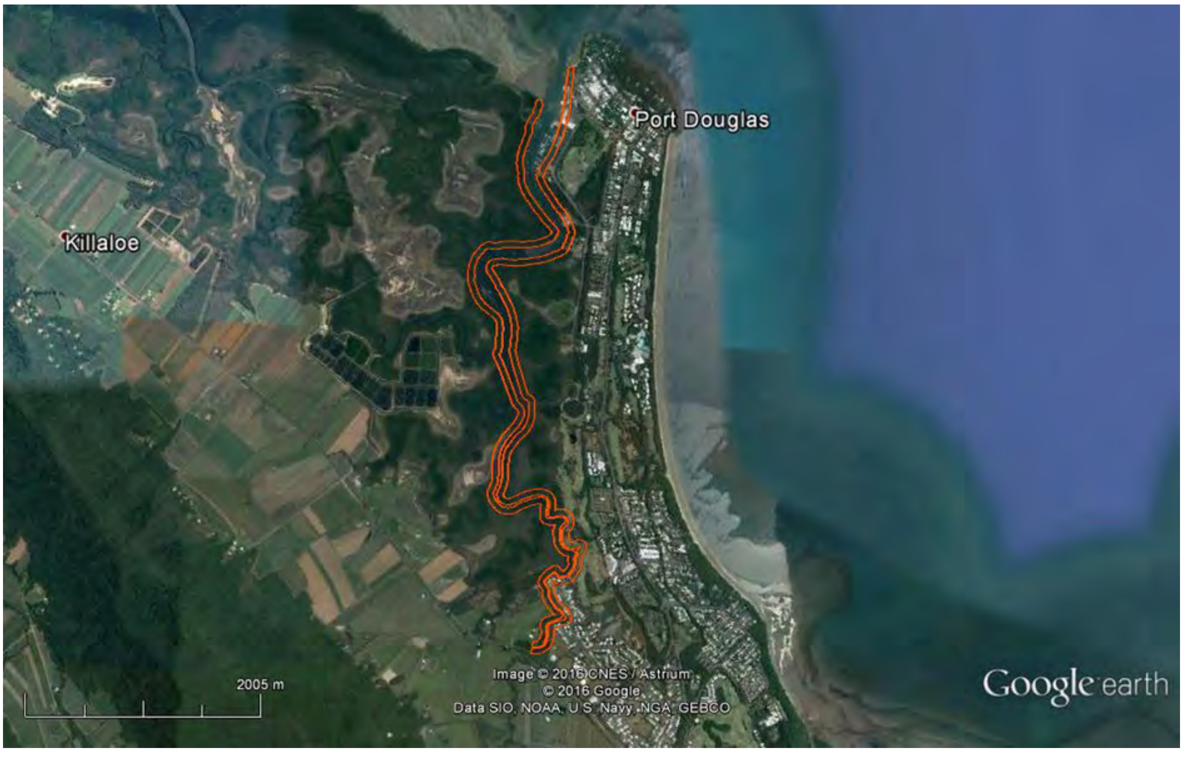

Figure 19 Dickson Inlet estuary riparian extent assessment area.

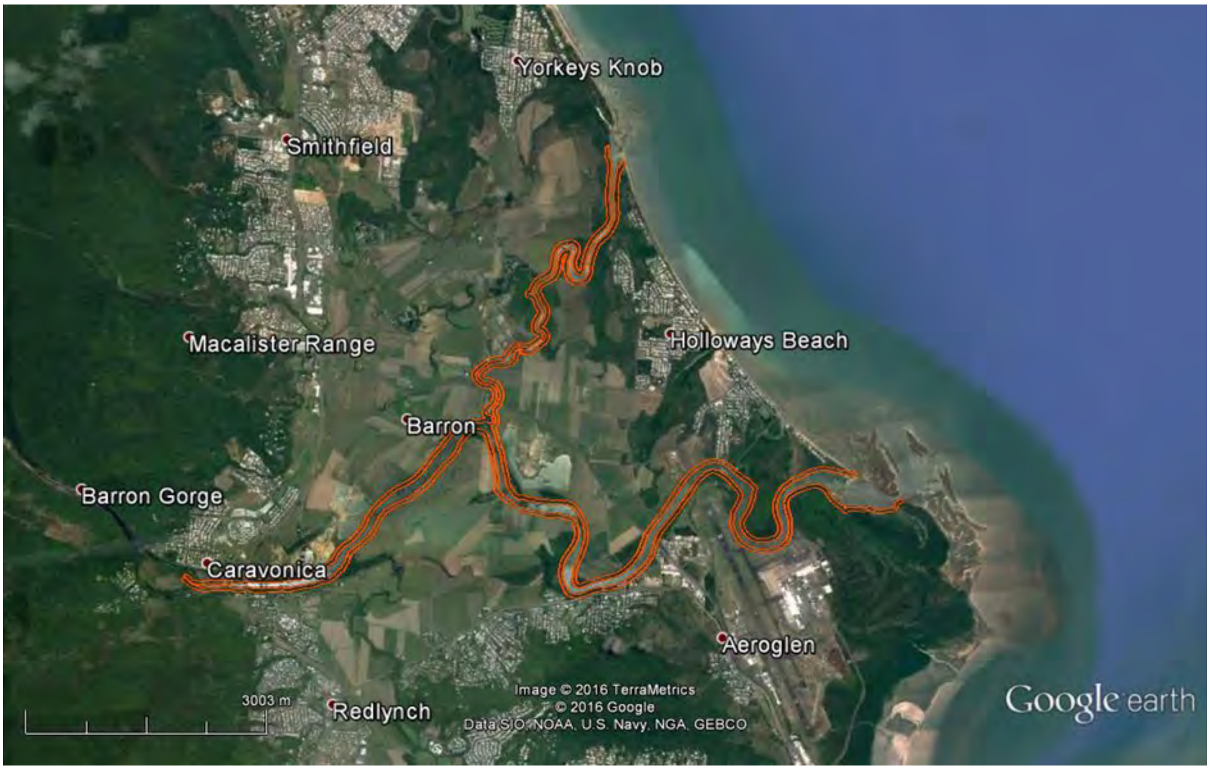

Figure 20 Barron estuary riparian extent assessment area.

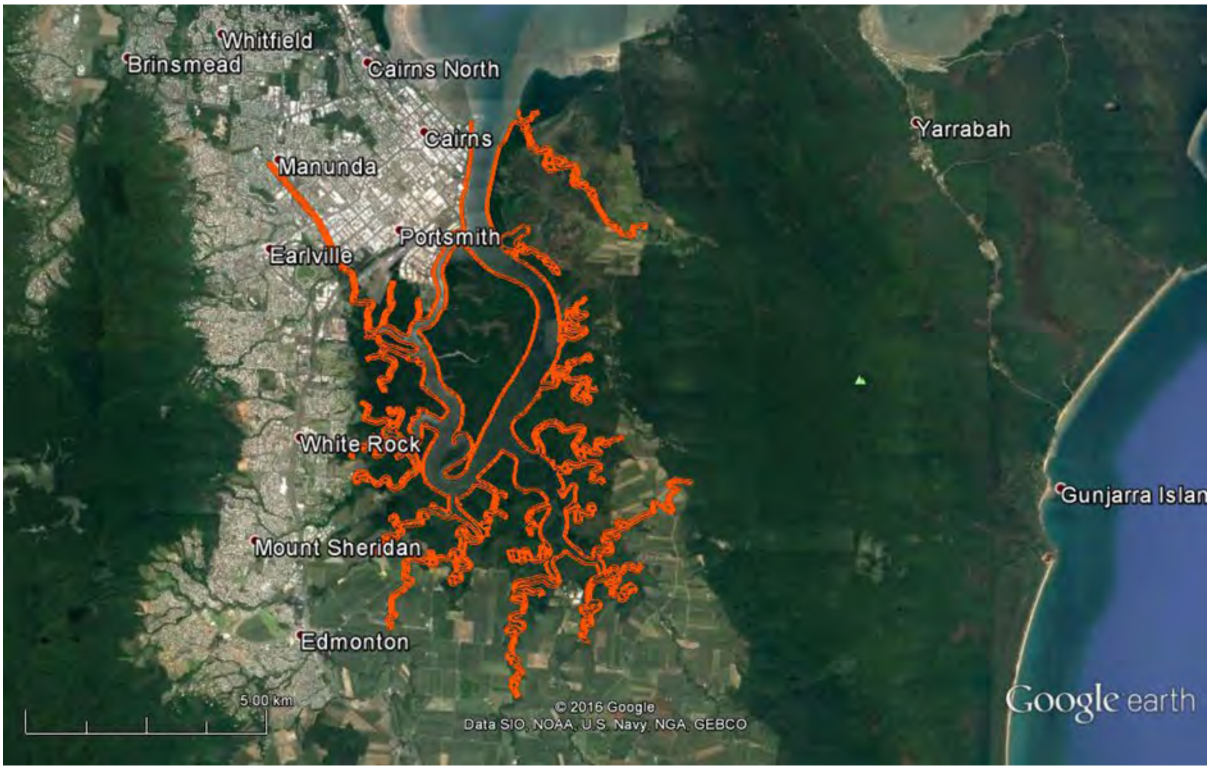

Figure 21 Trinity Inlet estuary riparian extent assessment area.

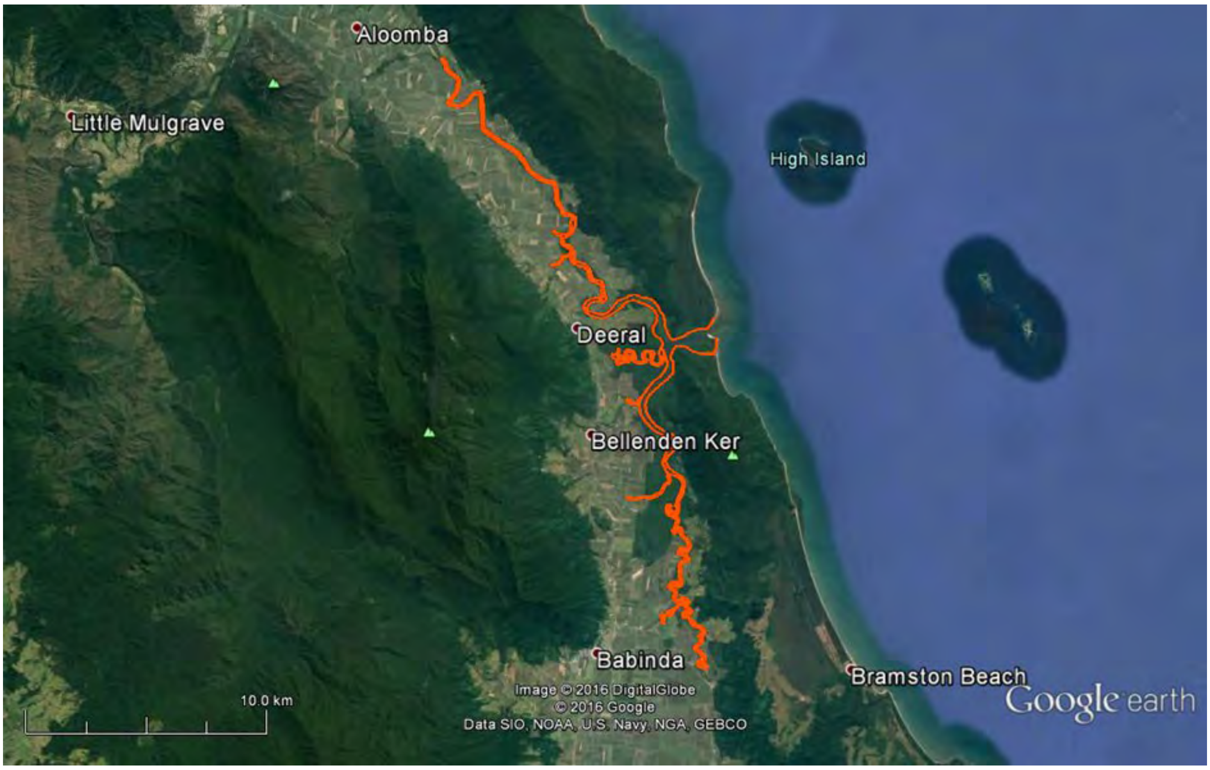

Figure 22 Russell-Mulgrave estuary riparian extent assessment area.

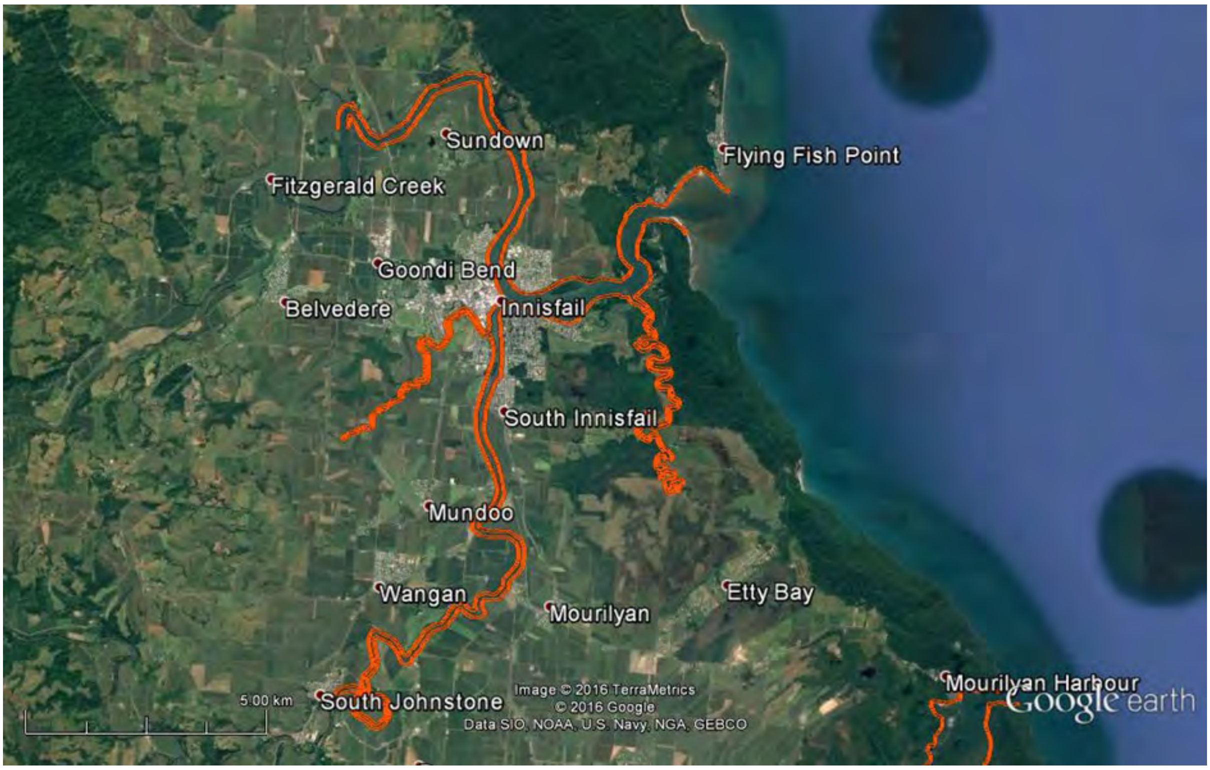

Figure 23 Johnstone estuary riparian extent assessment area.

Figure 24 Moresby estuary riparian extent assessment area.

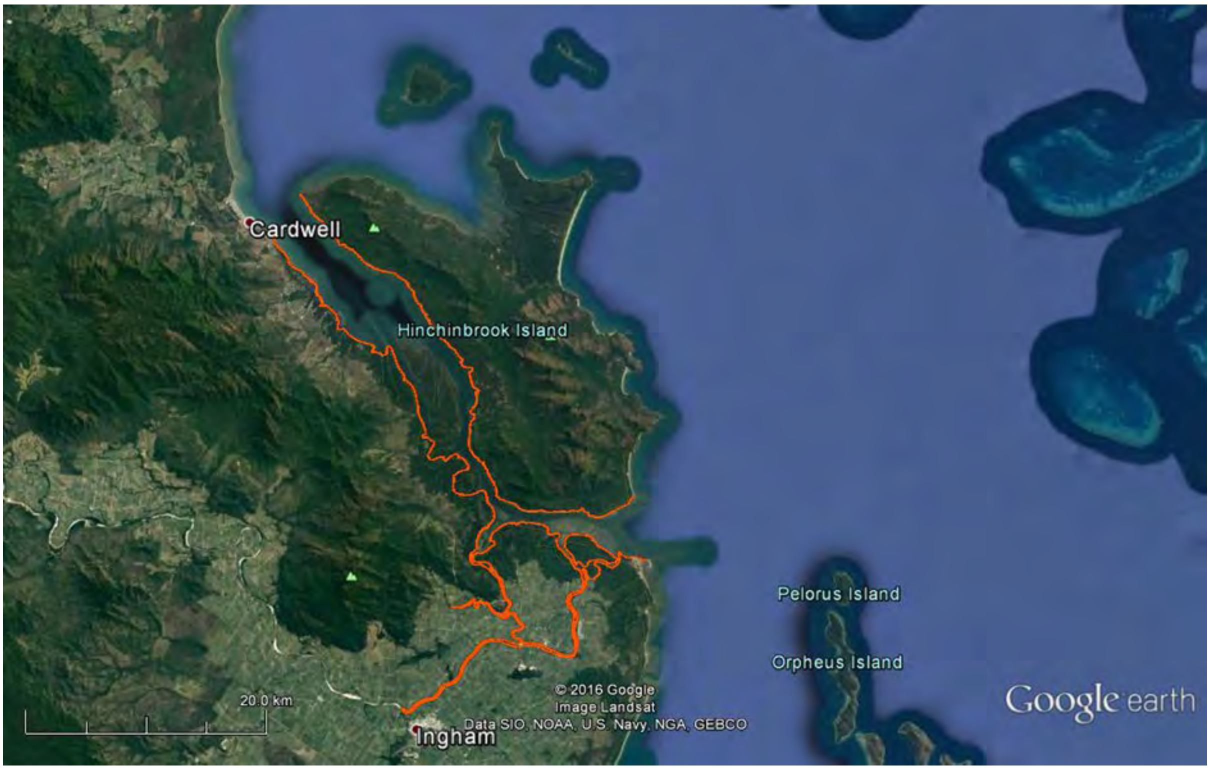

Figure 25 Hinchinbrook Channel estuary riparian extent assessment area.

APPENDIX C Estuarine Mangrove and Salt Marsh Extent Maps: Assessment Area and Pre-cleared Remnant Regional Ecosystem Vegetation Layer

Figure 26 Daintree estuary mangrove and salt marsh extent assessment area (shown by the orange line) and pre-cleared remnant ecosystem vegetation layer.

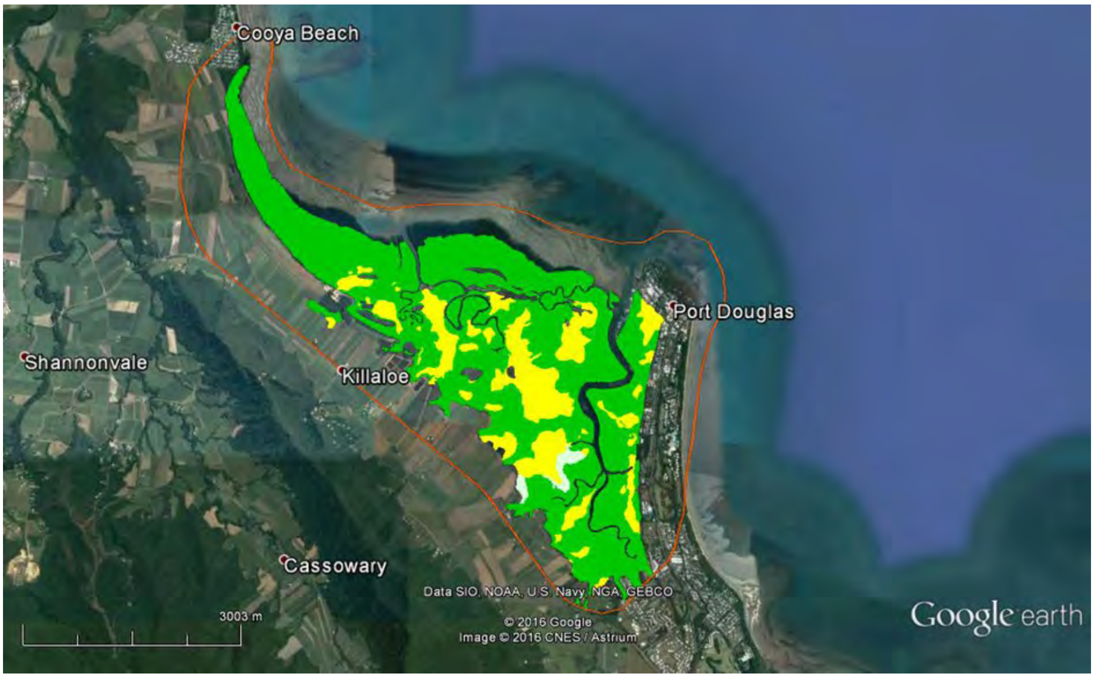

Figure 27 Dickson Inlet estuary mangrove and salt marsh extent assessment area (shown by the orange line) and pre-cleared remnant ecosystem vegetation layer.

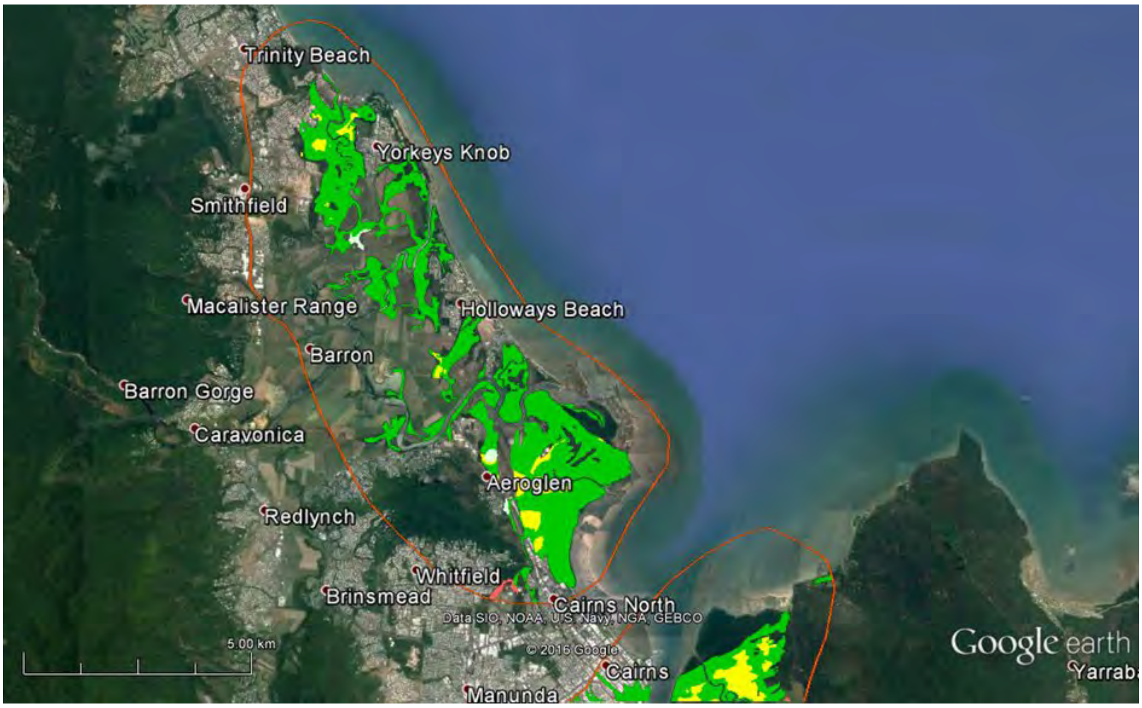

Figure 28 Barron estuary mangrove and salt marsh extent assessment area (shown by the orange line) and pre-cleared remnant ecosystem vegetation layer.

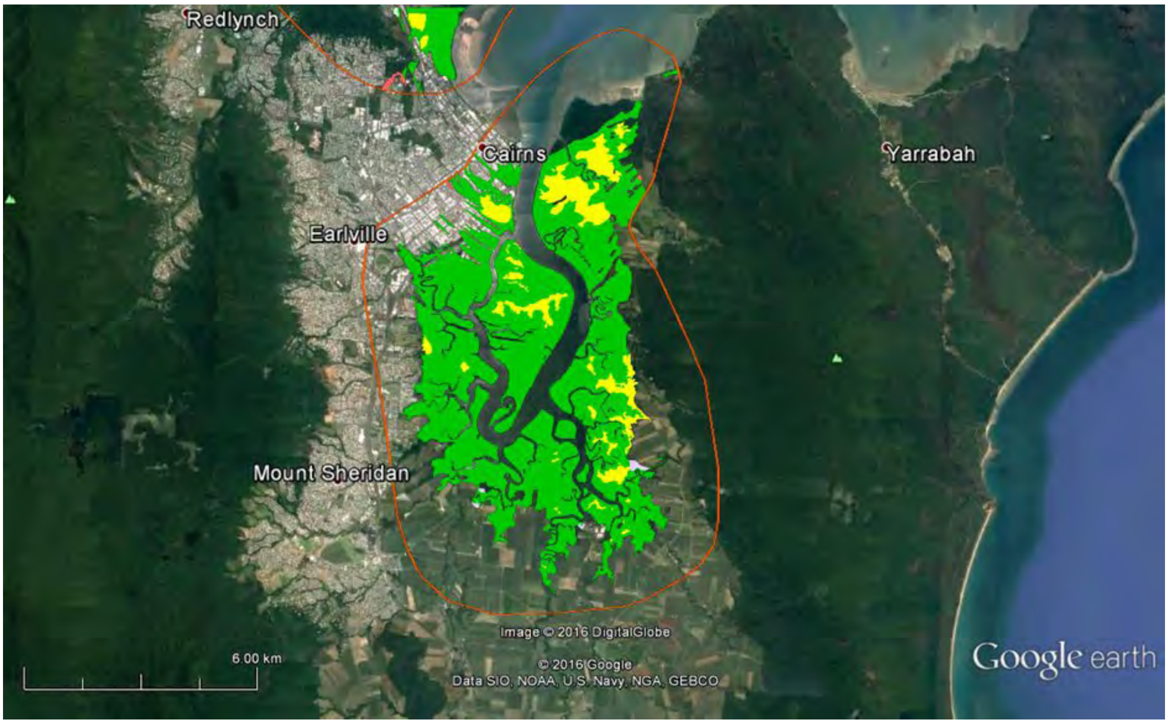

Figure 29 Trinity Inlet estuary mangrove and salt marsh extent assessment area (shown by the orange line) and pre-cleared remnant ecosystem vegetation layer.

Figure 30 Russell-Mulgrave estuary mangrove and salt marsh extent assessment (shown by the orange line) area and pre-cleared remnant ecosystem vegetation layer.

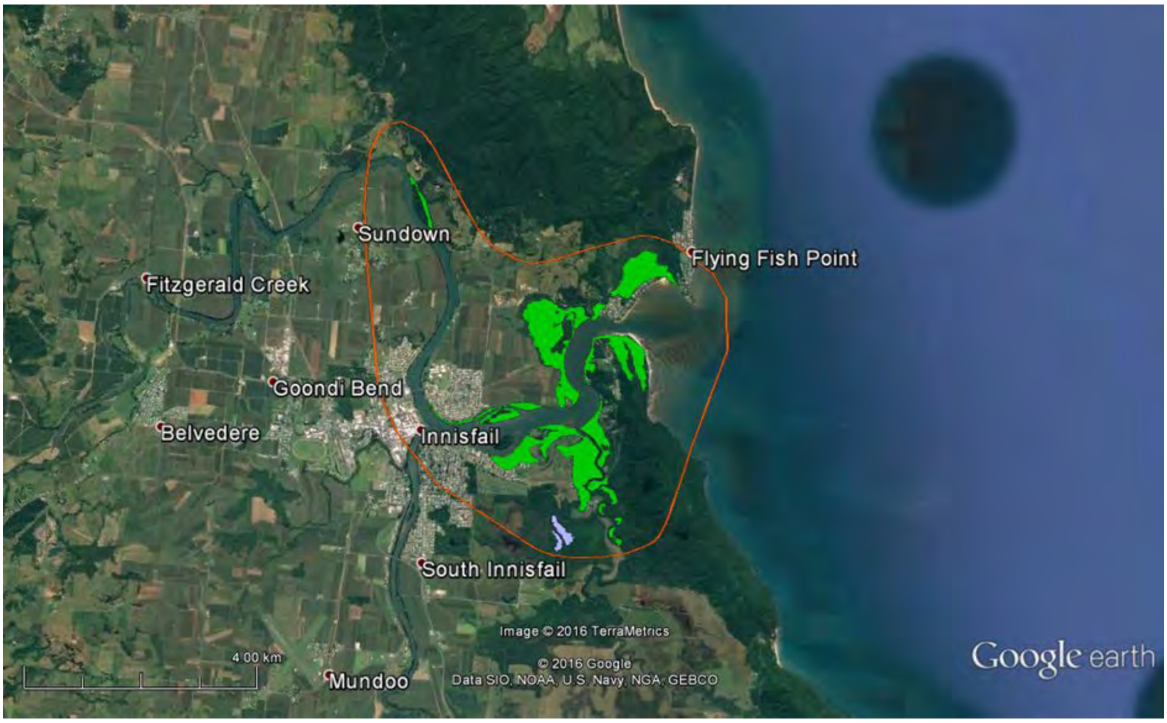

Figure 31 Johnstone estuary mangrove and salt marsh extent assessment (shown by the orange line) area and pre-cleared remnant ecosystem vegetation layer.

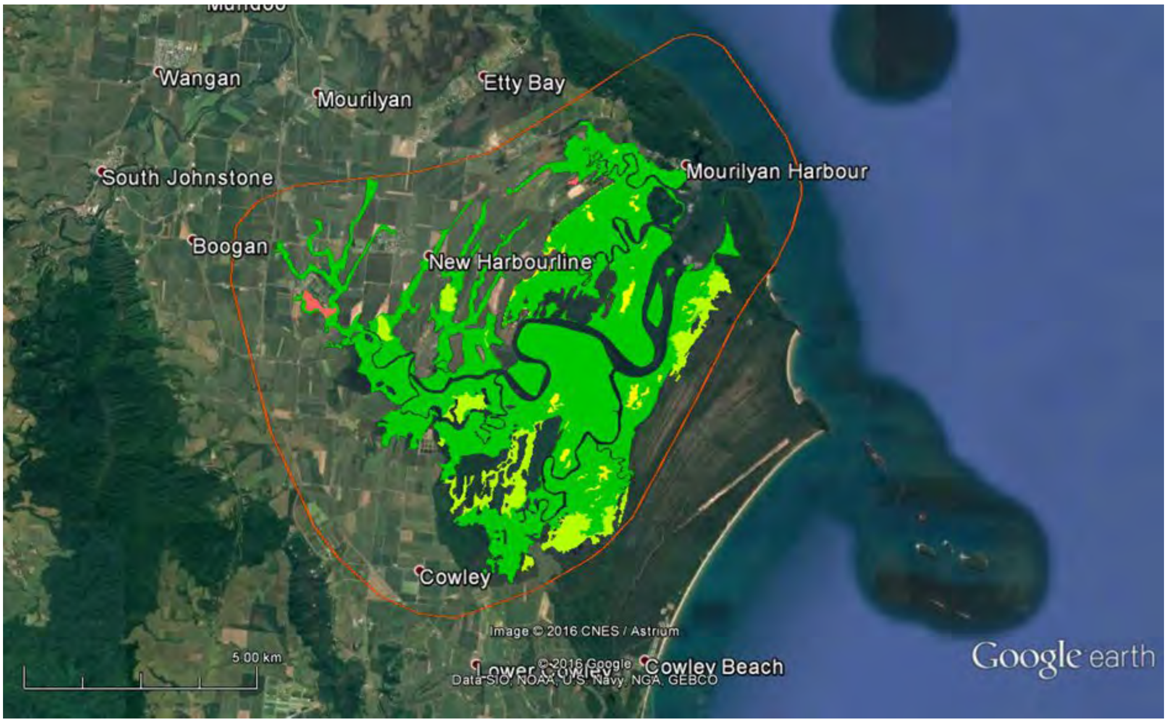

Figure 32 Moresby estuary mangrove and salt marsh extent assessment area (shown by the orange line) and pre-cleared remnant ecosystem vegetation layer.

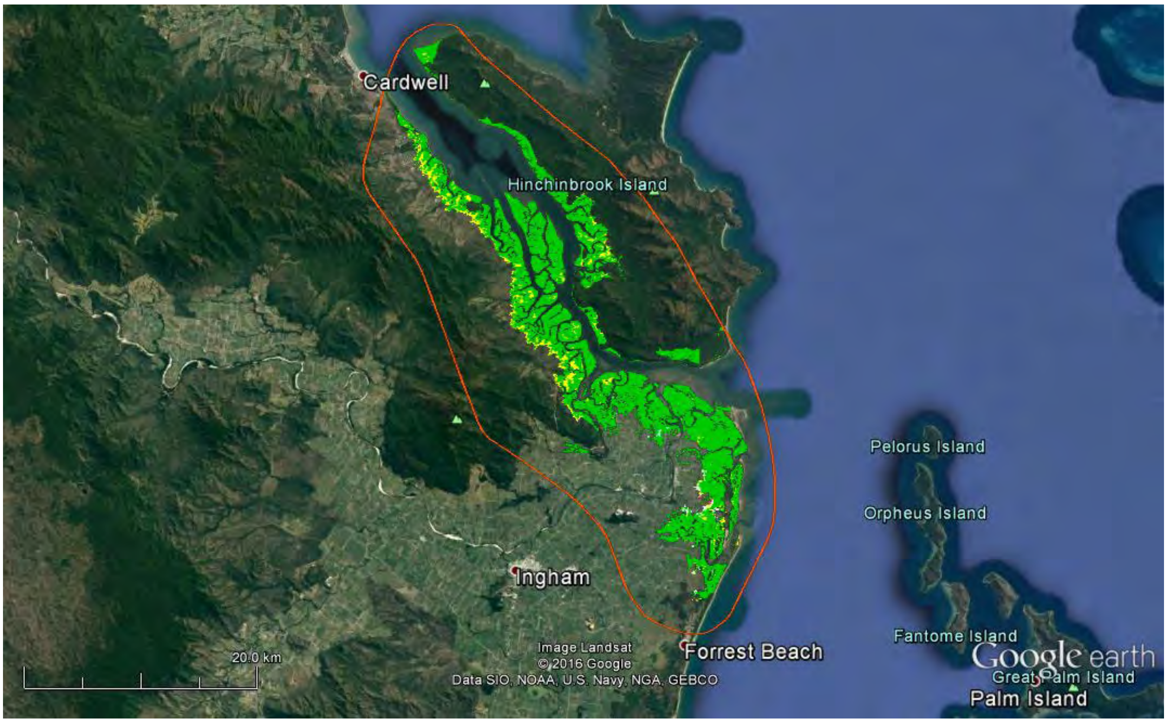

Figure 33 Hinchinbrook Channel estuary mangrove and salt marsh extent assessment (shown by the orange line) area and pre-cleared remnant ecosystem vegetation layer.

APPENDIX D Monitoring sites for inshore marine zones.

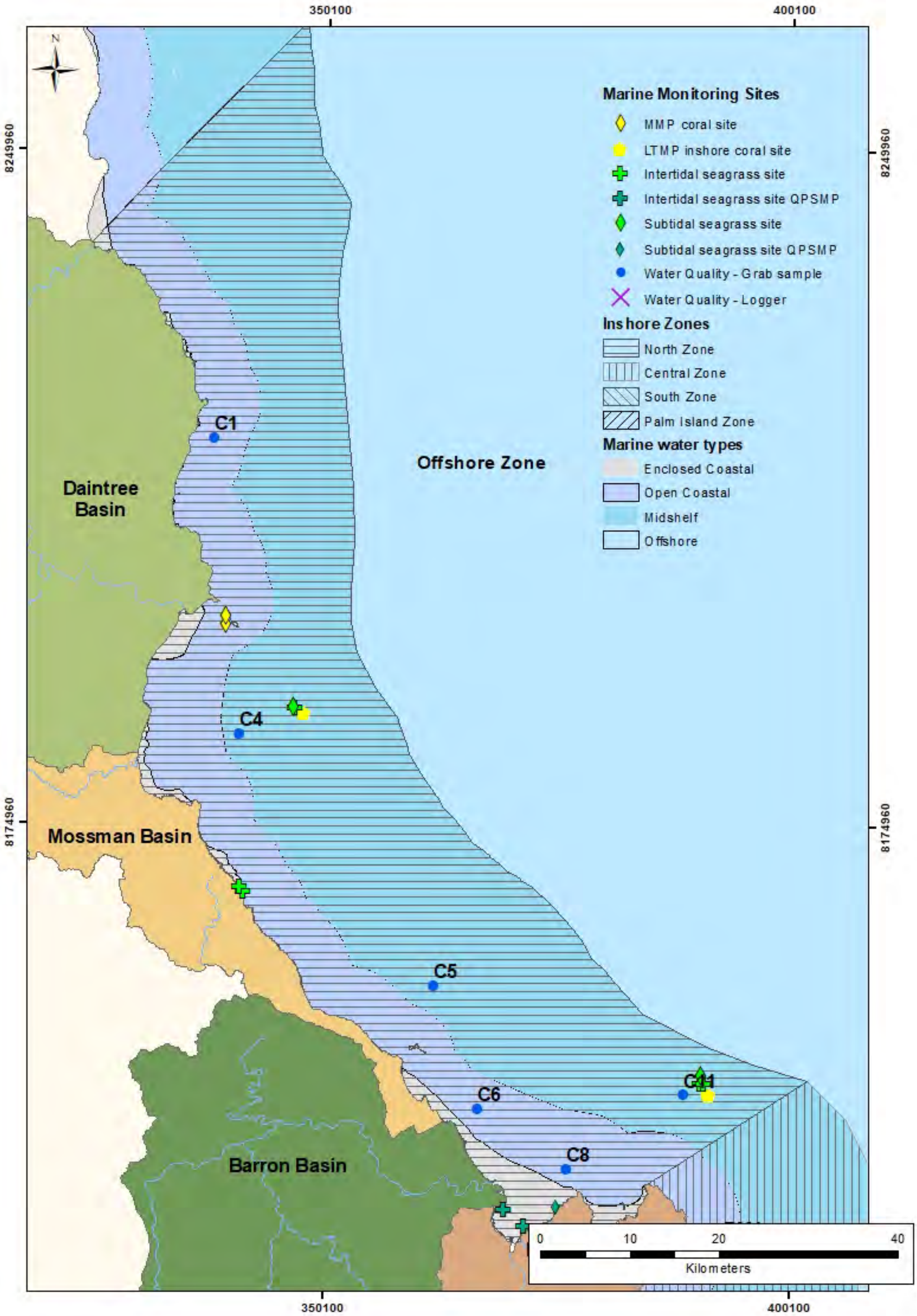

Figure 34 Water quality, seagrass and coral monitoring sites for the inshore North zone. Water quality sites are labelled with site code.

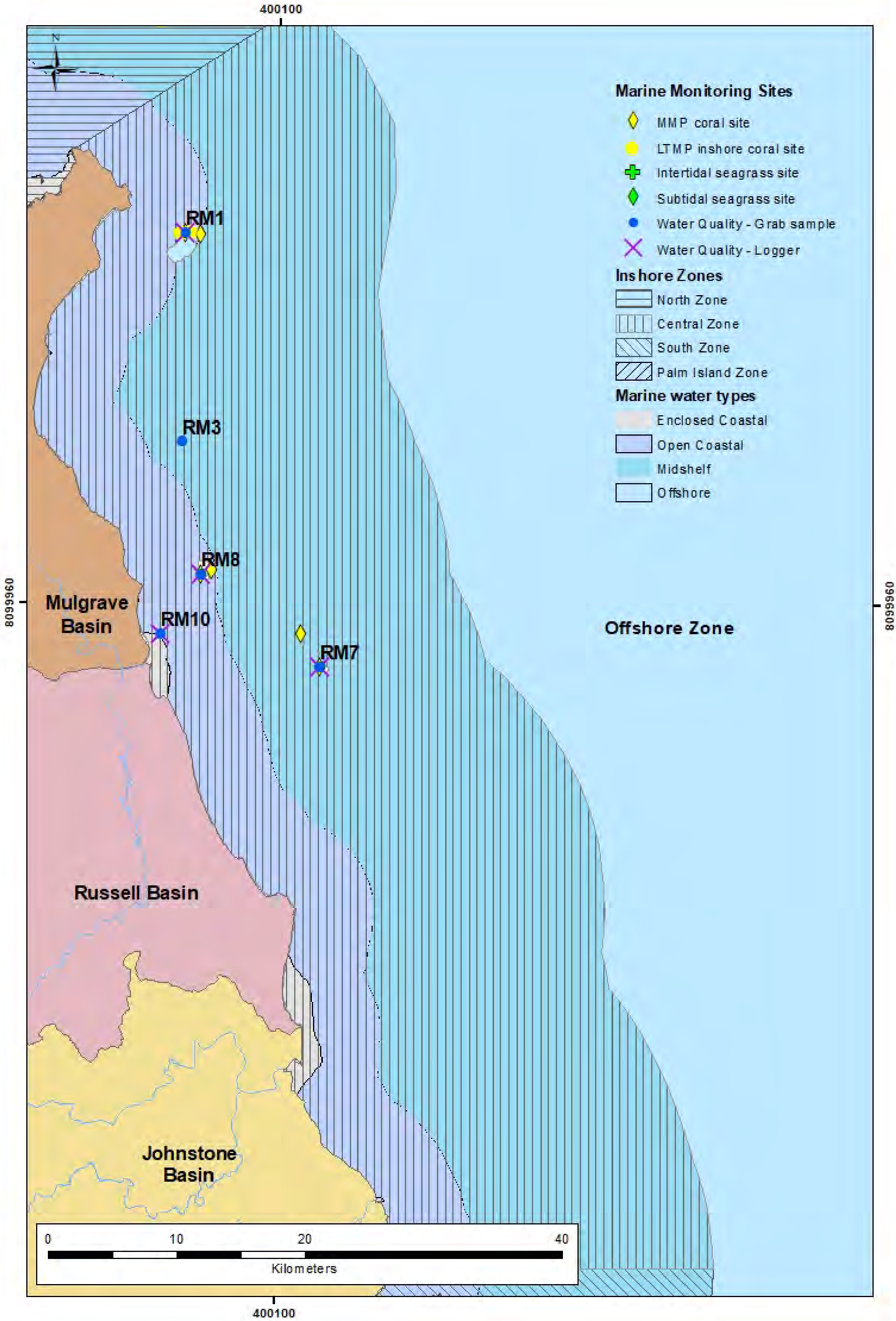

Figure 35 Water quality and coral monitoring sites for the inshore Central zone. Water quality sites are labelled with site code.

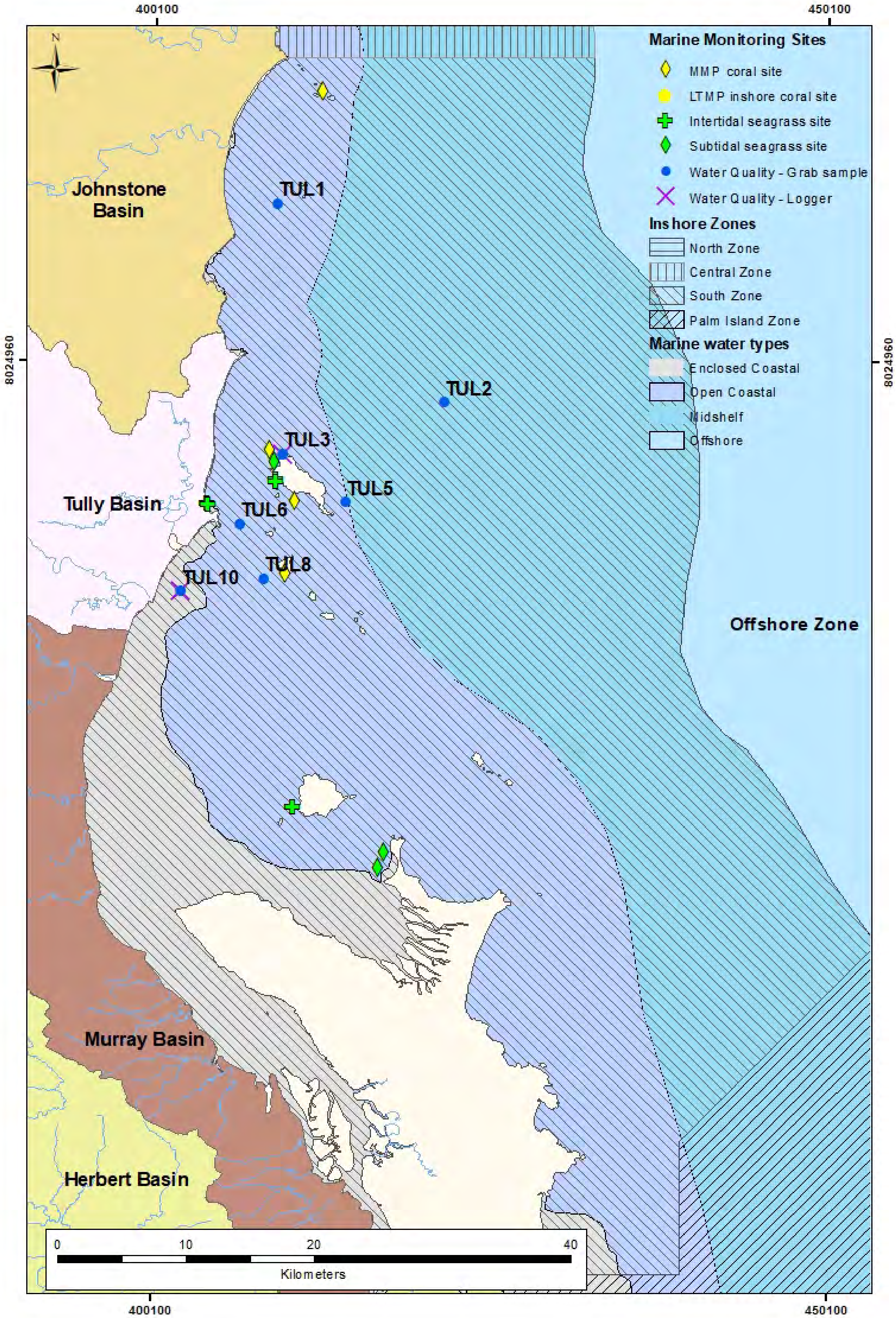

Figure 36 Water quality, seagrass and coral monitoring sites for the inshore South zone. Water quality sites are labelled with site code.

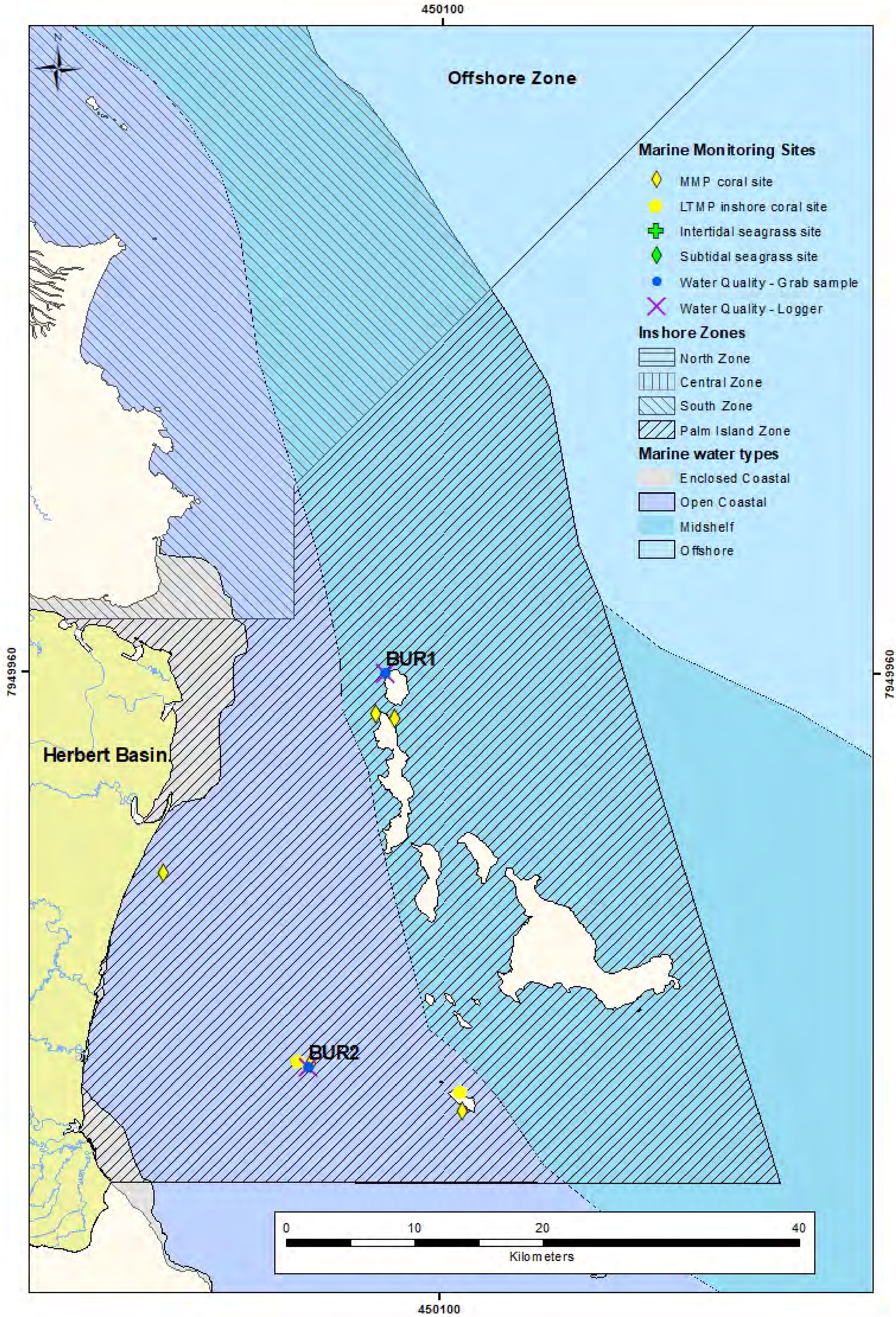

Figure 37 Water quality and coral monitoring sites for the inshore Palm Island zone. Water quality sites are labelled with site code.

APPENDIX E Inshore Marine Zones and Coral Monitoring Sites.

Table 55 Inshore reporting zones and coral monitoring sites.

Reporting Zone	Program	Reef	Number of sites	Number of depths
Inshore North	LTMP	Green	3	1
		Low Isles	3	1
	MMP	Snapper North	3	2
		Snapper South	3	2
Inshore central	LTMP	Fitzroy West LTMP	3	1
	MMP	Fitzroy East	2	2
		Fitzroy West	2	2
		Franklands East	2	2
		Franklands West	2	2
		High East	2	2
		High West	2	2
Inshore South	MMP	Barnards	2	2
		Bedarra	2	2
		Dunk North	2	2
		Dunk South	2	2
Palms	LTMP	Havannah North	3	1
		Pandora North	3	1
	MMP	Havannah	2	2
		Lady Elliot	2	5
		Palms East	2	2
		Palms West	2	2
		Pandora	1	2
Offshore	LTMP	Mackay	3	1
		Michaelmas	3	1
		Opal 2	3	1
		Agincourt 1	3	1
		Arlington	3	1
		Hastings	3	1
		St Crispin	3	1
		Thetford	3	1
		Farquharson 1	3	1
		Feather	3	1
		Hedley	3	1
		Mcculloch	3	1
		Moore	3	1
		Peart	3	1
		Taylor	3	1

APPENDIX F Flow indicator ecological assets and flow measures.

The tables below provide details of the flow requirements of the ecological assets (Table 56), measure types for assessing hydrological measures and key ecological assets (Table 57), and selected flow measures used for the flow indicator (Table 58)

Table 56 Summary of Ecological Assets and key flow events to meet flow requirements.

ASSET	Mog	Mel	Amb	Cai	Tan	Pse	Ljung	Lwil	Bara	Praw	Riff	Wat
Locations present	WT (all)	WT (all)	WT (mos, bar, mul, joh, tul, her, mur)	WT (mul, joh, tul)	WT (dai, mos, bar, mul, joh, tul, mur)	WT (all)	WT (joh, tul, mur, her)	WT (joh)	estuaries	estuaries	WT (all)	WT (all)
Low stable flows and timing of these	Aug-Nov	Aug-Nov	Aug-Nov	Sep - Oct	Oct - Jan	July - Oct						
Continuous baseflow to provide refugial waterholes > 2m deep												All year
Stable low and medium flows							Nov - Mar	Nov-Mar			All year	
High flows at end of system									Dec-Feb	Dec-Feb		

Note: codes: Mog (*Mogurnda* sp.), Mel (*Melanotaenia splendida splendida*), Amb (*Ambassis agassizii*), Cai (*Cairnsichthys rhombosomoides*), Tan (*Tandanus tandanus*), Pse (*Pseudomugil signifer*), Ljung (*Littoria jungguy*), Lwil (*Littoria wilcoxii*). Bara (Barramundi fishery), praw (banana prawn fishery, riff (riffle habitat) wat (waterholes). Catchments: Wet Tropics (WT): – dain (Daintree), mos (Mossman), bar (Barron), mul (Mulgrave Russell), Joh (Johnstone), tul (Tully), her (Herbert), mur (Murray).

Table 57 Measure types for assessing hydrological measures relevant to ecological assets and key ecosystem components and processes.

Flow category	Key Asset	Additional assets	Types of measures	Timing of flow event (season)	Duration of flow
Low flows	Low flow spawning fish	Maintain critical aquatic habitat (e.g aquatic macrophytes) and water quality for aquatic biota. Maintain river longitudinal connectivity	Duration of low flow events Frequency of low flow events Timing of low flow event Magnitude of flow events Variability of baseflow	July – Jan (Mostly dry)	Maximum change in depth of 5cm over whole stable period (min of 25 d to meet needs of all species)
Cease to flow	Amphibians	Macro-invertebrates Maintenance of refugial waterholes and provision of critical habitat for dependant taxa	Duration of low flow events Timing of low flow event	Aug – Dec (dry)	Short duration of zero flow
Low to Medium flows	Creation or maintenance of riffle habitat and associated biota	Maintain macrophyte habitat	Duration of low to medium event Frequency of low-medium medium flows	Year round (all)	Long duration of low to medium events High frequency of these events
High flows	High production of prawns and barramundi fisheries Downstream sediment delivery	Scouring of riparian zones ensures no vegetation encroachment	Magnitude of high flow events Duration of high flow events	Dec- Mar (wet)	High magnitude and duration of high flow events

Table 58 Selected flow measures used for the flow indicator.

Flow measure	Season	Flow threshold	Hydrologic Measure definition
Low flow Duration	July-Jan	Test three thresholds: 25th, 10th, 5th percentiles*	Total duration of flows which remain equal to or below a lower threshold for the reporting period (annual).
Low flow Frequency	July-Jan	Test three thresholds: 25th, 10th, 5th percentiles*	Count of the number of occurrences during which the magnitude of flow falls to or below the threshold during the reporting period (annual).
Low flow variability	July-Dec		Coefficient of variation (stdev/mean) of daily flow for dry season.
Driest six Months	July-Dec		Proportion of annual discharge contributed during the months July-December.
Cease to flow Duration	All year	0	Total duration of where flow ceases during the reporting period (annual).
Cease to flow Frequency	All year	0	Count of the number of occurrences during which flow ceases during the reporting period (annual).
Medium flow Duration	All year	Median (50th percentile)	Total duration of flows which remain equal to or above a threshold for the reporting period (annual)
Medium flow Frequency	All year	Median (50th percentile)	Count of the number of occurrences during which the magnitude of flow passes from below to equal or above the threshold during the reporting period (annual).
High flow duration	All year	Test three thresholds: 75th, 90th, 95th percentiles*	Total duration of flows which remain equal to or above a threshold for the reporting period (annual)
High flow Frequency	All year	Test three thresholds: 75th, 90th, 95th percentiles*	Total count of flows which remain equal to or above a threshold for the reporting period (annual)

*percentile – the percentage of the flow record below this value (low percentile = low flow). This is often confused with the often used hydrological nomenclature of Q10, Q90 – where Q10 is the flow that is exceeded 10% of the time.

APPENDIX G Basin fish assessment survey dates and sites.

Table 59 List of fish assessment sites for each basin with waterway name, site code and date of survey.

Basin	Waterway	SiteCode	FishDate
Daintree	Saltwater Creek	108-0017	17 Sep 19
Daintree	Whyanbeel Creek	108-0023	17 Sep 19
Daintree	Saltwater Creek	108-0033	16 Sep 19
Mossman	Parker Creek	109-0002	17 Sep 19
Mossman	South Mossman River	109-0007	17 Sep 19
Mossman	Spring Creek	109-0010	16 Sep 19
Mossman	Tributary of Ball Creek	109-0011	17 Sep 19
Mossman	Spring Creek	109-0014	16 Sep 19
Mossman	Flin Creek	109-0020	18 Sep 19
Mossman	Cassowary Creek	109-0024	19 Sep 19
Mossman	Ball Creek	109-0027	19 Sep 19
Mossman	South Mossman River	109-0043	17 Sep 19
Mossman	Mossman River	109-0061	18 Sep 19
Mossman	Mossman River	109-0061	19 Sep 19
Mossman	Mossman River	109-0064	17 Sep 19
Mossman	Mossman River	109-0074	18 Sep 19
Barron	Severin Creek	110-0001	11 Sep 19
Barron	Davies Creek	110-0002	09 Sep 19
Barron	Oaky Creek	110-0003	10 Sep 19
Barron	Wright Creek	110-0004	10 Sep 19
Barron	Atherton Creek	110-0007	11 Sep 19
Barron	Tinaroo Creek	110-0008	11 Sep 19
Barron	Varch Creek	110-0009	10 Sep 19
Barron	Poona Creek	110-0011	11 Sep 19
Barron	Barron River	110-0013	12 Sep 19
Barron	Freshwater Creek	110-0021	12 Sep 19
Barron	Clohesy River	110-0083	12 Sep 19
Mulgrave	Wright Creek	111-0009	06 Aug 19
Mulgrave	Little Mulgrave River	111-0025	07 Aug 19
Mulgrave	Mulgrave River	111-0053	01 Aug 19
Mulgrave	Gray Creek	111-0073	05 Aug 19
Mulgrave	Mulgrave River	111-0086	30 Jul 19
Mulgrave	Little Mulgrave River	111-0137	07 Aug 19
Mulgrave	Fishery Creek	111-0146	05 Aug 19
Mulgrave	Tributary of Mulgrave River	111-0150	07 Aug 19
Mulgrave	Middle Creek	111-0153	06 Aug 19
Mulgrave	McDonnell Creek	111-0162	07 Aug 19
Mulgrave	Tributary of Behana Creek	111-0181	06 Aug 19
Mulgrave	Mulgrave River	111-0201	30 Jul 19
Mulgrave	Tributary of Behana Creek	111-0437	06 Aug 19
Russell	Woopen Creek	111-0122	06 Aug 19
Russell	Cane drain	111-0045	05 Aug 19
Russell	Harvey Creek	111-0050	07 Aug 19

Basin	Waterway	SiteCode	FishDate
Russell	Allison Creek	111-0058	06 Aug 19
Russell	Pugh Creek	111-0061	07 Aug 19
Russell	Pugh Creek	111-0066	06 Aug 19
Russell	Babinda Creek	111-0074	07 Aug 19
Russell	Menzies Creek	111-0106	06 Aug 19
Russell	Tributary of Babinda Creek	111-0109	05 Aug 19
Russell	Cane drain	111-0125	07 Aug 19
Russell	Russell River	111-0173	31 Jul 19
Russell	Russell River	111-0221	31 Jul 19
Russell	Russell River	111-0362	01 Aug 19
Russell	Chooky Chooky Creek	111-0618	06 Aug 19
Johnstone	Tributary of Malanda Creek	112-0001	09 Sep 19
Johnstone	Malanda Creek	112-0006	09 Sep 19
Johnstone	Cowley Creek	112-0007	10 Sep 19
Johnstone	North Beatrice River	112-0009	12 Sep 19
Johnstone	South Maria Creek	112-0010	10 Sep 19
Johnstone	Eel Creek	112-0015	11 Sep 19
Johnstone	Tributary of Mena Creek	112-0016	11 Sep 19
Johnstone	Muston Creek	112-0017	12 Sep 19
Johnstone	Utchee Creek	112-0028	10 Sep 19
Johnstone	Liverpool Creek	112-0030	11 Sep 19
Johnstone	Fitzgerald Creek	112-0036	13 Sep 19
Tully	Cane drain	113-0002	26 Aug 19
Tully	Davidson Creek	113-0006	27 Aug 19
Tully	Marquette Creek	113-0012	28 Aug 19
Tully	Banyan Creek	113-0016	28 Aug 19
Tully	Cane drain	113-0022	27 Aug 19
Tully	Tributary of Python Creek	113-0023	28 Aug 19
Tully	Hull River	113-0025	27 Aug 19
Tully	Tributary of Davidson Creek	113-0026	29 Aug 19
Tully	Banyan Creek	113-0041	30 Aug 19
Tully	Tributary of Tully River	113-0062	28 Aug 19
Tully	Wongaling Creek	113-0580	29 Aug 19
Murray	Stony Creek	114-0001	26 Aug 19
Murray	Cane drain	114-0003	27 Aug 19
Murray	Scrubby Creek	114-0005	26 Aug 19
Murray	Tributary of Woodfield Creek	114-0007	27 Aug 19
Murray	Cane drain	114-0011	27 Aug 19
Murray	Dallachy Creek	114-0014	28 Aug 19
Murray	Cane drain	114-0016	29 Aug 19
Murray	Murray River	114-0031	27 Aug 19
Murray	Murray River	114-0046	28 Aug 19
Murray	Murray River	114-0079	29 Aug 19
Murray	Meunga Creek	114-0081	29 Aug 19
Murray	Tributary of Kennedy Creek	114-9998	28 Aug 19
Murray	Tributary of Kennedy Creek	114-9999	28 Aug 19
Herbert	Trebonne Creek	116-0005	27 Aug 20

Basin	Waterway	SiteCode	FishDate
Herbert	Tributary of Herbert River	116-0006	25 Aug 20
Herbert	Blunder Creek	116-0007	19 Aug 20
Herbert	Breakaway Creek	116-0009	26 Aug 20
Herbert	Ashton Creek	116-0013	26 Aug 20
Herbert	White Adder Creek*	116-0014	25 Aug 20
Herbert	Tributary of Jacky Jacky Creek*	116-0016	20 Aug 20
Herbert	Hawkins Creek*	116-0018	26 Aug 20
Herbert	Mill Creek	116-0019	18 Aug 20
Herbert	Wild River	116-0026	18 Aug 20
Herbert	Stone River	116-0029	24 Aug 20
Herbert	Spring Creek (North Branch)	116-0033	24 Aug 20
Herbert	Robinson Creek	116-0035	17 Aug 20
Herbert	Wigwam Creek	116-0038	24 Aug 20
Herbert	Blunder Creek	116-0039	19 Aug 20
Herbert	Anabranch of Rudd Creek	116-0048	18 Aug 20
Herbert	Gowrie Creek	116-0054	25 Aug 20
Herbert	Wild River	116-0059	18 Aug 20
Herbert	Arnot Creek	116-0061	24 Aug 20
Herbert	Wild River	116-0090	18 Aug 20
Herbert	Vine Creek	116-0099	18 Aug 20
Herbert	Herbert River	116-0220	19 Aug 20
Herbert	Palm Creek	116-0274	27 Aug 20
Herbert	Blencoe Creek	116-0303	20 Aug 20
Herbert	Herbert River	116-0652	19 Aug 20
Herbert	Break-O-Day Creek	116-0871	19 Aug 20
Herbert	Tin Creek	116-0998	25 Aug 20
Herbert	Black Adder Creek	116-1018	25 Aug 20
Herbert	Garrawalt Creek	116-1029	25 Aug 20
Herbert	Tributary of Kirrama Creek	116-1120	20 Aug 20
Herbert	Yuccabine Creek*	116-1336	20 Aug 20
Herbert	Gowrie Creek	116-1475	26 Aug 20

* indicates sites that were used for developing the modelled maximum species richness baseline but were not included in the calculations of the basin scores due to uncertainty of model. Note that all four of these sites were in the Upper Herbert.

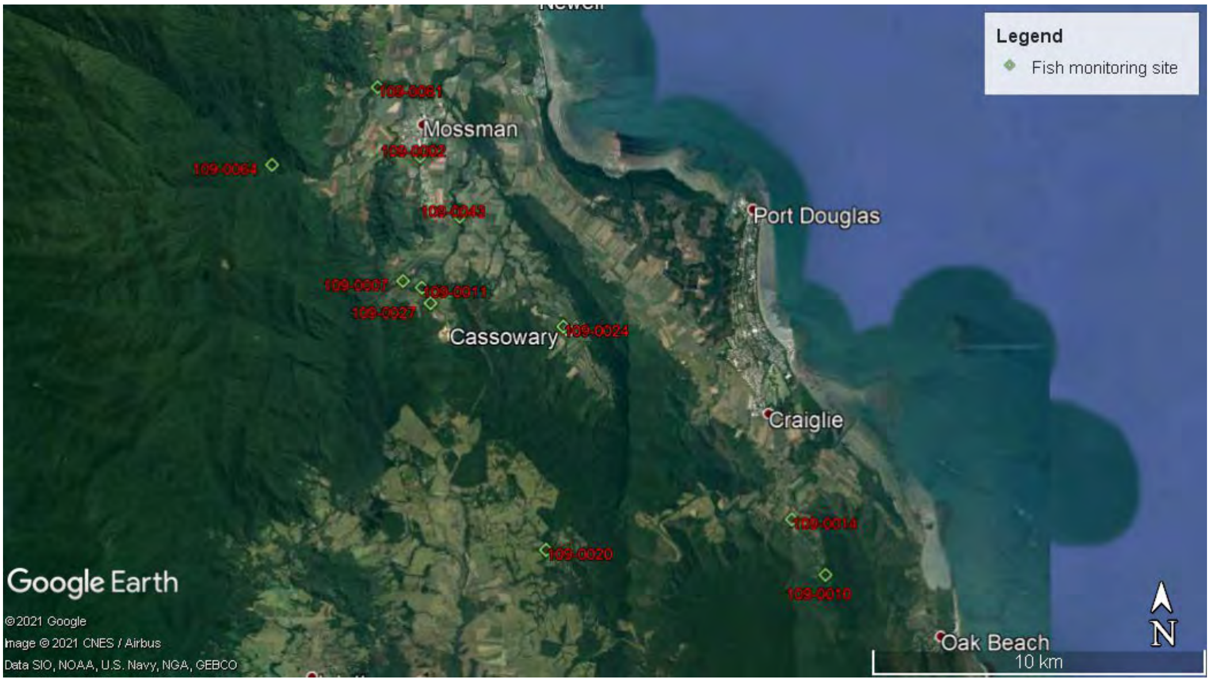

Figure 38 Mossman Basin fish assessment sites for 2019-20.

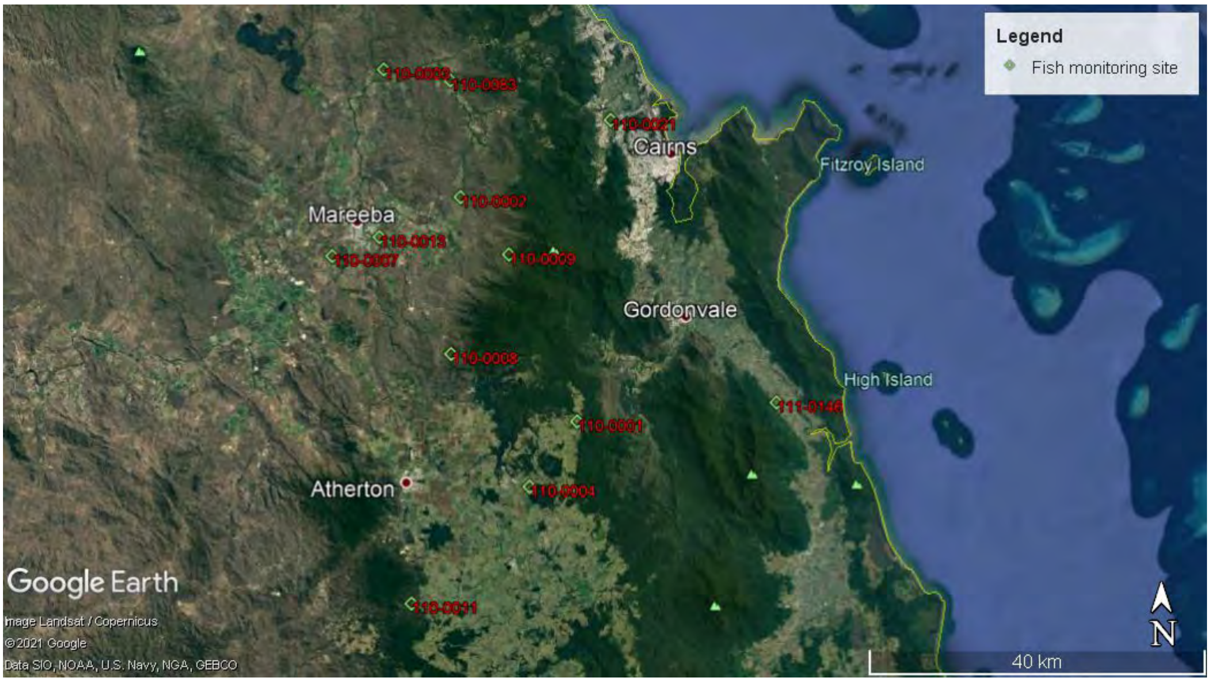

Figure 39 Barron Basin fish assessment sites for 2019-20.

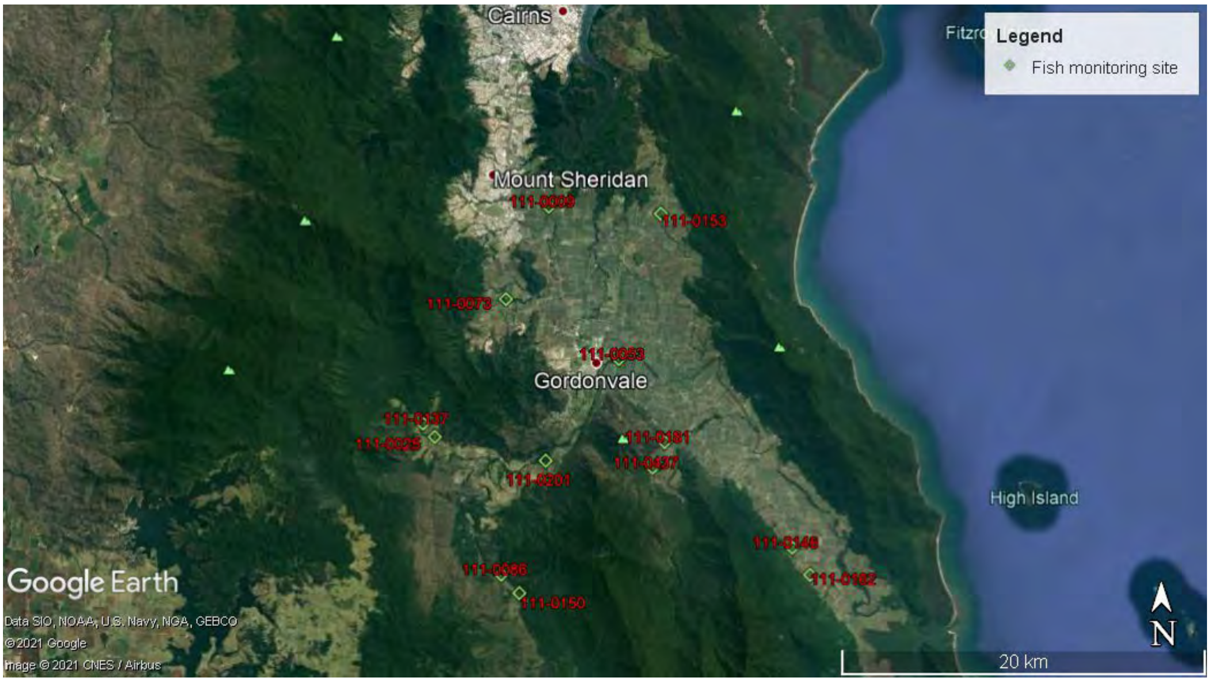

Figure 40 Mulgrave Basin fish assessment sites for 2019-20.

Figure 41 Russell Basin fish assessment sites for 2019-20.

Figure 42 Johnstone Basin fish assessment sites for 2019-20.

Figure 43 Tully Basin fish assessment sites for 2019-20

Figure 44 Murray Basin fish assessment sites for 2019-20.

Figure 45 Herbert Basin fish assessment sites for 2019-20.

Appendix H Log of updates for 2020-21.

The table below lists section number, page and paragraph number, and summary of updates for the 2020-21 methods technical report to assist reviewers.

Section number and title	Paragraph and page number	Details
Title pages	p. i-ii	Dates
Executive Summary	par1, p.iii	Report card dates,
	p.iii-iv	Shoreline mangrove condition indicator added.
1. INTRODUCTION		
1.1 General	par1, p.1	Dates
1.4. Indicators for waterway environments	Table 1, p.2-3	Addition of shoreline mangrove habitat to the mangrove and saltmarsh indicator category for mangroves.
2. METHODS FOR DATA COLLECTION		
2.3. Estuaries Data Collection		
2.3.1. Water quality Estuary monitoring programs	Table 7, p.16	Estuary monitoring programs. n/year updated for Daintree, Dickson inlet, Russell-Mulgrave, Johnstone, Moresby, Hinchinbrook.
	Table 7, p.16. Appendix A. Fig. 14, p.74.	MMP sites RM11 and RM12 for the Russell-Mulgrave estuary discontinued in 2019.
	Table 7, p.16	Estuary monitoring programs. Johnstone: no sufficient monitoring for Turbidity.
	Table 8, p.17	Sampling month for each estuary
	Appendix A. Fig. 16, p.75	Sites updated for the Moresby estuary: Site 6 added.
2.3.2.3. Shoreline mangrove habitat	p.18-20	Data collection for mangrove habitat indicator: section added.
2.3.2.5 Fish barriers	p.21-23	Hinchinbrook estuary zone fish barrier update. Planned assessments for Daintree, Mossman and Barron basins.
2.4. Inshore and Offshore Data Collection		
2.4.1. Inshore Water Quality	Fig 7, p. 25. Table 12, p.26-27.	WQ site update: Five Central zone sites and three South zone sites removed from MMP routine sampling program.
	p.27	Pesticide monitoring suspended for all zones.
	Appendix D Figures 34-37. p.84-87.	Maps with updated water quality sites.
2.4.2 Offshore Water Quality Data Collection	p.27	No monitoring available for 2020-21.
2.4.3. Inshore and Offshore Coral Data Collection	Table 13 Table 14, p.27-29	Survey dates and schedules updated: text and tables.
2.4.4. Inshore Seagrass Data Collection	p.30-31	Report card update: change in MMP seagrass index indicators.
3. CONDITION AND STATE ASSESSMENT SCORING METHODS		
3.2.3.4. Shoreline mangrove habitat	Table 37, p.47-50.	*Scoring methods* - section added for Shoreline mangrove habitat
Inshore MMP seagrass	Table 48, p. 57-58,	Addition of resilience indicator for MMP seagrass scoring.

APPENDIX D Monitoring sites for inshore marine zones	Figs 34, 35, 36 and 37, p.84-87	Pesticide sites removed for all zones. Selected water quality sites removed for Central and South zones.