Mackay-Whitsunday-Isaac 2021 Report Card Methods

Technical Report
Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership
July 2022

Authorship Statement

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Acknowledgements

The authors would like to thank TWG members and Richard Hunt, Bonny Stutsel, James Donaldson, Jamie Corfield, Nathan Waltham, Catherine Neelamraju, Olivier Cheneval, Katie Chartrand, Nicole Nash, and Christina Stiles for their technical input into various aspects of document development and/or their review of the document. Members of the Reef Independent Science Panel (ISP) are also gratefully acknowledged for their advice and review of this document. Thank you also to Jordan Gacutan from the University of New South Wales (UNSW) for contributions to the litter metric.

The Partnership acknowledges the Traditional Owners from the Land and Sea Country of (or within) the region, including the Yuwibara, Koinmerburra, Barada, Widi, Ngaro, Gia, and Juru Peoples, and pays respect to the ancestors, the Elders both past and present, and to the people.

Suggested Citation

Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership (2022). *Mackay-Whitsunday-Isaac 2021 Report Card Results Technical Report*. Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership, Proserpine, QLD.

This technical report was finalised and released online in July 2022.

Contents

Terms and Acronyms

ABS	Absolute (positive) value
Adopted middle thread distance	The distance in kilometres, measured along the middle of a watercourse, that a specific point (in the watercourse) is from the watercourse's mouth.
AIMS	Australian Institute of Marine Science
AM	Annual median (AM) or the mean of a measured indicator.
AMDI	Australian Marine Debris Initiative
Basin	An area of land where surface water runs into smaller channels, creeks, or rivers and discharges into a common point and may include many sub-basins or sub-catchments. Also known as river basin or catchment.
Biodiversity	The variability among living organisms from all sources. It includes diversity within species and between species and the diversity of ecosystems.
Biomass	The total quantity or weight of organisms over a given area or volume.
BoM	Bureau of Meteorology
Chl-*a*	Chlorophyll-*a*: An indicator of overall phytoplankton biomass. It is widely considered a useful proxy for measuring nutrient availability and the productivity of a system.
CI	Confidence interval
COVID-19	Coronavirus Disease 2019—in reference to the worldwide pandemic in 2020–2022
CTF	Cease-to-flow
CV	Coefficient of variation
DDL	Declared downstream limit
DES	Department of Environment and Science, Queensland Government
DHW	Degree Heating Weeks (DHW) are an accumulated measurement of sea surface temperature (SST) that assesses the instantaneous bleaching heat stress during the prior 12-week period. Significant coral bleaching usually occurs when the DHW value reaches 4 °C-weeks. By the time the DHW value reaches 8 °C-weeks, severe, widespread bleaching and significant mortality are likely. Source: Coral Reef Watch, National Oceanic and Atmospheric Administration (CRW, NOAA)[1]
Diadromous	Diadromous fish are truly migratory species whose distinctive characteristics include that they (i) migrate between freshwaters and the sea; (ii) the movement is usually obligatory; and (iii) migration takes place at fixed seasons or life stages. There are three distinctions within the diadromous category: catadromous, amphidromous, and anadromous.
DIN	Dissolved inorganic nitrogen
DO	Dissolved oxygen
Ecosystem	A dynamic complex of plant, animal, and microorganism communities

[1] https://coralreefwatch.noaa.gov/product/50km/index.php

	and their non-living environment interacting as a functional unit.
Ecosystem health	"An ecological system is healthy and free from "distress syndrome" if it is stable and sustainable—that is, if it is active and maintains its organization and autonomy over time and is resilient to stress. Ecosystem health is thus closely linked to the idea of sustainability, which is seen to be a comprehensive, multiscale, dynamic measure of system resilience, organization, and vigour." (Costanza, 1992).
EC	An enclosed coastal (EC) water body includes shallow, enclosed waters near an estuary mouth and extends seaward towards deeper, more oceanic waters further out. The seaward cut-off of an EC water body is defined by the Great Barrier Reef Marine Park Authority (GBRMPA (Great Barrier Reef Marine Park Authority), 2010).
eReefs	A Commonwealth Scientific and Industrial Research Organisation (CSIRO) program to collate data and new and integrated modelling to produce powerful visualisation, communication, and reporting tools for the Great Barrier Reef.
ESF	Empirical survivor function
Estuary	The aquatic environment at the interface between freshwater and marine ecosystems.
Fish (as an index)	The fish community index, measured by two indicators (the number of indigenous and non-indigenous fish, respectively), is evaluated and included in the ecosystem health assessment (coasters) for basins. Inclusion in the Report Card will contribute to an understanding of the local fish communities.
Fish Barriers (as an indicator)	Fish barriers relate to any man-made barriers that 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, 2015a).
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
FSS	QLD Health Forensic and Scientific Services Laboratory
GBR	Great Barrier Reef
GBRCLMP	Great Barrier Reef Catchment Loads Monitoring Program
GBR Report Card	Great Barrier Reef Report Card developed under the Reef Water Quality Protection Plan (2013).
GBRMPA	Great Barrier Reef Marine Park Authority
GV	Guideline value—Limits that are defined by experts in their respective fields used to gauge the condition of an indicator/site. If grades/scores do not meet guideline values, this signifies that changes impacting ecosystem health have occurred at a level beyond naturally occurring processes.
HEV	High ecological value: the management intent (level of protection) to achieve an effectively unmodified condition.
Impoundment (also	An indicator used in the 'in-stream habitat modification' indicator for freshwater basins in the region. This index reports on the proportion

impoundment length)	(%) of the linear length of the main river channel inundated at the Full Supply Level of artificial in-stream structures, such as dams and weirs.
Index	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., nutrients made up of particulate nitrogen and particulate phosphorus).
Inshore (as a reporting zone)	A reporting zone in the Mackay-Whitsunday-Isaac Report Card that includes enclosed coastal, open coastal, and mid-shelf waters.
In-stream habitat modification (as an indicator)	This basin indicator category is made up of two indicators: fish barriers and impoundment length.
IQQM	Integrated water quantity and quality simulation model—used to model pre-development flow for the flow tool score calculations.
ISP	Independent Science Panel established under the Reef Water Quality Protection Plan (now Reef 2050 Water Quality Improvement Plan), who have independently reviewed the methodologies involved in the report card assessments.
JCU	James Cook University
LAT	Lowest astronomical tide
LGA	Local Government Area
LOR	Limit of reporting
LTMP	Long-Term Monitoring Program—run by the Australian Institute of Marine Science (AIMS).
Macroalgae (cover)	An indicator used in part to assess coral health. Macroalgae is a collective term used for seaweed and other benthic (attached to the bottom) marine algae that are generally visible to the naked eye.
MD	The management intent (level of protection) to achieve a moderately disturbed (MD) condition.
MAG	Management Activity Group—Components of a framework used to calculate scores for urban water stewardship at the local government level.
Measure	A measured value that contributes to an indicator score for indicators that are comprised of multiple measures (e.g., flow, estuary fish barriers).
MERI	Monitoring, evaluation, reporting, and improvement within the context of the Urban Water Stewardship Framework.
Mid-shelf (water body)	Mid-shelf water bodies begin 15 km from the enclosed coastal boundary and extend to 60 km in the Mackay-Whitsunday-Isaac Region (GBRMPA, 2010)
MMP	Great Barrier Reef Marine Monitoring Program. This provides water quality, coral, and seagrass data for the Central and Whitsunday reporting zones in 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.
MPA	Management Practice Adoption

MWI	Mackay-Whitsunday-Isaac
n	Sample size
NATA	National Association of Testing Authorities
NB	Negative binomial
NO_x	Oxidised nitrogen (nitrate (NO_3) and nitrite (NO_2))
NQBP	North Queensland Bulk Ports Corporation Ltd
NRM	Natural resource management organisation
Offshore Zone	The Offshore Zone is a reporting zone in the Mackay-Whitsunday-Isaac Report Card that includes mid-shelf and offshore water bodies.
Offshore (water body)	Offshore water bodies begin 60 km from the enclosed coastal boundary and extend to 280 km in the Mackay-Whitsunday-Isaac Region (GBRMPA, 2010).
OC	Open coastal (OC) water bodies are delineated by the seaward boundary of enclosed coastal waters to a defined distance across the continental shelf. For the Mackay-Whitsunday-Isaac Region, open coastal waters extend from enclosed coastal waters to 15 km (GBRMPA, 2010).
Overall Score	The overall scores for each reporting zone used in the Report Card are generated by an index or an aggregation of indices.
P2R	Paddock to Reef Integrated Monitoring, Modelling and Reporting Program
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 Table 4.
Pesticide Risk Metric (PRM)	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
Ports	NQBP Port Authority
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 (Nelder et al., 2019).
Pre-development Flow	The pattern of water flows, 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[2].

[2] Queensland Government 2016. Water Plan (Wet Tropics) 2013. Water Act 2000. https://www.legislation.qld.gov.au/view/pdf/2016-12-06/sl-2013-0282

PSII herbicides	Photosystem II inhibiting herbicides (ametryn, atrazine, diuron, hexazinone, tebuthiuron, bromacil, fluometuron, metribuzin, prometryn, propazine, simazine, terbuthylazine, terbutryn).
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
QLD Government	The Queensland Government includes several departments that provide data sources and support for the report card, including the Department of Environment and Sciences (includes management of the GBRCLMP), the Department of Regional Development, Manufacturing and Water (includes management of water monitoring), and the Department of Resources (includes management of Queensland Spatial).
RAP	In the context of freshwater flow—river analysis package
RCA	Reef Check Australia
RE	Regional ecosystem
Resilience (as an indicator)	A multivariate metric developed by the MMP to measure the capacity of seagrass to cope with disturbances (Collier et al., 2021). The resilience metric better accommodates differences in recovery strategies between species in comparison to previous indicators.
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 in Report Cards released to date. This indicator uses mapping resources to determine the extent of the vegetated interface between land and waterways in the region.
SD	The management intent (level of protection) to achieve a slightly disturbed (SD) condition.
Secchi	Secchi depth (m)—a measure of water clarity determined as the depth at which an opaque disc lowered into a water column is no longer visible.
SF	Scaling factor
SIP	Southern Inshore Monitoring Program (Partnership-funded)
SMD	The management intent (level of protection) to achieve a slightly to moderately disturbed condition.
Standardised condition score	The transformation of indicator scores into the MWI Report Card scoring range of 0 to 100.
TSS	Total suspended solids
TWG	Technical Working Group for the Wet Tropics, Dry Tropics, and MWI regional report cards.
UNSW	University of New South Wales
UQ	University of Queensland
Waterway	All freshwater, estuarine, and marine bodies of water, including storm drains, channels, and other human-made structures in the MWI Region.
Water quality guideline	For the purposes of waterway assessment, the term water quality guideline refers to the values for condition assessment of water

	quality, 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 (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	Wastewater Treatment Plant

Executive Summary

The Mackay-Whitsunday-Isaac (MWI) Healthy Rivers to Reef Partnership (the Partnership) was established in October 2014 with the primary focus of producing an annual report card on the health of our region's waterways. The boundaries of the region extend latitudinally from the Don River in the north to the Carmila coast in the south.

The 2021 Report Card, reporting on the 2020–21 financial year, is the Partnership's eighth report card, demonstrating the region's ongoing commitment to understanding and caring for the local environment. This commitment is matched outside of regional reporting boundaries, with the MWI Report Card being one of five regional report cards released annually in the Great Barrier Reef (GBR) region.

The 2021 Report Card contains data from a variety of condition assessments of our local waterways, including freshwater, estuarine, and inshore and offshore marine environments. For each of these waterway types, a series of environmental *indicators* are reported, which are aggregated into *indicator categories* and then into *indices*.

The purpose of this document is to provide the detailed methods of the 2021 MWI Report Card, including assessments of condition and state for regional waterways. This report describes data collection methods, development of scoring methods, and confidence associated with results.

i. Freshwater Basins

Freshwater monitoring is conducted in five basins in the region, including the Don (Don River), Proserpine (Proserpine River), O'Connell (O'Connell River, two locations), Pioneer (Pioneer River), and Plane (Sandy and Plane Creeks) basins.

Monitoring within freshwater basins is grouped by water quality, habitat and hydrology, and fish indices (Figure I). Within these indices, indicator categories and indicators are updated either every year (water quality), every three years (fish), or between one and four years depending on the specific indicator (habitat and hydrology).

The water quality index includes sediment, nutrients, and pesticides (Pesticide Risk Metric (PRM) based on 22 pesticides). The habitat and hydrology index includes riparian extent, wetland extent, flow, and in-stream habitat modification. The fish index includes the Proportion of Indigenous Species Expected (POISE) and Proportion of Non-Indigenous Fish (PONI) indicator categories (Figure I).

Data are sourced from a range of Partnership-funded and previous existing monitoring projects, including the Great Barrier Reef Catchment Loads Monitoring Program (GBRCLMP), fish barrier monitoring (Catchment Solutions Pty Limited), Aquatic Ecosystem Health monitoring (Department of

Environment and Science (DES)), as well as Regional Ecosystem (RE) mapping data contributed by DES and the Department of Resources. Data was collected by remote sensing, automated sampling, grab sampling, on-ground field assessments, and vessel electrofishing surveys.

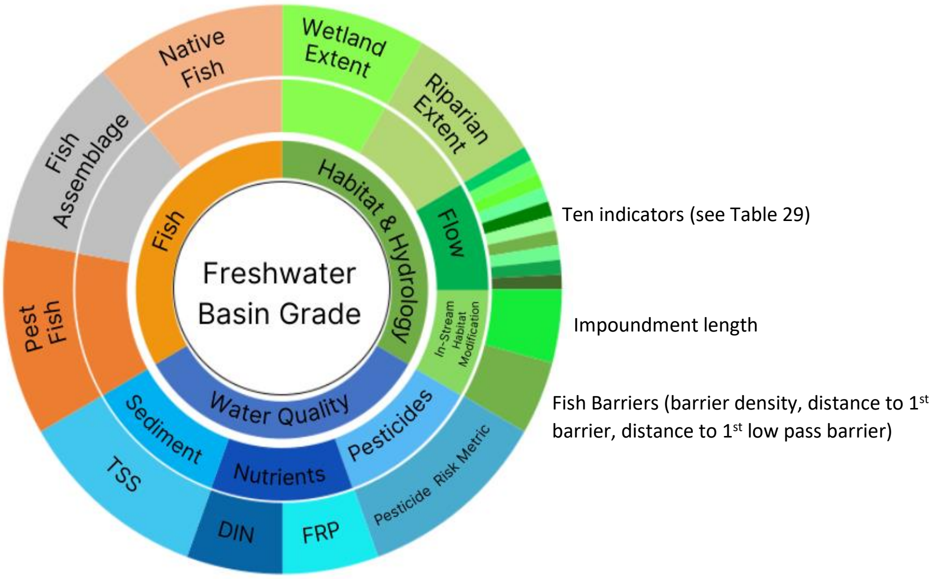


Figure I. Indicator/s (outer ring), indicator categories (middle ring), and index/indices (inner ring) that contribute to overall freshwater basin scores/grades. Where no indicator category is listed, this represents that the indicator/s (e.g., native fish) do/does not fit into any specific category below the index level (e.g., fish). Note: TSS = total suspended solids, DIN = dissolved inorganic nitrogen, and FRP = filterable reactive phosphorus.

ii. Estuaries

The MWI Report Card reports on eight estuaries within four basins:

Proserpine Basin—Gregory River,

O'Connell Basin—O'Connell River and St Helens/Murray Creeks,

Pioneer Basin—Vines Creek[3]

Plane Basin—Sandy Creek, Plane Creek, Rocky Dam Creek, and Carmila Creek.

Monitoring within estuaries is grouped by water quality, habitat and hydrology, and fish indices (Figure II). Within these indices, indicator categories, and indicators are updated either every year (water quality) or between one and four years depending on the indicator (habitat and hydrology). The fish index and flow indicator category are still under development and therefore are not reported in the 2021 Report Card.

[3] Vines Creek is more indicative of the urban Mackay city area rather than the greater Pioneer Basin

The water quality index includes physical–chemical, nutrients, and pesticides (PRM based on 22 pesticides) indicator categories. The habitat and hydrology index includes mangrove and saltmarsh extent, riparian extent, flow, and fish barriers indicator categories (Figure II).

Data are sourced from a range of Partnership-funded and previously existing monitoring projects, such as the Regional Estuary Monitoring Program (DES), the Estuary Pesticide Monitoring Program (the Partnership and Reef Catchments), fish barrier monitoring (Catchment Solutions), as well as RE mapping data contributed by DES and the Department of Resources. Data was collected using various techniques, including remote sensing, grab sampling, and on-ground field assessments.

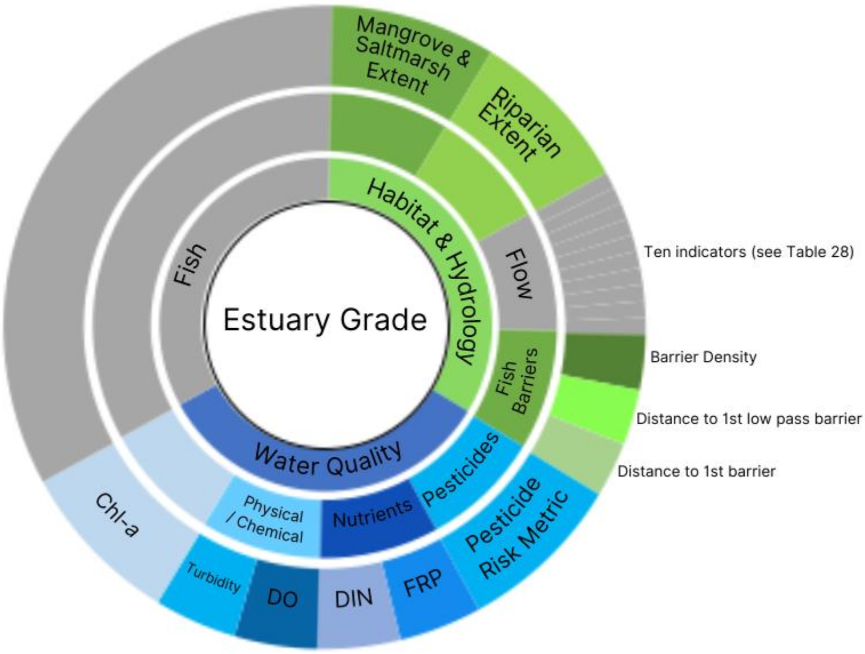


Figure II. Indicator/s (outer ring), indicator categories (middle ring), and index/indices (inner ring) that contribute to overall estuary scores/grades. Where no indicator category is listed, this represents that the indicator/s (e.g., riparian extent) do/does not fit into any specific category below the index level (e.g., habitat and hydrology). Dark grey represents no data. Note: chl-*a* = chlorophyll-*a* concentration, DO = dissolved oxygen, DIN = dissolved inorganic nitrogen, and FRP = filterable reactive phosphorus.

iii. Inshore and Offshore Marine

Reporting for the MWI marine environment is split into four inshore zones (the Northern, Whitsunday, Central, and Southern Zones) and one offshore zone. Monitoring is conducted on coral, water quality, and seagrass indices, with the fish index as an aspirational goal for future report cards (Figure III). All indicators within these indices are updated annually. The 2021 Report Card includes an inshore and urban litter metric, although this is site-based and does not contribute to overall zone scores.

In the inshore marine region, the water quality index includes water clarity, chlorophyll-*a* (chl-*a*), nutrients, and pesticides (PRM based on up to 22 pesticides) (Figure III). The seagrass index includes indicators of area, abundance, species composition, biomass, and resilience. The coral index includes indicators of species composition, community change (%), macroalgal cover, juvenile density, and total cover (%) (Figure III). In the offshore zone, the coral index includes community change (%), juvenile density, and total cover (%) (Figure III).

Data are sourced from a range of existing monitoring programs, such as the North Queensland Bulk Ports Corporation Ltd (NQBP) environmental monitoring program, the GBR Marine Monitoring Program (MMP), the Australian Institute of Marine Science (AIMS) Long-term Monitoring Program (LTMP), as well as the Partnership-funded Southern Inshore Monitoring Program (SIP) and citizen science projects. Data was collected using various techniques, including remote sensing, boat, helicopter or shore-based coral and seagrass surveys, and in-situ turbidity loggers and pesticide samplers.

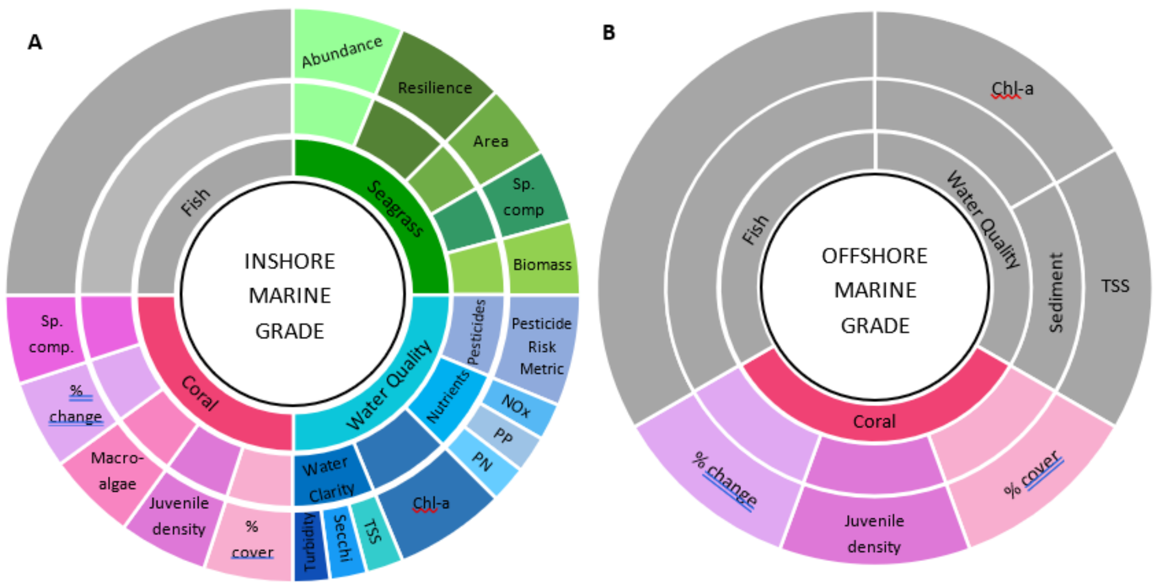


Figure III. Indicator/s (outer ring), indicator categories (middle ring), and index/indices (inner ring) that contribute to overall inshore (A) and offshore (B) marine zone scores/grades. Where no indicator category is listed, this represents that the indicator/s (e.g., juvenile density) do/does not fit into any category below the index level (e.g., coral). Dark grey represents no data. Note: NO_x = oxidised nitrogen, PP = particulate phosphorus, PN = particulate nitrogen, TSS = total suspended solids, chl-*a* = chlorophyll-*a* concentration, and Sp. comp. = species composition.

iv. Scoring

Ordinal categories are used to describe scores for the condition of indicators, indicator categories, indices, and the overall basin/estuary/zone grade. This follows a five-point scoring system: 'very good' (A), 'good' (B), 'moderate' (C), 'poor' (D), and 'very poor' (E).

All indicators have specific scoring ranges and bandwidths, which correspond to the five-point system. Results for indicators that have differing scoring ranges and bandwidths are translated into a common scoring range before aggregating. The common scoring range is based on that used by the GBR Report Card (Table I).

Table I. Overall scoring range, associated grades, and colour codes as per the GBR Report Card.

Scoring Range	Condition Grade and Colour Code
81 to 100	A = Very good
61 to <81	B = Good

Table I. Overall scoring range, associated grades, and colour codes as per the GBR Report Card.

Scoring Range	Condition Grade and Colour Code
41 to <61	C = Moderate
21 to <41	D = Poor
0 to <21	E = Very poor

1. Introduction

1.1. Purpose of this document

This document describes the methods used in the production of the Mackay-Whitsunday-Isaac (MWI) Healthy Rivers to Reef Partnership (the Partnership) 2021 Report Card. This includes the indicator selection process, data collection methods, and scoring methods. Condition assessments and scoring of the environmental indicators are divided by habitat and include freshwater basins, estuaries, and marine environments (both inshore and offshore). Human dimensions, such as cultural heritage and agricultural stewardship, are assessed alongside the environmental indicators, although are not incorporated into the region's grade.

1.2. Background

The Partnership was established in October 2014 with the primary focus of producing an annual report card on the health of the MWI Region's waterways, including freshwater, estuarine, wetland, and marine ecosystems (Figure 1).

The 2021 Report Card includes condition assessments of the region's waterways extending to the eastern boundary of the Great Barrier Reef (GBR) Marine Park. Human dimensions, such as cultural heritage, urban and agricultural stewardship, and anthropogenic litter are also reported for the region. A series of indicators, often broken into different indicator categories, are used to provide a holistic assessment of the factors for each index.

Since the release of the Pilot Report Card in 2014, there has been significant review and refinement, with new indices and indicators added as data gaps are identified. The release of our eighth report card now includes seagrass scores for the Southern inshore zone for the first time, as well as an updated methodology in our freshwater fish assessments (Section 3.1.3). Identifying and addressing knowledge gaps is important to the Partnership, and these priorities and opportunities will be revisited and formalised in a program design review scheduled to occur after the release of the 2021 Report Card. For more information on the MWI Report Card and Partnership, refer to the MWI Report Card Program Design 2017 to 2022[4]. The indicator selection process and descriptions of the environmental indicators are described in further detail in the Program Design.

[4] https://healthyriverstoreef.org.au/report-card/program-design/

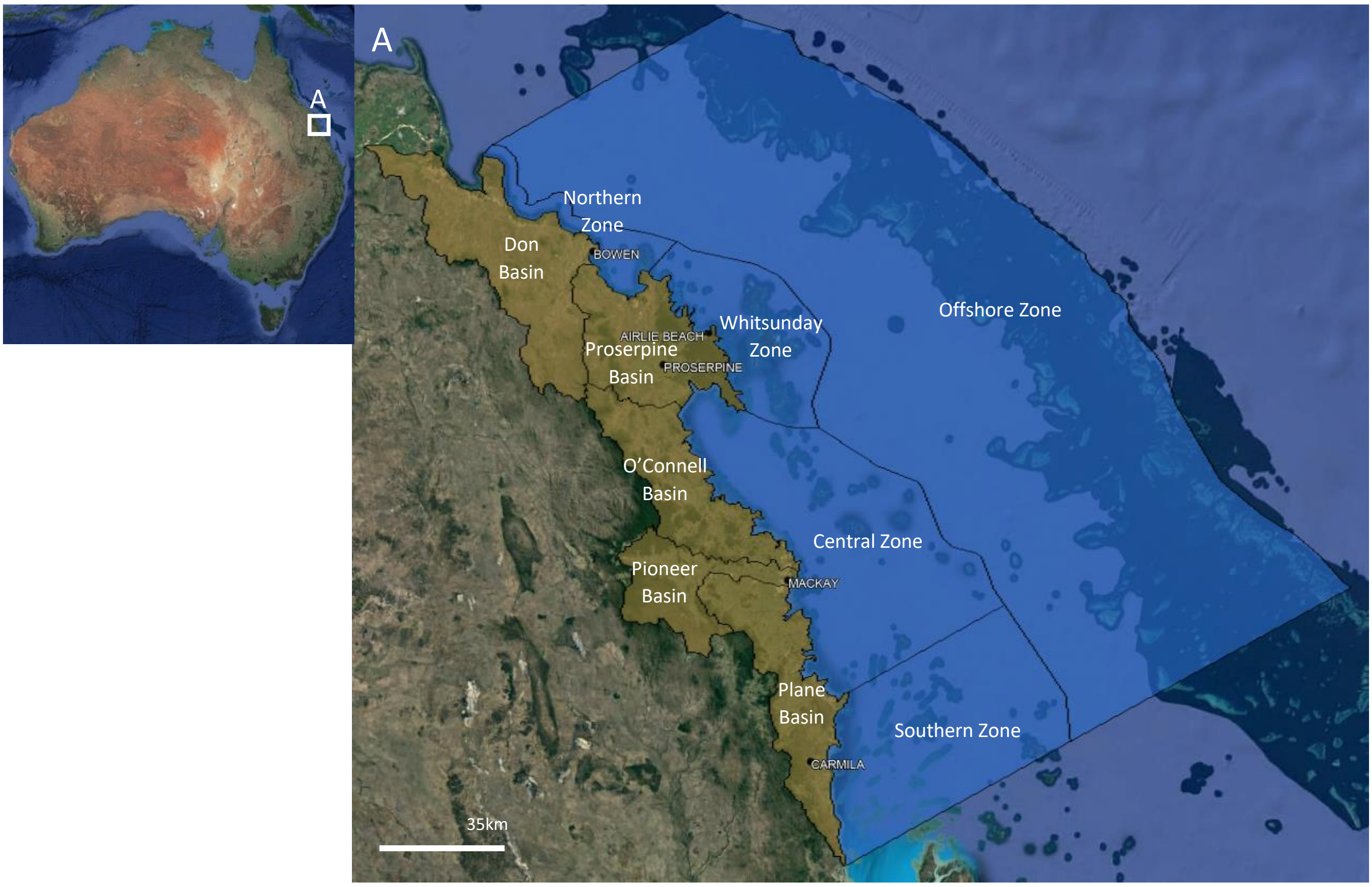


Figure 1. The MWI Healthy Rivers to Reef Partnership reporting region. Basins are shown in brown, while marine zones are shown in blue.

1.3. Terminology

The Report Card assesses different ecosystem (environmental) indicators to report on the overall condition of MWI waterways. Scores for indicators are aggregated depending on the aspect of the environment they are assessing and typically follow three key themes: water quality, habitat, and fish. Report card themes related to human dimensions (e.g., cultural heritage, urban water stewardship, and litter) are presented at the site level rather than rolled up into the regional score.

In the Report Card, overall and index grades/scores are represented in the format of a coaster (Figure 2). Presentation of the coasters can vary, as different levels of categorisation are used for each different ecosystem type. Samples are taken to measure indicators (e.g., nitrogen concentration) and are then aggregated into indicator categories (e.g., nutrients). Indicator categories are aggregated into indices (e.g., water quality), which are then aggregated to generate a final score.

Figure 2. Terminology used for defining the level of aggregation of indicators and how they are displayed in coasters in the Report Card.

2. Data Collection Methods

We report on the condition of freshwater basins, estuaries, and inshore and offshore marine environments across the MWI Region. Across these ecosystems, a series of indices are assessed and divided into indicator categories and indicators, with data collected across the region (Figure 3).

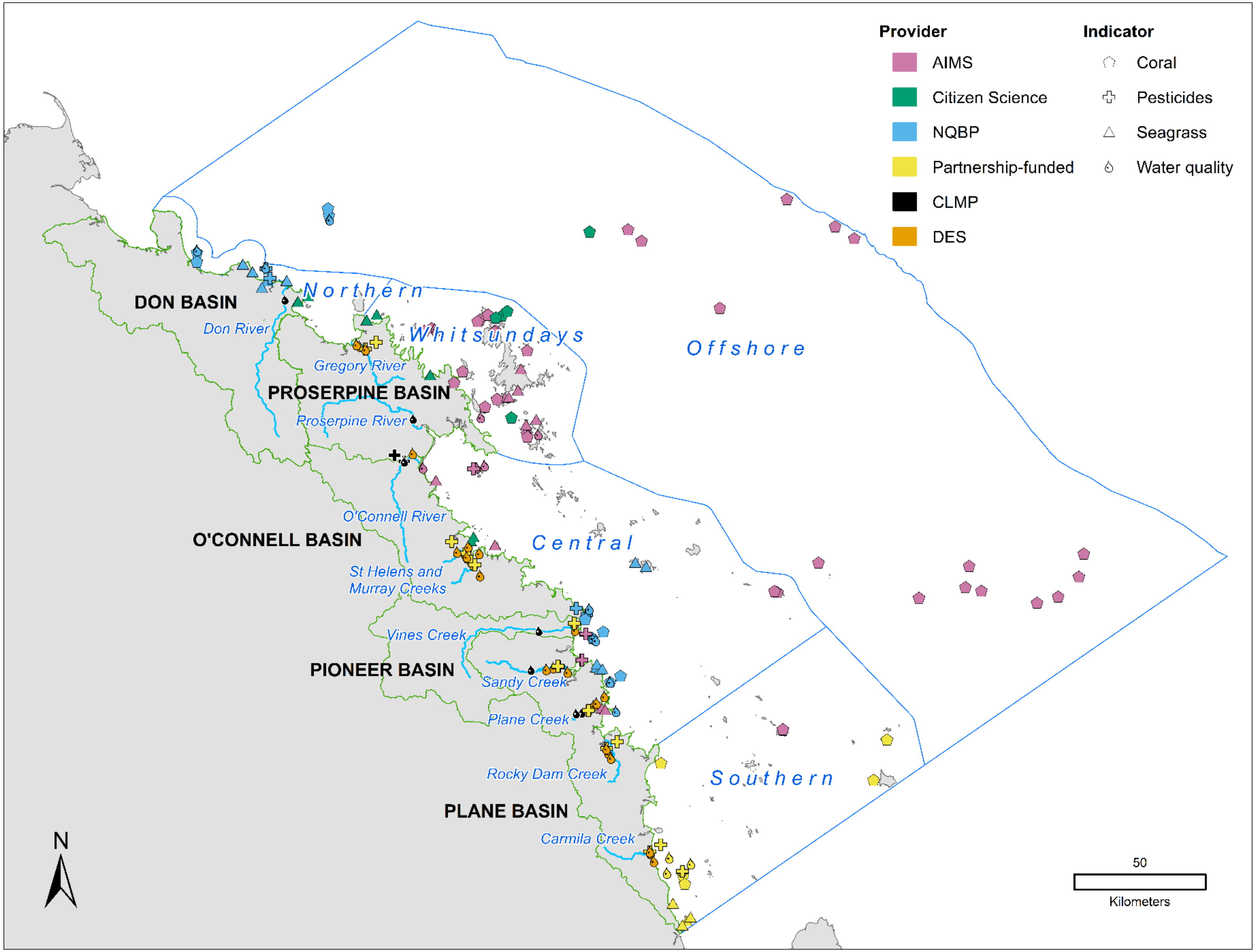


Figure 3. Sampling locations for water quality, pesticides, coral, and seagrass monitoring in the MWI Region for the 2021 Report Card. Blue lines in the marine environment delineate inshore and offshore marine zones.

2.1. Freshwater Basins

Freshwater basins are assessed using three indices: fish, habitat and hydrology, and water quality (Figure 4). Due to differences in the time scales at which notable changes typically occur for each indicator and/or logistical constraints, some are assessed annually, while others are updated every three or four years (Table 1. F). The freshwater basin zones reported in the MWI Report Card are the Don, Proserpine, O'Connell, Pioneer, and Plane basins (Figure 3). The boundaries of these zones are defined as per the Queensland (QLD) Government[5].

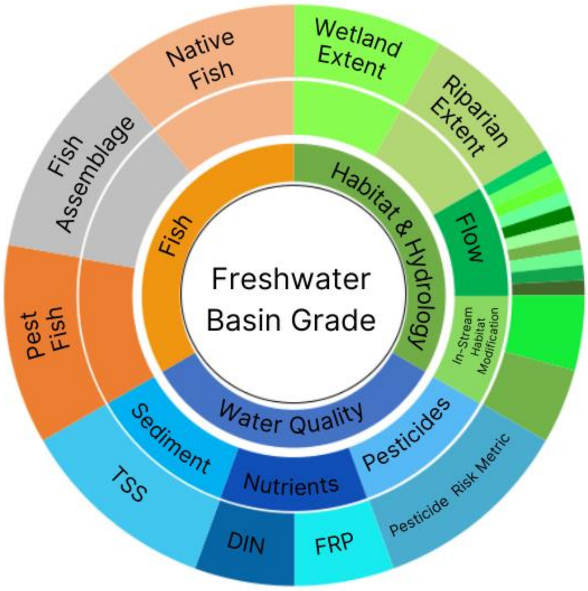


Figure 4. Indicator/s (outer ring), indicator categories (middle ring), and index/indices (inner ring) that contribute to overall freshwater basin scores/grades. Where no indicator category is listed, this represents that the indicator/s (e.g., native fish) do/does not fit into any specific category below the index level (e.g., fish).

Table 1. Frequency of reporting for specific indicator categories and their update status for the 2021 Report Card. Note: the reporting frequency is the same for each freshwater basin indicator within an indicator category.

Index	Indicator Categories	Frequency of Reporting	Last Updated
Water Quality	Sediment	Annually	**2021**
	Nutrients	Annually	**2021**
	Pesticides	Annually	**2021**
Habitat and Hydrology	In-stream habitat modification	4 Yearly	**2019**—Impoundment Length
			2018—Fish Barriers
	Flow	Annually	**2021**
	Riparian ground cover	4 Yearly*	**2014** (scores revised in 2016)
	Freshwater wetlands	4 Yearly	**2019**
Fish	Fish	3 Yearly	**2018**

*Due to methodology changes to riparian ground cover mapping (provided by the Department of Environment and Science), this indicator category has not been updated since 2014; it is expected to be updated for the 2022 Report Card, pending finalisation of methodology refinements.

[5] Department of Resources; previously the Department of Natural Resources, Mines and Energy

2.1.1. Water Quality Index

The water quality index in freshwater basins comprises three different indicator categories and a series of indicators (Figure 4; sediment (total suspended solids (TSS), nutrients (dissolved inorganic nitrogen (DIN), filterable reactive phosphorus (FRP), and pesticides). TSS was selected as an indicator for sediment over turbidity (used for estuary and inshore marine environment) given the availability of data and published guideline values for freshwater systems (Newham et al., 2017).

Samples for all water quality indicators were collected concurrently through the Great Barrier Reef Catchment Loads Monitoring Program (GBRCLMP), led by the QLD Government[6]. Water samples were collected for analysis using manual grab sampling techniques and automatic samplers (DES, 2018; Huggins et al., 2017).

Water quality condition scores in the 2021 Report Card represent the period between 1st July 2020 and 30th June 2021. Data were available from six end-of-system GBRCLMP sites within the MWI Region (**Error! Reference source not found.**):

- **Don Basin**: Don River at Bowen,
- **Proserpine Basin**: Proserpine River at Glen Isla,
- **O'Connell Basin:** O'Connell River at the Caravan Park and O'Connell River at Stafford's Crossing[7],
- **Pioneer Basin:** Pioneer River at Dumbleton Pump Station,
- **Plane Basin:** Sandy Creek at Homebush and Plane Creek at Sucrogen Weir[7].

High-frequency sampling (up to hourly) occurred during high flow events, and monthly sampling was undertaken during ambient (low or base-flow) conditions (Table 2 and Table 3). Unlike other water quality parameters (Table 2), pesticide samples were only taken during a designated six-month period in the wet season (Table 3).

[6] Department of Environment and Science (DES).

[7] Sites were first included in the 2018 Report Card. Pesticide monitoring was discontinued at Stafford's Crossing in the 2020–2021 monitoring period.

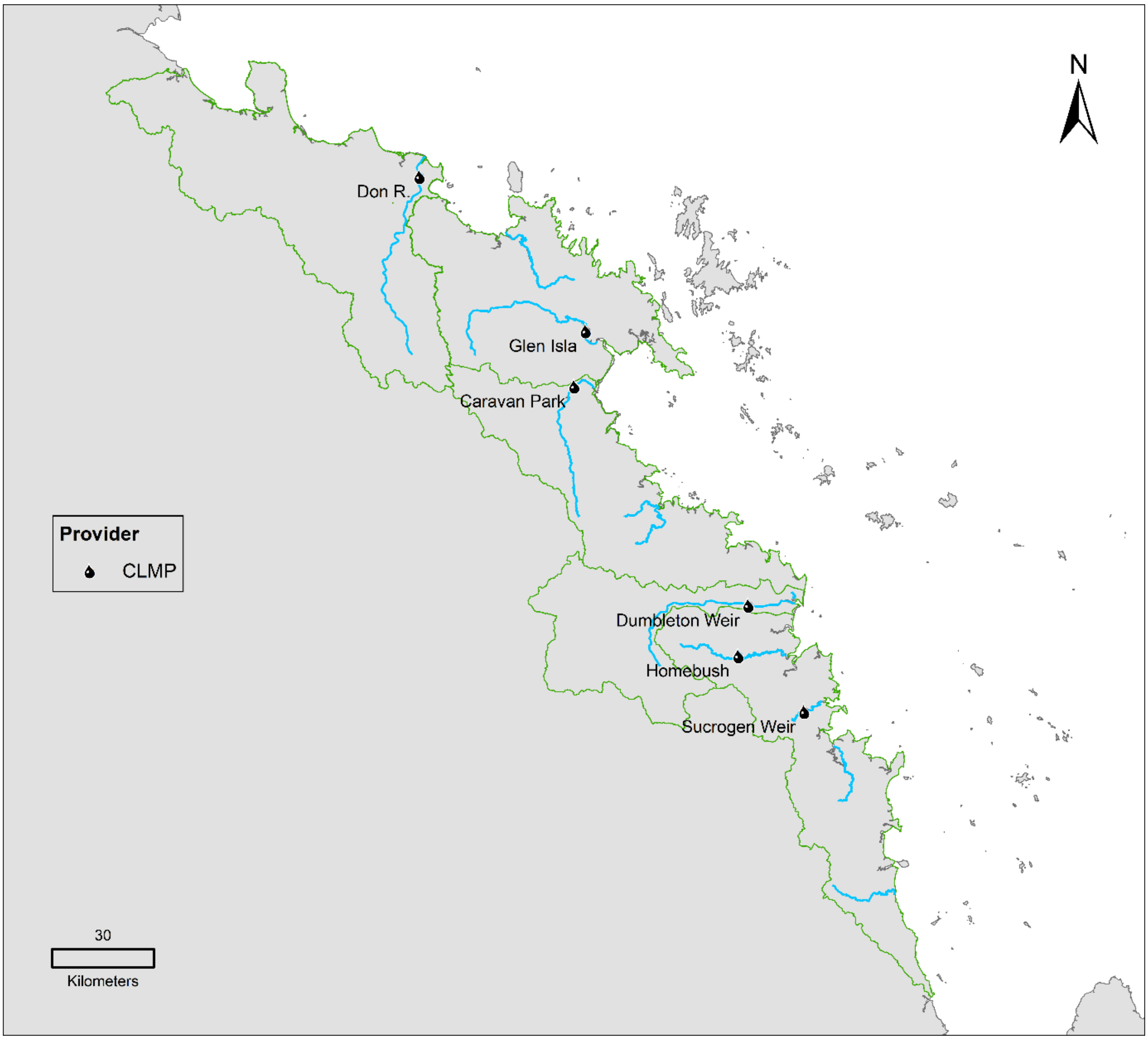


Figure 5. Sampling locations for freshwater water quality monitoring (including pesticides) in the MWI region for the 2021 Report Card. Data provided by the Catchment Loads Monitoring Program (CLMP) as part of the Queensland Government.

To develop an overall score for the O'Connell and Plane basins, scores for each monitoring site were aggregated using a weighted average. Weighting was determined using the relative proportion of catchment area associated with each monitoring site.

The Don River is ephemeral in nature, characterised by episodic flow and periodic drying. Consequently, monitoring activity is limited to periods where there is sufficient surface flow, usually during or shortly after rainfall events. This is different to the other rivers reported in the MWI Region, which are typically permanent in nature. As a result, the sampling size used to inform water quality scores in the Don Basin will vary depending on the prevailing hydrological conditions. Due to a lack of surface flow in the Don Basin across much of the 2020–21 monitoring season, ambient conditions were only captured from January–April 2021. The results obtained from a total of 38 ambient and event samples were used to derive an indicator score for DIN, FRP, and TSS (Table 2). This is similar compared to the previous year in which there were only 35 samples recorded across three months (February–April 2020). However, in previous years, there has been year-round monitoring possible in the Don Basin, with at least one sample taken per month for 2019 and 41 samples total for 2018. The result of this reduction in sample size in the 2019–20 and 2020–21 monitoring periods make these results less temporally representative of the ambient condition of the basin.

Table 2. Water quality monitoring within the MWI basins, where *n* denotes the number of samples analysed for contaminants.

Year	Month	Don River (*n*)*	Proserpine River (*n*)	O'Connell (Stafford's Crossing) (*n*)	O'Connell (Caravan Park) (*n*)	Pioneer River (*n*)	Sandy Creek (*n*)	Plane Creek (*n*)
2020	July		1	1	1	1	1	1
	August		1	1	1	1	1	1
	September		1	1	1	1	1	1
	October		1	1	1	1	1	1
	November		2	2	2	6	12	6
	December		10	7	9	10	21	7
2021	January	20	27	26	30	26	39	18
	February	5	4	10	11	1	1	1
	March	11	8	4	7	10	14	9
	April	2	1	1	1	2	2	2
	May		1	1	1	1	1	1
	June		1	1	1	1	6	1
	TOTAL	38	58	56	66	61	100	49

*No samples were collected for the Don River between July and December 2020 due to a lack of surface flow in the basin.

Similar to previous report cards, sediment and nutrient condition in the Proserpine Basin were not reported for the 2021 Report Card. In the 2018 review of water quality data, the concentration of TSS at this site was found to be confounded by tidally resuspended sedimentation and therefore not fully representative of the freshwater environment. There was also a strong correlation between TSS and the observed concentration of nutrients (DIN and FRP), suggesting nutrients are similarly confounded at this site. To fill this data gap, the Partnership undertook a pilot monitoring project in the 2020–21 monitoring period, using an upstream monitoring location that is largely outside of the range of tidal influence. The pilot project sampled nutrients and suspended solids in the Proserpine Basin on a monthly basis, and the results from the project are set to help inform future monitoring of the basin. However, pesticides were still reported in the 2021 Report Card using data from the original Proserpine Basin site. This site was considered to still provide a reasonable estimate of pesticide pressures in the freshwater catchment. The pesticide risk score calculated from samples taken above the tidal zone would not necessarily provide a more accurate picture of the catchment's pesticide pressures, as it would likely miss some land-based inputs (see the 2018 Results Report[8] for more information).

[8] https://healthyriverstoreef.org.au/report-card/report-card-download/

Table 3. Water quality monitoring within the MWI basins, where *n* denotes the number of samples analysed for contaminants. Grey highlighted cells represent where monitoring did not take place (e.g., outside of wet season) or where no data are available.

Year	Month	Don River (*n*)	Proserpine River (*n*)	O'Connell (Stafford's Crossing)* (*n*)	O'Connell (Caravan Park) (*n*)	Pioneer River (*n*)	Plane Creek (*n*)	Sandy Creek (*n*)
2020	July		1		1	1	1	1
	August							
	September		1		1	1	1	1
	October							
	November		1		1	5	4	7
	December		7		7	7	5	12
2021	January	13	15		19	15	12	19
	February	5	5		5	1	1	1
	March	6	7		6	9	6	13
	April	2	1		1	2	2	2
	May		1		1	1	1	1
	June		1		1	1	1	4
	TOTAL	26	40		43	43	34	61

*This site was not sampled for the 2020–21 period.

Pesticide monitoring at the Stafford's Creek site in the O'Connell Basin was discontinued in the 2020–2021 monitoring period. Therefore, the pesticide grade in the O'Connell Basin is less spatially representative of basin condition than previous years.

Pesticide indicator scores for 2021 were developed by the QLD Government's GBR CLMP using the Pesticide Risk Metric (PRM). The aim of this approach is to quantify the ecological risk associated with exposure to a mixture of up to 22 pesticides (herbicides and insecticides) (Table 4) in any given sample. From the 2019 Report Card onwards, the PRM approach has been applied to pesticides with multiple modes of action (MoAs) to better represent pesticide risk (Table 4).

Table 4. Pesticides included in Pesticide Risk Metric. Note, not all pesticides listed were necessarily detected in every water sample.

Pesticide	Mode of Action	Pesticide Type
Chlorpyrifos	Acetylcholine esterase (AChE) inhibitor	Insecticide
Fipronil	Gamma-aminobutyric acid (GABA) gated chloride channel blocker	
Imidacloprid	Nicotinic receptor agonist	
Haloxyfop	Acetyl-coenzyme A carboxylase (ACCase) inhibitor	Non-PSII herbicides
Imazapic	Group 1 Acetolactate synthase (ALS) inhibitor	
Metsulfuron-methyl	Group 2 Acetolactate synthase (ALS) inhibitor	
Pendimethalin	Microtubule synthesis inhibitor	
Metolachlor	Inhib of VLCFA	
2,4-D	Auxin mimic (Phenoxy-carboxylic acid auxins)	

Table 4. Pesticides included in Pesticide Risk Metric. Note, not all pesticides listed were necessarily detected in every water sample.

Pesticide	Mode of Action	Pesticide Type
MCPA	Auxin mimic (Phenoxy-carboxylic acid auxins)	
Fluroxypyr	Auxin mimic (Pyridine-carboxylic acid auxins)	
Triclopyr	Auxin mimic (Pyridine-carboxylic acid auxins)	
Isoxaflutole	4-hydroxyphenylpyruvate dioxygenase (4-HPPD) inhibitor	
Ametryn		
Atrazine		
Prometryn		
Terbuthylazine		
Tebuthiuron	PSII inhibitor	PSII herbicides
Simazine		
Diuron		
Hexazinone		
Metribuzin		

2.1.2. Habitat and Hydrology Index

Indicators used to report on the habitat and hydrology index in freshwater basins are impoundment length, fish barriers, riparian extent, wetland extent, and flow. Impoundment length and fish barriers are grouped together as the in-stream habitat modification indicator category.

2.1.2.1. In-stream Habitat Modification

Impoundment Length

This indicator was selected to describe how much 'natural' channel habitat remained in the region compared to artificially ponded channel habitat, which has relatively little diversity in terms of depth (benthic light availability, oxygen availability), flow rate, and natural wetting and drying cycles. The impoundment length indicator is updated every four years and was last updated in the 2018 Report Card. As a result, impoundment length scores presented in the 2021 Report Card represent repeated data.

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. This is compared to the reference condition of no artificial impoundments (0%).

Impoundment locations and estimates of impounded lengths were derived from the QLD Government[5], including 1:100,000 ordered drainage network, Google Earth imagery, QLD Globe spatial layers (Dams, Weirs and Barrages, Referable Dams and Reservoirs), and local knowledge, including from regional hydrographic staff[5]. The proportion of impoundment length was calculated as a percentage of the total linear length of the river channel.

Fish Barriers

The majority of freshwater fish species in the MWI Region migrate between freshwater and estuarine habitats at some stage during their life cycle (Moore, 2015b). Therefore, barriers that prevent or delay connectivity between key habitats have the potential to impact migratory fish populations, decrease the diversity of fish communities in freshwater and estuaries, and reduce the condition of aquatic systems (Moore, 2015b).

The fish barrier index is based on an assessment of three indicators: 'barrier density', 'proportion of stream length to the first barrier', and 'proportion of stream length to the first low/no passability barrier' (Figure 6). Only barriers located on 'major' (Strahler stream orders 4-7) and 'high' (Strahler stream orders 2–3 with low gradient, Strahler stream order 3 with medium gradient) risk category waterways were included in the analysis[9] (Figure 6). A low "passability" barrier was defined as a barrier that never or rarely 'drowns out'[10] (<1 flow event per year), a dam or weir with >2m head loss, a causeway >2 m high with pipe/culvert configuration <10 %, and/or bankfull stream width and head loss >1 m.

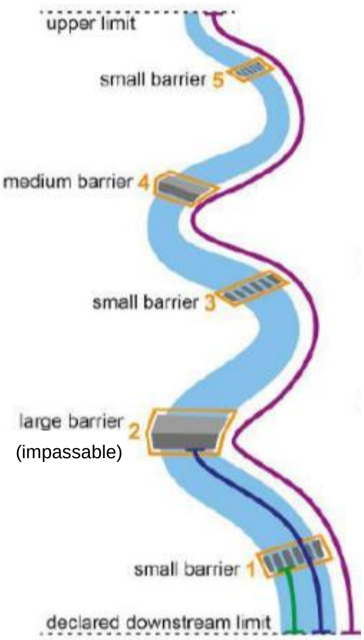
For the freshwater basins, all measurements were made upstream of the Declared Downstream Limit (DDL), defined as the lower-most freshwater reach of a stream as determined by the QLD Government[5]. The DDL was selected because any potential barriers downstream of this point clearly allow tidal movements and thus do not prevent connectivity with this interface.

To assess potential barriers to fish passage within the MWI Region, Geographic Information Systems (GIS) software was utilised to prioritise the large number of anthropogenic barriers that prevent, delay, or obstruct fish migration within the region's waterways. On-ground validation of priority potential barriers was undertaken to determine the authenticity of barriers and collate important barrier characteristics (Moore, 2015a). In the Proserpine, O'Connell, Pioneer, and Plane basins, fish barriers were assessed utilising known barriers that were identified and assessed in the MWI Region Freshwater Fish Barrier Prioritisation report (Moore, 2015a).

The fish barriers score is updated every four years, most recently in 2018–19. In the preceding assessment (2014–15) of the Don Basin, fish barriers were provisionally assessed using the Burdekin Dry Tropics Natural Resource Management Group Region Fish Passage Study (J. Carter et al., 2007). Due to recent improvements and availability of aerial imagery, a desktop study of potential barriers in the Don Basin was undertaken to complement the existing data. Despite this, insufficient data was available to inform the no/low "passability" barriers indicator using this method alone. Instead, expert opinion was used to assess the 'proportion of stream length to the first no/low "passability" barrier' indicator. In the 2018–19 assessment of the Don Basin, fish barriers were assessed based on updated desktop investigation of potential barriers (using spatial imaging and local knowledge) and subsequent field works.

[9] Queensland waterways that fall within these two risk categories were determined by Fisheries Queensland, based on the following criteria: stream order, stream slope, flow regime, number of fish present, and fish swimming ability. The combined analysis of these characteristics determined the classification, based on the risk of impact from fish barriers on fish movement and fish communities.

[10] Denotes a barrier with potential to ascend only during very high flooding flow.



$$\text{Barrier density} = \frac{\text{total stream length of major and high impact waterways}}{\text{total number of barriers on these streams within the basin}}$$

$$\text{Percent of stream length to the first barrier} = \frac{\text{stream length from declared downstream limit (DDL) to the first barrier}}{\text{total stream length of major and high impact waterways (km)}} * 100$$

$$\text{Percent of stream length to the first impassable barrier} = \frac{\text{stream length from DDL to the first impassable barrier}}{\text{total stream length of major and high impact waterways (km)}} * 100$$

Fish barriers index score

Figure 6. Diagram of the three fish barrier indicators and how they are calculated. For the purposes of the diagram, the declared downstream limit is equivalent to the upper tidal limit. The fish barriers indicator category comprises 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.

2.1.2.2. Flow

The flow indicator provides a score for each waterway, based on the modification of the flow regime from an unmodified reference condition. A highly modified waterway with large deviations from an unregulated reference condition will score poorly, while a waterway with an unmodified flow regime resulting in a flow regime similar to the reference condition will score well. Observed flow data are assessed for deviations from the reference pre-development flow data (specific to each assessment site and measured against rainfall for each reporting year) to create the flow metrics used for scoring. (see Section **Error! Reference source not found.** for further detail).

This is the fourth consecutive year of reporting flow scores. The flow tool is suited to basins where sufficient flow monitoring data exists and where there are no prolonged low or no-flow scenarios. Since 2019, flow scores have been reported for the Plane and Pioneer Basins, as there are sites with operational stream gauging stations that provide daily flow data, and time series modelled pre-development daily flows exist to provide the reference condition. The flow tool is scheduled to undergo a review process for future report cards in collaboration with the TWG and aquatic ecology experts to identify further refinements to the tool and methods, including rainfall seasonality.

Observed daily flows (ML/day) were obtained from stream gauging stations managed by the QLD Government[11] and reported via the QLD Government Water Monitoring Information Portal (*water-monitoring.information.qld.gov.au/*) (Table 5 and Figure 7). Gaps in observed daily flow data were 'patched' using the River Analysis Package (RAP), developed by the Cooperative Research Centre for Catchment Hydrology at Monash University, Melbourne. Modelled pre-development time series

[11] Department of Regional Development, Manufacturing and Water (DRDMW)

(100+ years, date ranging typically from 1890–2008) of daily flows (ML/day) were obtained from QLD Government hydrologic models (Integrated Water Quantity and Quality Model (IQQM)), which were developed for QLD basin water resource plans. This model excludes storages and extractions.

Table 5. Flow assessment sites with QLD Government[11] gauging stations used for the flow indicator within each basin.

Basin	Flow Assessment Site	Gauging Station Number
Pioneer	Cattle Creek at Gargett	125004B
	Blacks Creek at Whitefords	125005A
	Finch Hatton Creek at Gorge Road	125006A
	Pioneer River at Mirani Weir TW	125007A
	Pioneer River at Dumbleton Weir TW	125016A
Plane	Sandy Creek at Homebush	126001A

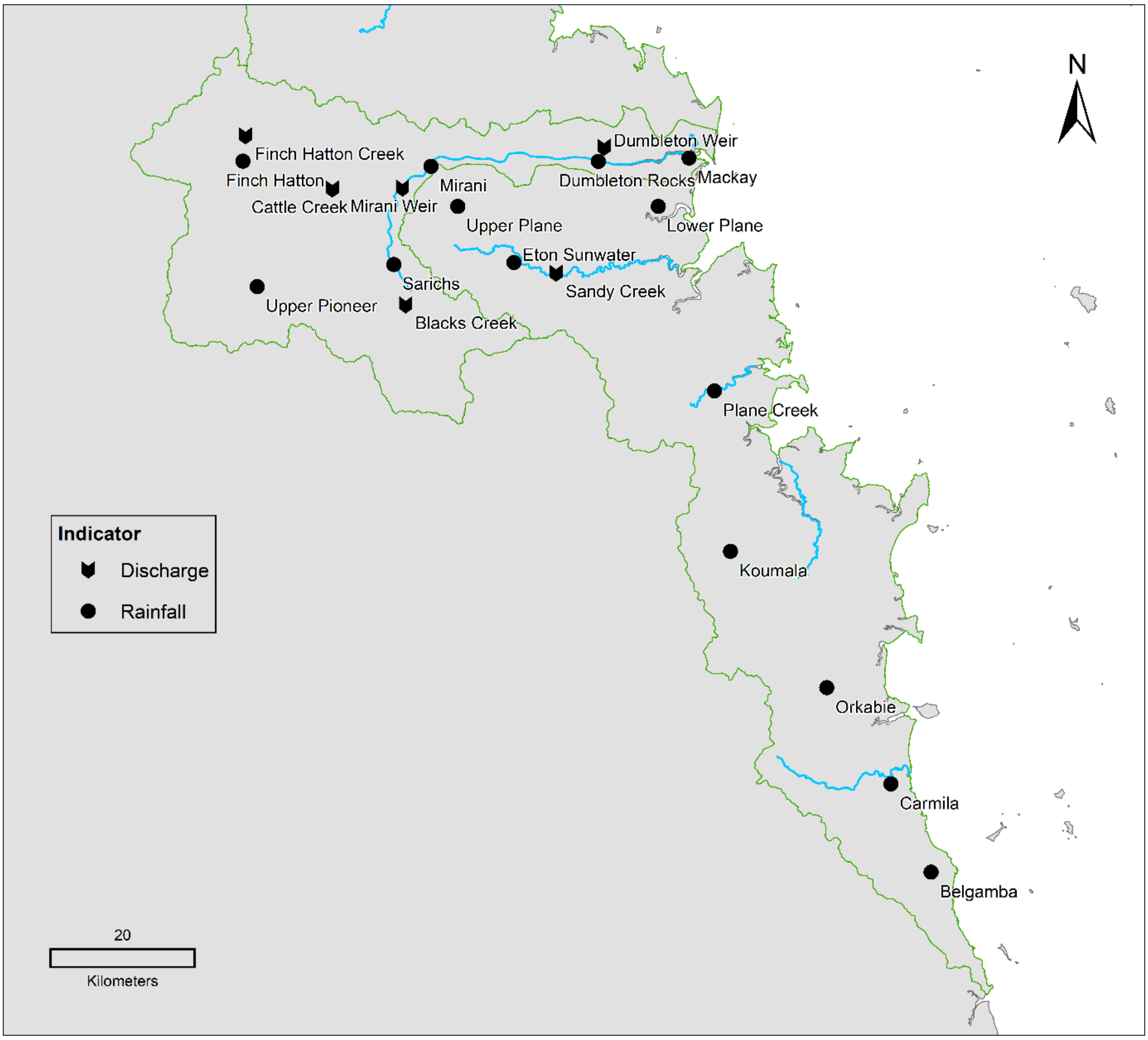


Figure 7. Sampling locations for flow monitoring in the MWI region for the 2021 Report Card. Flow rainfall data provided by the Bureau of Meteorology (BoM) and the QLD SILO database. Flow discharge data provided by the Queensland Department of Regional Development, Manufacturing and Water (DRDMW).

The annual flow pattern in any given river will vary naturally with the prevailing rainfall conditions. To account for differences in rainfall between years, catchment historical daily rainfall data (100+ years) was obtained from the QLD SILO program (https://www.longpaddock.qld.gov.au/silo/) and the Bureau of Meteorology (BoM) (http://www.bom.gov.au/) (Table 6). The SILO rainfall record covers the entire hydrological modelling period (1890–2008) and continues to the end of the reporting year for each report card (Table 6).

Table 6. Rainfall site details used to present catchment rainfall for flow indicator sites.

Basin	Site	Station Name/Location	Station Number	Latitude	Longitude	Elevation (m)
Pioneer	PB1 S	Mackay Alert	33303	-21.1397	149.1883	11.0
	PB2 S	Dumbleton Rocks Alert	33300	-21.1439	149.0753	0.0
	PB3 P	Mirani Post Office	33052	-21.1500	148.8667	50.0
	PB4 P	Finch Hatton Cook St	33026	-21.1436	148.6322	105.0
	PB5 S	Sarichs Alert	33299	-21.2725	148.8203	47.8
	PB6 GP	Upper Pioneer catchment	N/A	-21.3000	148.6500	392.9
Plane	PB1 P	Plane Creek Sugar Milll	33059	-21.4300	149.2200	16.0
	PB2 P	Eton Sunwater	33134	-21.2700	148.9700	30.0
	PB3 P	Koumala Hatfields Road	33038	-21.6300	149.2400	30.0
	PB4 P	Carmila Beach Road	33186	-21.9200	149.4400	23.0
	PB5 P	Orkabie West Hill	33095	-21.8000	149.3600	22.0
	PB6 P	Belgamba	33188	-22.0300	149.4900	30.0
	PB7 GP	Upper Plane Catchment	N/A	-21.2000	148.9000	51.7
	PB8 GP	Lower Plane Catchment	N/A	-21.2000	149.1500	7.5

Note: Sites are either station (S), grid point (GP) or point (P) locations.

Historical daily rainfall data were averaged from all rainfall sites within a basin and were 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

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 a reference distribution for each rainfall type at each flow assessment site. Generation of rainfall types and determining rainfall type of the reporting year was conducted using the flow indicator tool (Stewart-Koster et al., 2018).

2.1.2.3. Riparian Extent

The assessment of riparian extent follows the same methodology used for the GBR Report Card. This methodology first defines riparian areas using topographic drainage data and riverine wetlands derived from the 2009 QLD Wetland Mapping Programme data. The present extent of riparian forest is defined by those areas with a foliage projective cover of at least 11% (Folkers et al., 2014) using the 2013 Landsat foliage projective cover data. This is then compared against the pre-development extent of riparian forest Regional Ecosystem (RE) mapping data (based on RE mapping version 9) to estimate the amount of riparian forest remaining in the five basin areas. The method assumes that the pre-clearing riparian forest REs were 100% forested.

The riparian extent indicator is updated in broad accordance with mapping updates produced by the QLD Government Remote Sensing Centre[6]. Consequently, the update period is approximately four years. To date, the riparian extent scores reported in preceding report cards have been developed based on data collected in the previous assessment, which occurred in 2013–14. Scores for this indicator were due to be updated for the 2018 Report Card. However, the data collected is subject to considerable change to improve the resolution and accuracy of vegetation mapping. As a result, updated mapping methodology for this indicator is currently under review and will not be released until after the 2021 Report Card.

2.1.2.4. Wetland Extent

The assessment of wetland extent uses similar methods to those employed in the GBR Report Card; however, only palustrine systems are reported for the MWI Report Card.

Palustrine systems were defined as wetlands with more than 30% emergent vegetation cover or less than 8 ha. Wetland extent is defined as the aerial extent of a wetland. The condition of wetland extent was determined through a comparison of the current extent against pre-clearing extent of vegetated freshwater swamp (palustrine) systems using the QLD RE mapping version 5. The RE mapping is derived by delineating pre-clearing Res using multiple lines of evidence, including stereo aerial photography, geology and soils mapping, historical survey records, and field survey information.

A combination of automated and manual interpretation of imagery is used to delineate the change in wetland extent due to the clearing of vegetation, destruction of water bodies from draining or earthworks, or the creation of new water bodies through dam or weir construction. Changes in wetland extent due to seasonal wetting and drying are not recorded as wetland loss or gain. Natural wetlands are distinguished from hydrologically modified wetlands (i.e., human-made inputs, such as levees or bunds) within this analysis, and artificial or highly modified wetlands are not reported (Australian and Queensland Governments, 2018).

The wetland extent indicator is updated every four years and was last updated in the 2019 Report Card (2017–18 mapping). Due to refinements such as error correction and remapping to a finer scale compared to the previous 2013–14 assessment, scores are not directly comparable between years. To rectify this, wetland extent scores were back-calculated for the 2013 assessment using the updated mapping (see the 2020 Results Report[8]). The 2021 Report Card scores are therefore directly comparable only to the back-calculated scores, with results represented in Report Cards prior to 2019 all superseded.

2.1.3. Fish Index

The fish community index is based on the condition of native and pest fish, with field monitoring surveys, data collection, and analysis conducted by the QLD Government[6] in each basin in the MWI Region. The indicators for fish community condition in freshwater basins are assessed by comparing observed data to modelled data and include:

Proportion of Indigenous Species Expected (POISE):
The number of naturally occurring native Australian fish species caught as a proportion to the number predicted to occur at the site (in a single sample, using a standardised method) by a quantitative statistical model.

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. Sub-indices include:

- ***Proportion of Alien Fish:*** The number of non-Australian fish caught, expressed as a proportion of the total fish catch at the site.
- ***Proportion Translocated Fish:*** The number of translocated native Australian fish caught, expressed as a proportion of the total fish catch at the site.

Fish survey sites were randomly selected using Generalised Random-Tessellation Stratified (GRTS) methods, weighted by stream order. An ordered list of sites was generated and reviewed to identify limitations to sampling, including dense vegetation, which may restrict access and safety risks (e.g., presence of crocodiles). If a site was rejected on this basis, the next listed site was used. The most recent fish surveys were conducted from September to October 2020, predominantly using backpack electrofishing techniques. Boat-mounted electrofishing techniques were used to assess sites unsuitable for wading (e.g., deeper water).

2.2. Estuaries

The eight estuaries reported on in the MWI Report Card are associated with the Gregory River, O'Connell River, St Helens/Murray Creeks, Vines Creek, Sandy Creek, Plane Creek, Rocky Dam Creek, and Carmila Creek (Figure 3). Indicator categories and indicators within two indices, habitat and hydrology and water quality, are reported annually or on four-year cycles (Figure 8, Table 7).

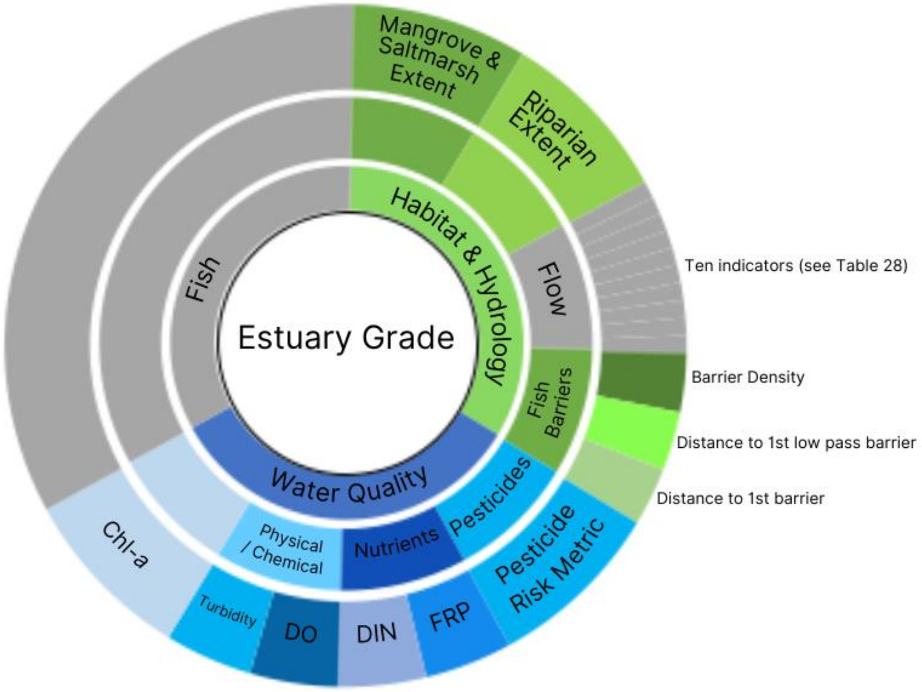


Figure 8. Indicators (outer ring), indicator categories (middle ring), and indices (inner ring) that contribute to overall estuary scores/grades. Where no indicator category is listed, this represents that the indicator/s (e.g., riparian extent) do/does not fit into any specific category below the index level (e.g., habitat & hydrology). Dark grey represents no data.

2.2.1. Water Quality Index

The indicator categories used to report on the water quality index in estuaries include Nutrients (DIN and FRP), Physical-chemical or Phys-chem (turbidity and dissolved oxygen (DO)), Pesticides (Pesticide risk metric (PRM)), and Chlorophyll-*a* (Chl-*a*). (Figure 8):

While chl-*a* concentration is considered a useful proxy for nutrient availability, it was not grouped into the nutrients category, given its linkages to measures of turbidity; instead, it is considered as an indicator in itself as a representative of the productivity of a system.

Table 7. Indicator categories (outer ring) and indices (inner ring) that contribute to overall basin scores, frequency of reporting, and update status for the 2021 Report Card.

Index	Indicator Categories	Frequency of Reporting	Last Updated
Water Quality	Phys–chem	Annually	**2021**
	Nutrients	Annually	**2021**
	Chlorophyll-*a*	Annually	**2021**
	Pesticides	Annually	**2021**
Habitat and Hydrology	Flow		
	Riparian Vegetation	4 Yearly	2019
	Mangrove and Saltmarsh	4 Yearly	2019
	Fish Barriers	4 Yearly	2019
Fish			

2.2.1.1. Indicator Category Details (Nutrients, Chl-a, Phys–chem, and Pesticides)

Water quality data used to report the condition of the eight estuaries was obtained through the Estuary Monitoring Program led by the QLD Government[6], with supplementary data added through the GBRCLMP and a Partnership-led Estuary Pesticide Monitoring Program. The Estuary Monitoring Program commenced in 2014 and is conducted once per month at between one and three sites in each estuary (Table 8). Sampling sites are located at varying distances upstream of the mouth of each estuary (Table 8 and **Error! Reference source not found.**). The distance of sampling sites are r eported as the adopted middle thread distance[12]. Hereafter, monitoring sites associated with this program will be referred to as 'mid-river' sites.

To increase the temporal representation of pesticide data, the supplementary monitoring program (Partnership-led Estuary Pesticide Monitoring Program) was established and funded by the Partnership in November 2018. Monitoring was conducted twice per month from a single site in each estuary. Sites were selected based on their proximity to existing mid-river sites, site accessibility, and safety risks. Hereafter, monitoring sites associated with this program will be referred to as 'land-based sites' (see 2019 Results Report[8]). The result of this program is increased confidence in estuary pesticide scores for the Report Card.

Given the Murray and St Helens Creeks are reported as one estuary (St Helens/Murray Creek estuary), the inclusion of sites upstream of both creeks collectively results in a greater representation for this large area. For the O'Connell River estuary only, pesticide and nutrients data were reported using the freshwater basin GBRCLMP water quality monitoring site (Table 8). As a result, estuary pesticide monitoring is not conducted in the O'Connell River at mid-river or corresponding land-based sites, and estuary monitoring O'Connell data are only used for dissolved oxygen and chl-a indicators.

Table 8. Estuaries monitored for water quality, the location of sampling sites upstream of the estuary mouth reported as 'middle thread distance', and number of monthly samples (n) for each indicator. Monitoring data for Murray Creek and St Helens Creek are combined to produce one score.

Monitoring Sites	Sites (km from estuary mouth)	Nutrients (n)	Phys–chem (n)	Chl-*a* (n)
Gregory River	3.6	13	12	13
	8.4	12	12	12
St Helens Creek	7.5	0	12	0
	8.9	12	12	12
Murray Creek	10.0	0	12	0
	12.5	12	12	12
	16.5	12	12	12
Vines Creek	2.0	12	12	12
Sandy Creek	4.5	12	12	12
	13.5	12	12	12
Plane Creek	6.0	12	12	12
	9.0	12	12	12
Rocky Dam Creek	8.9	11	11	11
	12.9	11	11	11
Carmila Creek	2.9	12	12	12

[12] Denotes the distance in kilometres, measured along the middle of a watercourse that a specific point in the watercourse is from the mouth or junction from the main watercourse. Australian Bureau of Meteorology. Australian Water Information Directory. http://www.bom.gov.au/water/awid/id-771.shtml

Data samples collected between 1st July 2020 and 30th June 2021 were used to calculate water quality condition scores for estuaries in the 2021 Report Card. Pesticide monitoring routinely occurs across the wet season for a period of six months (Table 9). This contrasts to the monitoring program for water quality, where ambient sampling activity occurs once per month for the duration of the monitoring year. Sampling was conducted on the ebb of neap tides when possible to minimise the effect of tidal variation and ensure that conditions at monitoring events were comparable. All water quality samples were collected, stored, and transported in accordance with the QLD Government's Monitoring and Sampling Manual (DES, 2018).

Laboratory analyses for chl-*a* and nutrients were conducted in-house at the QLD Government[6] Science Division Chemistry Centre (Ecoscience Precinct, Dutton Park, QLD). The laboratory is accredited by the National Association of Testing Authorities (NATA) for the chemical and physical analysis of water and soil, including for the assessment of chl-*a* and dissolved nutrients. This is to ensure compliance with relevant international and Australian standards and competency in providing consistent quality of results. As done for freshwater basins, to derive DIN from estuary data, oxidised nitrogen (NO_x) is summed with ammonia nitrogen.

To maintain consistency in the quality of results, pesticide samples across the ambient and supplementary monitoring program were both submitted to the QLD Health Forensic and Scientific Services Laboratory (FSS) for analysis. This laboratory is also accredited by NATA for the chemical and physical analysis of water, including for the assessment of toxicants, such as pesticides.

Table 9. Water quality monitoring for pesticides within the MWI estuaries. Where no monitoring data was available, cells have been highlighted in grey.

Year	Month	Gregory River	O' Connell River*	St Helens Creek	Murray Creek	Vines Creek	Sandy Creek	Plane Creek	Rocky Dam Creek	Carmila Creek
2020	July		1							
	August									
	September		1							
	October			1	1	1	1	1	1	1
	November	4	1	1	2	2	2[y]	2	2	2
	December	1	7	3	3	3	3	3	2	3
2021	January	3	19	3	3	3	3	3	3	3
	February	2	5	2	2	2	2	2	3	2
	March	4	6	5	4	5	5	5	4	5
	April	3	1	5	4	3	3	3	3	3
	May	1	1	2	1					
	June		1							
	TOTAL	18	43	22	20	19	19	19	18	19

*Pesticide data (and nutrients) in the O'Connell River estuary are derived from samples collected through the GBRCLMP rather than the mid-rover site referenced in Table 8. Changes in sample numbers across years for this site are due to the nature of event sampling.

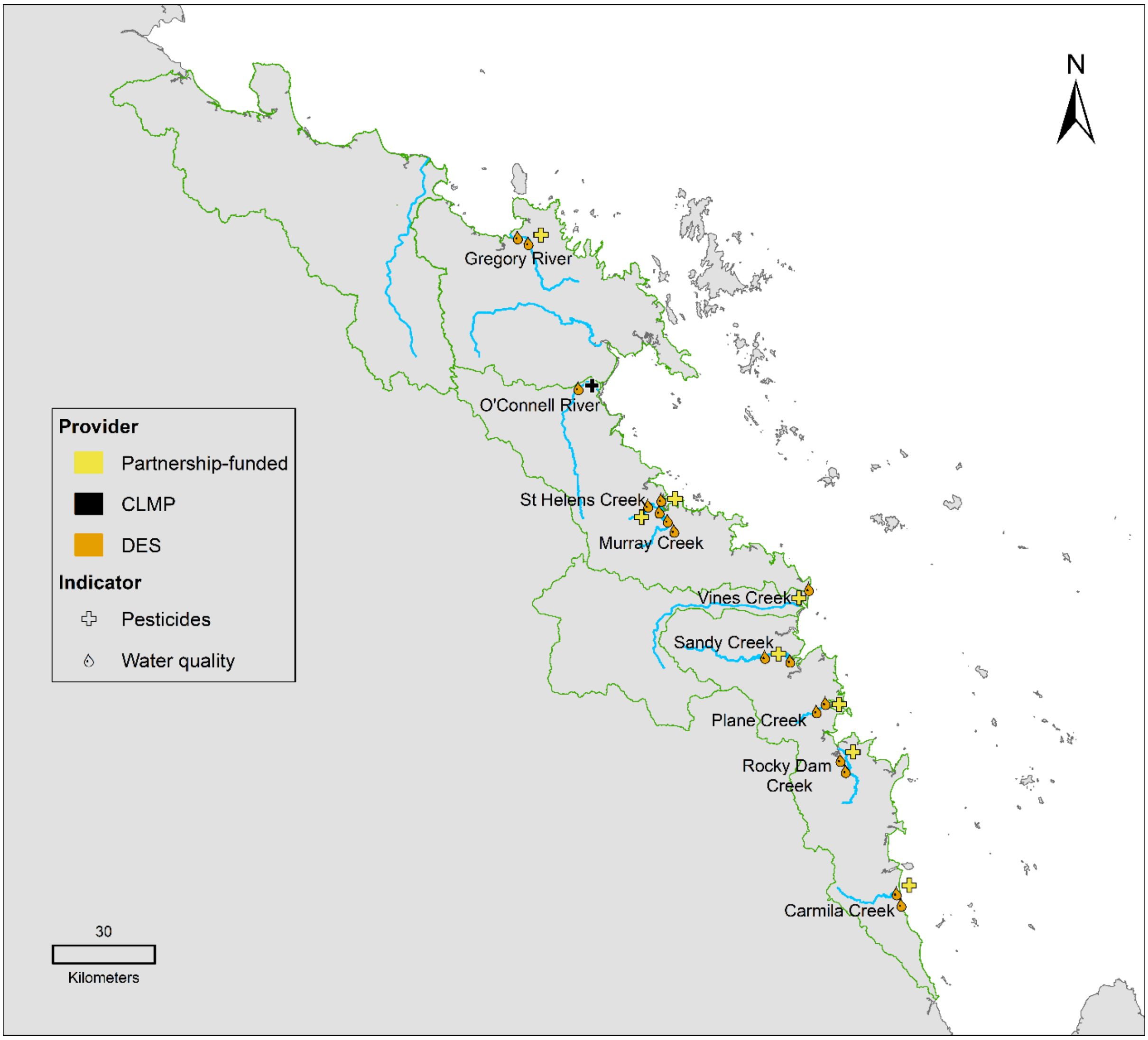


Figure 9. Sample locations for estuary water quality and pesticides monitoring for the MWI region for the 2021 Report Card. Water quality data provided by the QLD Department of Science (DES); pesticide data provided by a Partnership-funded initiative and CLMP.

2.2.2. Habitat and Hydrology Index

Indicators used to report on the habitat and hydrology index in estuaries are riparian extent, mangrove/saltmarsh extent, and fish barriers. There was not sufficient information available to report on the condition of flow within estuaries.

2.2.2.1. Riparian Extent

The assessment of riparian vegetation extent in the estuarine environment was conducted by reviewing the proportion of riparian area that had been cleared of natural vegetation. The riparian area was determined to be any vegetation within 50 metres (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 the comparison of report cards over time. The data prepared by the QLD Government[6] were obtained through Google Earth and the QLD Herbarium's RE (version 9) mapping.

The procedure 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 was:

1. Start from the upstream point that was considered by signs (vegetation) to be the tidal limit.
2. Construct lines from the tidal limit downstream, following the outermost waterline for both sides of the stream.
3. Construct areas 50 m wide as 'buffer strips' on the edge of the constructed lines.
4. Select all data within these defined areas to extract the latest Herbarium data (2013 Remnant REs of QLD, version 9 (April 2015)).
5. Using the non-ocean data within the selected area, calculate the proportional area of non-remnant vegetation as the estimated result of the proportional area of natural vegetation (of any sort) that has been cleared within 50 m of the water's edge.

Data for riparian extent was initially assessed in 2013–14 and again for the 2019 Report Card based on mapping, which depicts condition in 2017 as per its four-year assessment cycle. As noted in Section **Error! Reference source not found.**, the 2017 updates to this source mapping, including r efinements such as changes in source data, error correction, and mapping to a finer scale, were substantial. Therefore, the resulting data are not directly comparable to those previously reported, inhibiting any interpretation in change between years. To rectify this, riparian extent results have been back-calculated for the 2013 assessment using updated mapping (see 2020 Results Report[8]). Report Card scores are directly comparable only to the back-calculated scores, with all previous scores superseded. Updated mapping methodology for this indicator is currently under review and will not be released until after the 2021 Report Card.

2.2.2.2. Mangrove/Saltmarsh Extent

To assess the condition of mangrove/saltmarsh extent in the estuaries, the aerial extent of intertidal habitat categories (listed below) was compared to the same habitat areas in their pre-clearing condition. The spatial data were prepared by the QLD Government[6] and derived from the QLD Herbarium's RE (version 7.1.1, 7.1.2, 7.1.3, and 7.1.5) data. The 2013 aerial extent and pre-clearing data layers were compared, and the proportion of loss since pre-clearing was presented.

The procedure for the spatial estimation of the percentage loss (pre-clearing to 2013) of the four important dominant vegetation categories from the RE mapping data was:

1. Start with the defined area of each estuary.
2. Use the proportion of each of the selected REs of mangrove (8.1.1), samphire (8.1.2), tussock (8.1.3), and melaleuca (8.1.5) within these defined areas used as a "cookie cutter" to extract from the three Herbarium datasets of pre-development, 1997, and 2013 Remnant REs of QLD.
3. Calculate the percentage loss from the difference in pre-development to the 2013 combined area of mangrove, samphire, tussock, and melaleuca in the RE data.

All data for mangrove/saltmarsh extent results were last assessed for the 2019 Report Card based on mapping, which depicts the condition in 2017 (as per its four-year assessment cycle). As for riparian extent, data are not directly comparable to those previously reported, and therefore, results have been hindcasted for the 2013 assessment using updated mapping (see 2019 Results Report[8]).

2.2.2.3. Fish Barriers

Assessment of fish barriers in the estuarine environment was last undertaken in 2018–19 (as per the four-year reporting cycle), using the same indicators and scoring ranges described for freshwater basins. All barriers on 'major' or 'high' impact tributaries were included in the analysis, up to the threshold of 18.5 m above DDL. Barriers were assessed on waterways that intersected the Fisheries QLD 'Estuary Extent' Layer, regardless of the size of the waterway (Figure 10).

The elevation threshold (18.5 m above the DDL) was selected based on Fisheries QLD fish community monitoring data and local expert knowledge (Fisheries Biologists Matt Moore and Trent Power from the environmental consultancy Catchment Solutions Pty Limited). This was determined based on the highest known upstream location where diadromous and/or marine vagrant estuarine fish species were known to occur and were known to be important to estuarine fish habitat, particularly for QLD's most iconic estuarine fish species, barramundi. The minimum elevation was selected as the threshold value that would incorporate all upstream sites across the estuaries where such occurrence was known.

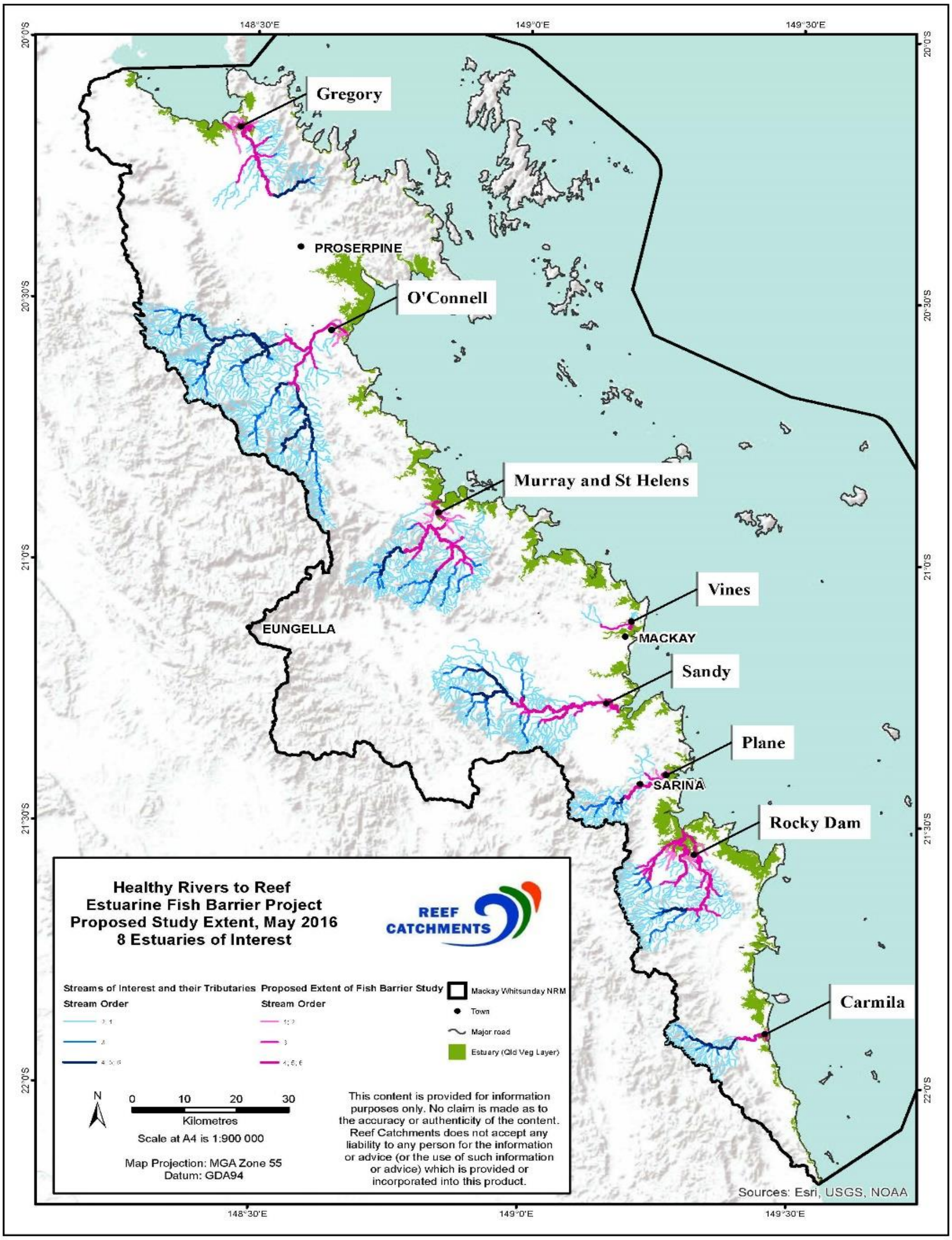


Figure 10. Extent of estuary assessment of fish barriers. Only pink/magenta waterways are included in the estuary barrier assessment; blue waterways are excluded, as they do not intersect the estuary layer, are not 'Major' or 'High' impact tributaries and/or are higher than 18.5m above DDL. Note: the major river near Mackay is the Pioneer River; however, it is not assessed for estuary condition and thus does not feature on this map.

2.3. Inshore and Offshore Marine Zones

The inshore and offshore marine environments, separated by the state jurisdiction boundary, are reported separately in the MWI Report Card. The inshore environment is further divided into four zones: Northern, Whitsunday, Central, and Southern inshore marine zones (Figure 1). Holbourne Island falls within the Offshore Zone however is included in the Northern Zone for both water quality and coral assessments as it includes conditions typical of inshore reefs. The Offshore marine zone extends from the state jurisdiction boundary to the eastern boundary of the GBR Marine Park (Figure 1). Assessment frequency of indicators for the inshore and offshore zones differ depending on the availability of data (Figure 11). Marine fish scores are currently in development for future reporting cycles, and offshore water quality will not be reported in the 2021 report card due to changes in the data availability (see section **Error! Reference source not found.**).

Litter scores are reported in inshore zones for the second time in the 2021 Report Card. These scores do not, however, contribute to the overall inshore marine grade as they are on a scale of 'very high pressure' to 'slight pressure', compared to 'very poor' to 'very good'. These results are therefore presented separate to the water quality, coral and seagrass scores (which contribute to the overall inshore zone grade).

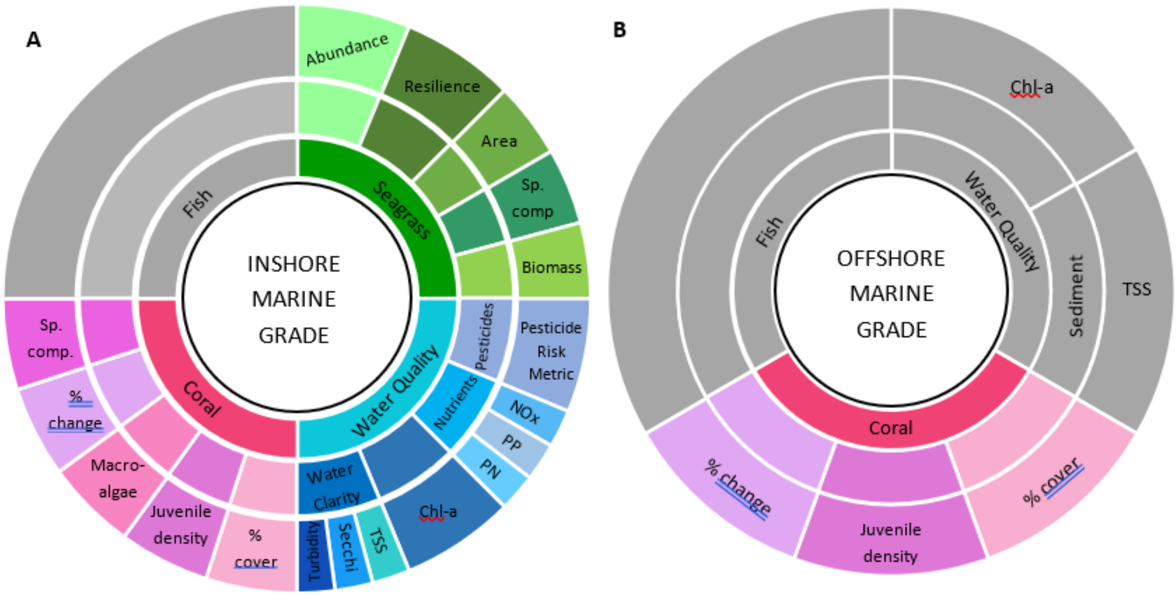


Figure 11. Indicators (outer ring), indicator categories (middle ring), and indices (inner ring) that contribute to overall inshore (A) and offshore (B) marine zone scores/grades. Where no indicator category is listed (e.g., within the coral index), the indicator does not fit into any category below the index level. Dark grey represents no data.

2.3.1. Water Quality Index

2.3.1.1. Inshore Water Quality

Water quality in the inshore marine environment was monitored using eight indicators across four indicator categories (Figure 11A). Data for these indicators in the Northern, Whitsunday, and Central Zones are sourced from three existing marine water quality monitoring programs (Appendix A):

1) The Inshore Marine Water Quality Monitoring program led by the Australian Institute of Marine Science (AIMS) as part of the GBR Marine Monitoring Program (MMP)
2) The North QLD Bulk Ports Corporation Ltd (NQBP) Abbot Point Ambient Marine Water Quality Monitoring Program, and

3) The NQBP Mackay and Hay Point Ambient Marine Water Quality Monitoring Program.

The MMP program aims to document ecosystem health in the GBR to feed into the management cycle.[13] The 2021 Report Card uses depth-weighted average (DWA) sample data from MMP rather than surface sample only as per previous years. Differences observed in these scores are likely due to stratification from different physical pressures between different water depths. DWA samples are commonly used to account for this variability within the water column and provide a better representation of what the substrate and associated sensitive receptors experience. (For back-calculations see Results Appendix D.1.3).

The NQBP programs were commissioned to establish a long-term understanding of the natural variability in key marine water quality characteristics for the region and to facilitate effective management of Port activities (Waltham et al., 2015).

Aligning closely with the data collected under the NQBP programs, water quality monitoring in the Southern Zone is part of the Southern Inshore Monitoring Program (SIP) (Appendix A). This program is Partnership-funded and highlights our commitment to improving our understanding of the region's waterways. The relevant program, number of samples taken, water type, and indicators measured by each monitoring program are summarised for each site and inshore reporting zone in Table 10.

It is worth noting that water clarity indicators are related but not completely comparable. The characteristics of suspended sediments can greatly influence turbidity measurements, where darker and finer grained sediment will result in much higher turbidity readings than lighter-coloured and coarser sediments. The former are considered the most damaging to seagrass and coral growth (Bainbridge et al., 2018; Storlazzi et al., 2015).

Pesticide condition was calculated using the PRM based on the monitored concentrations of up to 22 pesticides in passive sampler devices over the 2020–21 reporting year (Table 11). This method differs from pesticide condition in basins and estuaries which are based on multiple grab samples over the wet season (see Section **Error! Reference source not found.**). Passive samplers provide a s ingle time-integrated concentration for each sampler, representing the entire deployment time (typically four to eight weeks). Grab samples have the potential to identify acute, rapid, irregular peaks in pesticide concentration only if taken at the opportune time. As a result, only pesticide data collected by passive polar samplers were used to calculate the scores for the inshore marine zones (see Table 11).The 2021 Report Card will be the first year that NQBP programs have deployed passive samplers to collect pesticide data across the reporting period, and as such, the pesticide data are available for the Northern Zone and for an increased spatial representation in the Central Zone.

All water quality data was collected in accordance with the QLD Water Quality Monitoring and Sampling Manual (DES, 2018). The water type at each monitoring location is defined by the Environmental Protection (Water) Policy 2009 for Central QLD.

All sample sites are detailed in Table 10 and Figure 12. Details on sample sites, sampling methodology, and laboratory analysis can be found in the relevant reports for Abbot Point (Waltham et al., 2018), MMP (Grant et al., 2018), and Mackay and Hay Point (Waltham et al., 2015) water quality monitoring programs (also see Appendix A).

[13] https://www.gbrmpa.gov.au/our-work/our-programs-and-projects/marine-monitoring-program

Table 10. Summary of the water quality sampling conducted in each of the four inshore marine zones. Closed circles in green cells (●) represent data that are included in report card scores, and open circles in orange cells (o) show data that are collected at these sites, but no score is calculated due to the lack of relevant guideline values. Grey indicates no data. Note: AP = Abbot Point Ambient Water Quality Monitoring Program, MMP = Marine Monitoring Program, MHP = Mackay and Hay Point Ambient Water Quality Monitoring Program, SIP = Southern Inshore Monitoring Program, OC = open coastal, EC = enclosed coastal.

Inshore Zone	Site Name	Program	# Grab Samples	Water Type	Indicators Monitored by Sample Type							
					Grab						Passive Polar	Logger
					PN	PP	NO_x	Chl-*a*	TSS	Secchi	Pesticides	Turbidity
Northern	Euri Creek	AP	6^	OC	●	●		●	●	●	●	●
	Camp Island		6^	OC	●	●		●	●	●		●
	Holbourne Island		6^	OC	●	●		●	●	●		●
Whitsunday	Double Cone	MMP	5	OC	●	●	●	●	●	●		●
	Pine Island		5	OC	●	●	●	●	●	●		●
	Seaforth Island		5	OC	●	●	●	●	●	●		●
Central	Freshwater Point	NQBP	7	OC	●	●		●	●	●		●
	Round Top Island		7	OC	●	●		●	●	●		●
	Slade Island		7	OC	●	●		●	●	●	●	●
	Victor Island		7	OC	●	●		●	●	●		●
	Repulse Is. Dive Mooring	MMP	5	OC	●	●	●	●	●	●		●
	O'Connell River Mouth		5	EC	o	o	●	●	o	o		o
	Flat Top		NA	OC							●	
	Sandy Creek		NA	OC							●	
	Repulse Bay		NA	EC							●	
Southern	Aquila Island	SIP	7	OC	●	●	●	●	●	●	●	●
	Carmila 2		7	OC	●	●	●	●	●	●		
	Carmila 3		6~	OC	●	●	●	●	●	●		

~ 5 secchi samples
^4 secchi samples

Table 11. A record of chemicals included in the PRM that were sampled in each zone during the 2020–21 reporting cycle (●). All chemicals were sampled with passive polar samplers deployed from between four to eight weeks. Grey indicates no data. Light red ( ) indicates chemicals that are no longer sampled with the change from non-polar to polar passive samplers.

Name of Pesticide	Mode of Action	Pesticide Type	Zone			
			Northern	Central		Southern
				NQBP	MMP	
Chlorpyrifos	Acetylcholine esterase (AChE) inhibitor					
Fipronil	Gamma-aminobutyric acid (GABA) gated chloride channel blocker	Insecticide	●	●		
Imidacloprid	Nicotinic receptor agonist				●	●
Haloxyfop	Acetyl-coenzyme A carboxylase (ACCase) inhibitor		●	●	●	●
Imazapic	Group 1 Acetolactate synthase (ALS) inhibitor				●	●
Metsulfuron-methyl	Group 2 Acetolactate synthase (ALS) inhibitor				●	●
Pendimethalin	Microtubule synthesis inhibitor					
Metolachlor	Inhib of VLCFA	Non-PSII herbicides	●	●	●	●
2,4-D	Phenoxy-carboxylic acid auxin		●	●	●	●
MCPA	Phenoxy-carboxylic acid auxin		●	●	●	●
Fluroxypyr	Pyridine-carboxylic acid auxin				●	●
Triclopyr	Pyridine-carboxylic acid auxin		●	●		
Isoxaflutole	4-hydroxyphenylpyruvate dioxygenase (4-HPPD) inhibitor					
Ametryn			●	●	●	●
Atrazine			●	●	●	●
Prometryn			●	●	●	●
Terbuthylazine			●	●	●	●
Tebuthiuron	PSII inhibitors	PSII herbicides	●	●	●	
Simazine			●	●	●	●
Diuron			●	●	●	●
Hexazinone			●	●	●	●
Metribuzin					●	●

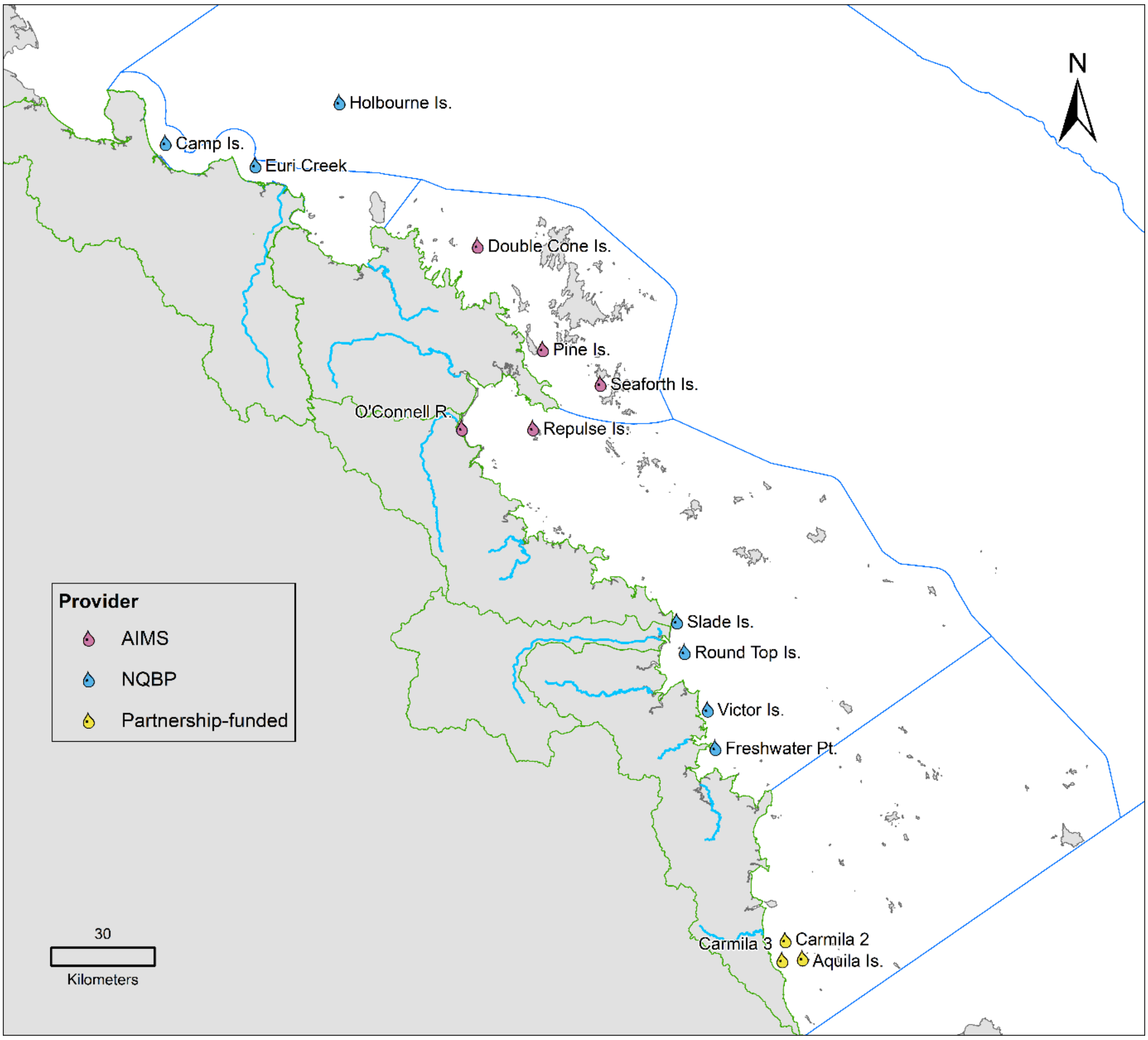


Figure 12. Water quality monitoring sites for the inshore marine zones. Sites in each zone are shown according to data provider. AIMS: Australian Institute of Marine Science; NQBP: Northern Queensland Bulk Ports.

2.3.1.2. Offshore Water Quality

The Offshore Zone extends from the State jurisdictional boundary to the eastern boundary of the GBR Marine Park; however, mid-shelf waters within this zone are excluded from condition assessments. In previous years, offshore water quality data was extracted from the BoM marine water quality dashboard (Appendix A). However, as the dashboard was recently decommissioned, alternative data sources are being investigated to address this gap. Options under consideration include the CSIRO Sentinel-3 remote sensing program and CSIRO eReefs marine modelling system. Regional Report Card technical officers are working with the TWG to resolve this data gap for the 2021–22 reporting cycle.

2.3.2. Coral Index

In the Whitsunday Zone, coral health data are drawn from the MMP, the Long-Term Monitoring Program (LTMP) (both also used by the GBR Report Card), and the citizen science program Reef Check Australia (RCA). In the Northern and Central Zones, data are collected by the NQBP coral monitoring programs, which aligns with indicators used in the MMP and LTMP (Appendix A). Indicators used in inshore zones include coral cover, composition (in Whitsunday Zone only), change, macroalgae, and juvenile density. This Report Card marks the third year that coral condition scores are reported for the Southern Zone, with four years of baseline data previously collected through the Partnership-funded SIP. Percent change and species composition indicators both require a longer period of baseline data before they can be reported in the Southern Zone. As a result, only coral cover, macroalgae, and juvenile density were used to generate coral scores in 2021. Coral condition scores for the Offshore Zone use LTMP and RCA coral data and report on coral cover, percent change, and juvenile density.

2.3.2.1. Survey Methods

Only data from the most recent survey is used to calculate scores. The MMP, LTMP, NQBP, and the SIP employ the photo point intercept method to record percentage cover estimates of the benthic communities (Table 12). In contrast, Reef Check Australia (RCA) use the line intercept technique, which records the intercept lengths for all colonies of a species or benthic group along each transect. These are totalled and converted to a percentage cover measurement (Table 12).

Table 12. Survey methods for relevant coral monitoring programs reporting in the MWI Region.

Zone	Program	Survey Method	No. of Reefs and Sites	Depths Sampled per Site	Transects per Survey
Northern	NQBP (Abbot Point)	Photo point intercept transect	2 reefs (4 sites per reef)	1 survey at either 2 m or 5 m depth*	5 x 20 m
		Belt transect			
Whitsunday	MMP	Photo point intercept transect	7 reefs (2 sites per reef)	1 survey at both 2 m and 5 m depths	5 x 20 m
		Belt transect			
	LTMP	Photo point intercept transect	3 reefs (2 sites per reef)	1 survey at 5 m depth	5 x 50 m
		Belt transect			5 x 5 m
	RCA	Line intercept transect	6 reefs (1 site per reef)**	1–2 surveys at various depths	5 x 20 m
Central	NQBP (Mackay & Hay Point)	Photo point intercept transect	3 reefs (4 sites per reef)***	1 survey from 0.5 m to 7 m depth depending on reef structure	4 x 20 m
		Belt transect			
Southern	SIP	Photo point intercept transect	5 reefs (2 sites per reef)^	1 survey at both 2 m and 5 m depths^^	5 x 20 m
		Belt transect			
Offshore	LTMP	Photo point intercept transect	9 reefs (3 sites per reef)	1 survey at 6–9 m depth	5 x 50 m
		Belt transect			5 x 5 m
	RCA	Line intercept transect	1 reef (2 sites per reef)	1 survey at 5 m depth	5 x 20 m

*Due to the reef structure, Camp Island is surveyed at a single depth of ~2 m and Holbourne Island at 5 m.
**The reef at Peter's Bay is monitored at two sites.
***Two sites at each reef were decommissioned in 2021
^Connor Island, previously included in 2019 and 2020, was decommissioned in 2021 due to difficulties surveying in low visibility
^^Due to the reef structure, Temple and Aquila Islands are surveyed at a single depth of 1 m only.

All programs, excluding RCA, record juvenile abundance within narrow belt transects from which the density of juvenile corals can be estimated (Table 12). These transects are 34 cm wide for all surveys, except those under the NQBP programs, which are 30 cm. Juvenile coral surveys aim to provide an estimate of the number of hard coral colonies that are successfully recruiting and surviving early post-settlement pressures. Importantly, this method aims to record only those small juvenile colonies (<5cm), which result from the settlement and subsequent survival and growth of coral larvae. It does not include small coral colonies that result from fragmentation or partial mortality of larger colonies. Both this method and the photo point intercept method closely follow the AIMS Standard operational procedure number 10 of the LTMP (Jonker et al., 2008). Despite some differences in survey methodology and transect dimensions, comparable data was collected across the various monitoring programs (Table 12). For further detail on the MMP and LTMP methods, refer to Thompson et. al 2021 (Thompson et al., 2021), and the AIMS Reef Monitoring website standard operating procedures[14], respectively. . NQBP monitoring closely follow AIMS methods and can be found online[15], as can the RCA methods[16].

Northern Zone

Coral data for the Northern Zone are collected under the NQBP Abbot Point Coral Monitoring Program from reefs around two island locations (Chartrand et al., 2021a) (Table 13; Figure 13). At each island (reef), four sites are surveyed (Table 12). For each site at Holbourne Island, surveys were conducted at 5 m below the lowest astronomical tide (LAT), while at Camp Island, sampling could only be conducted at 2 m depths due to reef structure (Chartrand et al., 2021a) (Table 12).

Whitsunday Zone

Photo point intercept or belt transect data were collected from MMP and RCA sites in the Whitsunday Zone (Table 12). The MMP stratify survey efforts at 2 m and 5 m, while LTMP sample at 5 m depth (Table 12). RCA surveys are conducted at a range of depths to accommodate for the location of coral communities at the monitored sites.

The MMP surveys annually, with only the most recent survey results included in the score (Table 13, Table 14). Values of each indicator from the most recent surveys are used to calculate the score each year. All data for the 2021 Report Card represent surveys undertaken in 2021.

Central Zone

Coral community health data for the Central Zone was collected from three island (reef) locations under the NQBP Mackay and Hay Point Coral Monitoring Program (Chartrand et al., 2021b) (Table 13; **Error! Reference source not found.**). At each island, four sites are surveyed. At each site, the cover of benthic reef organisms was assessed along transects between 0.5 m and 0.7 m below LAT (Table 12).

Southern Zone

Inshore coral data for the SIP was collected from five island locations (Table 13; **Error! Reference s ource not found.**). Transects were replicated at both 2 m and 5 m depths below LAT at Pine Peak Island, Pine Islets, and Henderson Island. At Temple Island and Aquila Island, however, the reef slope transitioned to sand at 1.0 - 1.5 m below LAT, and therefore, transects were set at 1 m below LAT only (Davidson et al., 2021) (Table 12).

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[14] https://www.aims.gov.au/docs/research/monitoring/reef/sops.html
[15] https://nqbp.com.au/sustainability/coral-monitoring
[16] https://www.reefcheckaustralia.org/methods

Table 13. Coral monitoring for inshore marine zones in the 2020 Report Card, displaying survey frequency (●) for each site and program. The MMP program normally surveys reefs across a two-year period; however, in response to thermal stress and acute disturbance from TC Debbie, some reefs were sampled out of schedule (+). Note, although surveys were undertaken, RCA data was not included in the MWI Report Card prior to 2019–20.

Zone	Program	Reef	Most Recent Survey	Year Updated				
				2020–21	2019–20	2018–19	2017–18	2016–17
Northern	NQBP	Camp Is.	April 2021	●	●	●	●	●
		Holbourne Is.		●	●	●	●	●
Whitsunday	LTMP	Langford-Bird Reef	February 2021	●		●		●
		Hayman Is. Reef		●		●		●
		Border Is. Reef (No.1)		●		●		●
	MMP	Double Cone Is.	June 2021	●	●	●	●	+
		Hook Is.		●	●		●	
		Daydream Is.		●	●		●	+
		Shute Harbour		●	●		●	+
		Dent Is.		●	+	●		●
		Pine Is.		●	+	●	+	●
		Seaforth Is.		●	+	●		●
	RCA	Blue Pearl Bay	June 2021	●	●	●		
		Butterfly Bay		●	●		●	
		Luncheon Bay		●	●			
		Lovers Cove		●	●		●	
		Mermaids Cove		●	●		●	
		Peter's Bay		●	●			
Central	NQBP	Keswick Is.*	April 2021		●	●	●	●
		Round Top Is.		●	●	●	●	●
		Slade Islet		●	●	●	●	●
		Victor Islet		●	●	●	●	●
Southern	SIP	Pine Peak	June 2021	●	●	●		
		Pine Islets		●	●	●		
		Henderson Is.		●	●	●	●	
		Temple Is.		●	●	●		
		Aquila Is.		●	●	●		

*Keswick Island site has been decommissioned as it is outside of NQBP jurisdiction

Offshore Zone

Offshore Zone coral data was collected from 16 sites surveyed by the LTMP and Hardy Reef surveyed by RCA (**Error! Reference source not found.**). Reefs in the LTMP are surveyed in alternate years (Table 14). Data for LTMP sites result from surveys conducted in February 2021 or carried forward data from the most recent surveys available (Table 14).

The intensive survey sites are located in the first stretch of continuous reef encountered when following the perimeter from the back-reef zone towards the front-reef in a clockwise direction, usually on the north-east flank of the reef. Where possible, sample sites were a minimum of 250 m apart, and five 50 m transects were completed at each site (Table 12). Transects follow depth contours on the reef slope parallel to the reef crest (at approximately 6–9 m depth). Coral community change with depth is most pronounced in inshore areas where the turbidity of waters causes a rapid attenuation of light, and as such, only one depth was sampled at each site.

Technically, Penrith Island falls within the Central Zone for the MWI Report Card, but the Penrith Island reef is characterised as 'mid-shelf' (**Error! Reference source not found.**) and as such is i ncluded with the offshore reefs for the Report Card. All coral reef sites included for assessment were selected based on expert advice and to meet the purposes of each specific coral monitoring program.

Table 14. Coral monitoring for Offshore Zone in the 2021 Report Card, displaying survey frequency (●) for each site and program. The LTMP surveys in alternate years, and scores for each reporting year for this program are calculated based on the most recent data for each reef. Note, although surveys were undertaken, RCA data were not included in the MWI Report Card prior to 2019–20.

Zone	Program	Reef	Most Recent Survey	Year Updated				
				2020–21	2019–20	2018–19	2017–18	2016–17
Offshore	LTMP	Slate Reef	February 2021	●		●		●
		Hyde Reef		●		●		●
		Rebe Reef		●		●		●
		19-131S		●		●		●
		19-138S		●		●		●
		20-104S		●				●
		Pompey Reef (No. 1)	Sept 2019		●		●	
		Pompey Reef (No. 2)			●		●	
		21-060S			●		●	
		21-591S			●		●	
		20-353S			●		●	
		21-064S			●		●	
		Tern Reef (20-309)			●		●	
		Penrith Reef			●		●	
		20-348S	March 2018		●		●	
		21-062S			●		●	
	RCA	Hardy Reef	March 2021	●	●		●	●

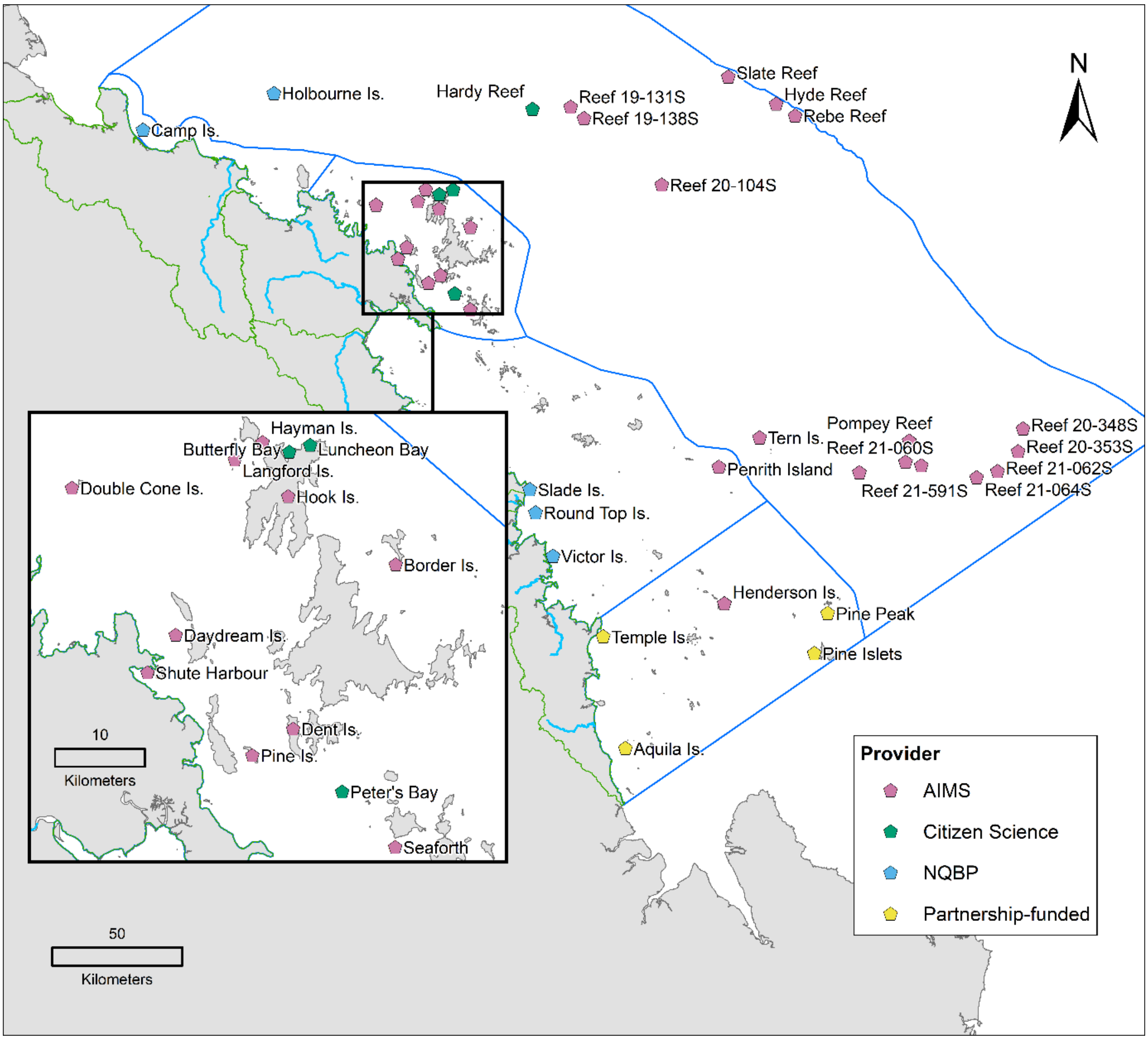


Figure 13. Coral monitoring sites for the inshore and offshore zones. Sites in each zone are shown according to data provider.

2.3.3. Seagrass Index

The seagrass indicators used in the MWI Report Card are based on those used in two existing monitoring programs (Figure 14, Table 15, Appendix A). The MMP, used in the GBR Report Card, provides data in the Whitsunday and Central Zones and includes data from the citizen science monitoring program Seagrass Watch (McKenzie et al., 2003). The QLD Ports Seagrass Monitoring Program (QPSMP) provides data in the Northern and Central Zones. A Partnership-funded seagrass monitoring program was established in the Southern Zone in 2017 and follows the methods in the QPSMP. Seagrass scores in the Southern Zone will be reported for the first time in 2021, as we now have the five years of monitoring needed to establish a baseline condition.

2.3.3.1. 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 the context of disturbance events (McKenzie & Collier, 2015). Historically, this program monitored the percentage cover of seagrass (McKenzie, 2009), tissue nutrient status (carbon:nitrogen ratio) (McKenzie & Collier, 2015), and reproductive effort (production of spathes, flowers, and fruits per unit area) (McKenzie & Collier, 2015) (Table 15). From 2021, both nutrient status and reproductive effort have been replaced with a multivariate resilience metric, measuring the capacity of seagrass to cope with disturbances (Collier et al., 2021). The resilience metric better 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 recover following loss by regeneration from seed and through plant growth.

Monitoring occurred during the late dry (growing) season and late wet season to obtain information on the seagrass communities' status pre- and post-wet season. The meadows monitored within the MMP were selected by GBRMPA using expert advice (McKenzie, 2009; McKenzie et al., 2010; McKenzie & Collier, 2015). This was performed using mapping surveys to select representative meadows, which had a greater extent of seagrass. They were also generally the dominant community type and within GBR average abundances. Meadows in both lower littoral (rarely exposed to air) and sub littoral (permanently covered with water) zones were sampled. Two sites (transect blocks) were selected at each location to account for spatial heterogeneity. Additionally, the minimum detectable difference between sites had to be below 20%. Where both transect blocks occur within the same meadow and at the same depth, they are treated as replicates, and the two scores are averaged to provide a location score.

Seagrass Watch citizen science surveys contribute data to the Whitsunday, Central, and Northern Zones (Table 15 and Figure 14).

2.3.3.2. Queensland Ports Seagrass Monitoring Program (QPSMP)

The objective of the QPSMP is to report on the condition of seagrass in the highest risk areas of QLD and use this information to assist in the planning and management of anthropogenic activities (A. Carter et al., 2019). The QPSMP monitors and reports on seagrass condition for entire meadows (Figure 14), and sampling occurs annually during the peak of the seagrass growing season in late spring/early summer at the end of the dry season. Meadow selection is based on the representation of the range of meadow types found in each location. The indicators surveyed by this program are mean above-ground biomass, meadow area, and species composition (York & Rasheed, 2019) (Table 15).

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 (A. Carter et al., 2015) and was implemented 2014. The methods for setting baseline conditions, score calculation, and indicator assessment (Bryant et al., 2014; A. Carter et al., 2015) received independent analysis and review through the GHHP Independent Science Panel (ISP), and the wider program's results are published in peer-reviewed journals (A. Carter et al., 2016a). For further information on site selection and methods in the MWI Region, refer to previous QPSMP reports for Abbot Point (McKenna et al., 2021) and Mackay and Hay Point (York & Rasheed, 2021).

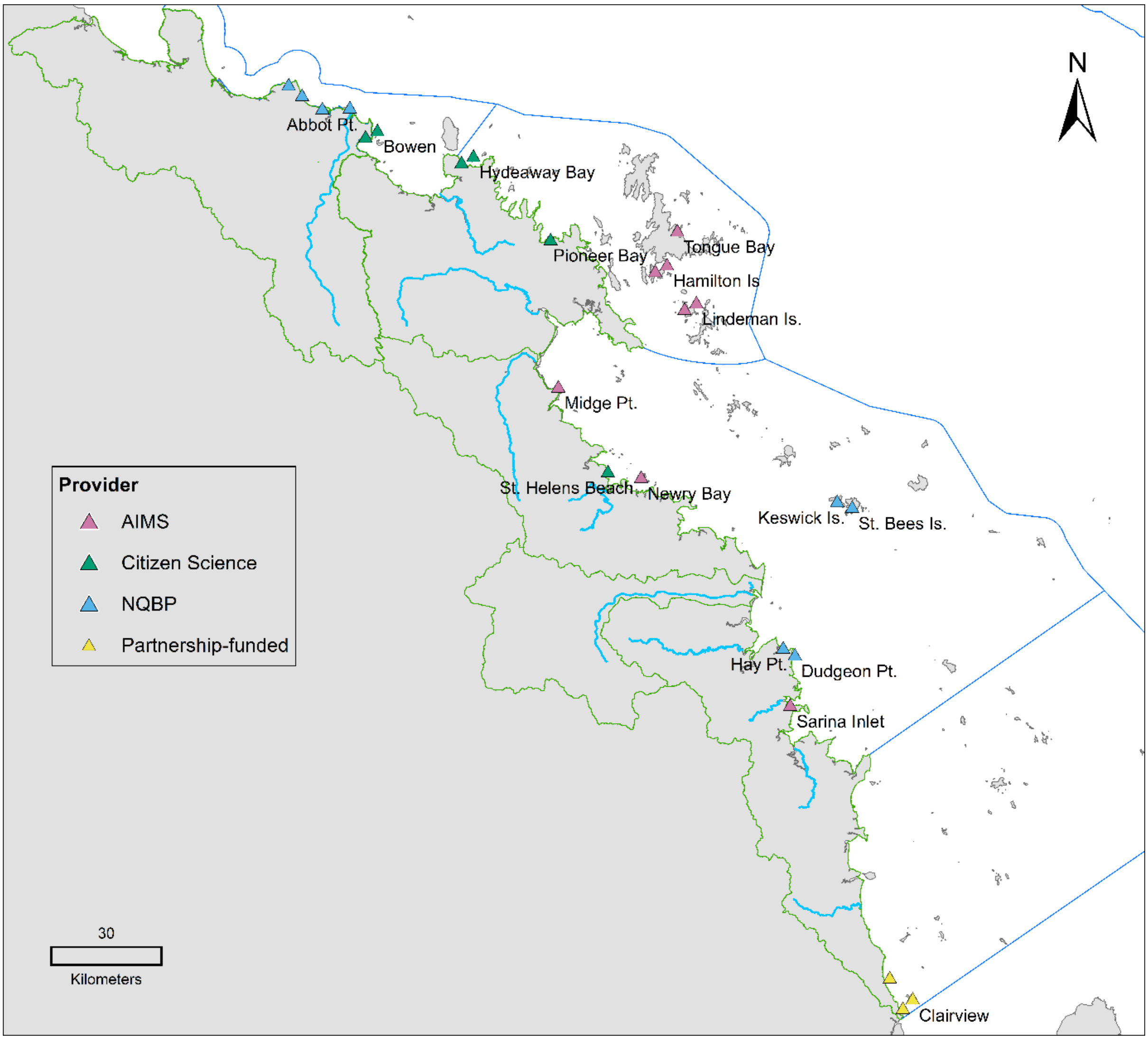


Figure 14. Seagrass monitoring sites for the inshore zones. Colours represent each data provider with MMP data from AIMS shown as pink, NQBP as blue, Seagrass Watch citizen science data as green, and Partnership-funded data from the SIP program as yellow. Seagrass is not currently reported on in the Offshore Zone.

Table 15. Seagrass monitoring programs and indicators in the MWI 2021 Report Card. A circle marks an indicator that is measured at that given site and green background indicates data that is used in the report card.

Zone	Habitat	Depth	Location	Site	Program Indicators				
					MMP		NQBP/SIP		
					Abundance	Resilience	Biomass	Area	Species Composition
Northern	Coastal	Intertidal	Bowen	BW1-3*	●				
		Inshore	Abbot Point	API3			●	●	●
				API5			●	●	●
				API9			●	●	●
		Subtidal		APD1-4			●	●	●
Whitsunday	Reef	Intertidal	Hydeaway Bay	HB1-2*	●				
			Hamilton Is.	HM1	●	●			
				HM2	●	●			
			Lindeman Is.	LN3	●	●			
		Subtidal	Lindeman Is.	LN1-2	●	●			
			Tongue Bay	TO1-2^	●				
	Coastal	Intertidal	Pioneer Bay	PI2-3*	●				
Central	Coastal	Intertidal	Midge Point	MP2-3	●	●			
			St. Helens Beach	SH1*#	●				
		Subtidal	Newry Bay	NB1-2^	●				
			St. Bees Is.	SB10			●	●	●
			Keswick Is.	KW14			●	●	●
			Hay Point	HPD1			●	●	●
		Intertidal /Subtidal	Dudgeon Point	DP1			●	●	●
	Estuarine	Intertidal	Sarina Inlet	SI1-2	●	●			
Southern	Coastal	Intertidal	Clairview	CV1-2*	●				
				CVH2			●	●	●
				CVH6			●	●	●
				CVH7			●	●	●

*Seagrass Watch
^QLD Parks and Wildlife Service (QPWS) drop-camera
#Not used in GBR wide MMP

2.3.4. Litter

Litter scores will be included in the report card for the second time in 2021. This indicator is composed of three litter items (plastic bags, single-use items, and cans/bottles) that are combined into a single 'generic item' count, that is used to generate scores per site for each year.

The 'generic item' count was compared against a baseline derived from four years of data from 1st July 2014 until 30th June 2018 (before management restrictions were imposed in QLD). Between 1st July 2014 and 30th June 2018, clean-ups occurred at nine inshore sites in the Northern Zone, four urban and 44 inshore sites in the Whitsunday Zone, six urban and 19 inshore sites in the Central Zone, and two inshore sites in the Southern Zone (Appendix B2: Table B3). The frequency that each site was cleaned during this four-year baseline period varied.

Data was sourced from the Australian Marine Debris Initiative (AMDI) Database (Appendix A), collected by volunteers from across Australia. Contributors included Tangaroa Blue Foundation and ReefClean events, in addition to individuals, community groups, NGOs, and government activities. Technical expertise for the calculation of scores and grades was provided to this project by William Venables and Tegan Whitehead (model development) and by Jordan Gacutan from the University of New South Wales (UNSW) (data filtering and processing). For further detail on the filtering and processing methods, see Appendix B – Litter Metric (7.1.1).

As this metric is based on a dataset collected by volunteers, there is significant variation in the duration of events and the frequency of sampling across zones and years within the reporting region. Scores are therefore presented at the site level, rather than aggregated into a zone-level score. This reduces bias due to sampling effort and allows for better representation and comparison of how the amount of litter has changed at sites across report cards.

The following method is described as per that designed for the Dry Tropics Partnership for Healthy Waters Report Card (Whitehead, 2020) with peer-reviewed data processing (Gacutan et al., 2022).

Debris surveys were recorded at 52 sites in the AMDI Database in 2020–21 across inshore and urban zones in the MWI Region (Figure 15). These clean-ups included standardised ReefClean monitoring, community clean-ups organised by ReefClean, and community organised events.

Standardised 'ReefClean' Sampling

The ReefClean project, led by the Tangaroa Blue Foundation and several partner organisations, began in early 2019 with funding from the Australian Government's Reef Trust. Volunteers collected litter in a standard method along measured transects and for a designated length of time, enabling comparisons across years. Standardised clean-ups began in mid-2018 and will continue quarterly until June 2023. All debris was sorted into 1 of 127 categories and recorded in the AMDI Database. ReefClean data are incorporated into the litter metric where available. For comparison with non-standard clean-ups, counts of items found within and outside transects were combined.

Non-standardised Clean-ups

Non-standardised clean-ups were conducted across the MWI Region, varying in location and frequency across years. Generally, easy-to-access and 'volunteer friendly' sites (such as popular beaches) are cleaned more frequently than other beaches. Non-standardised clean-ups have no defined boundary, and while the number of participants and the total duration of the clean-up event is recorded, individual effort is not (i.e., unequal effort of individuals across the duration of the event). All debris collected was sorted into the AMDI categories and entered in the database.

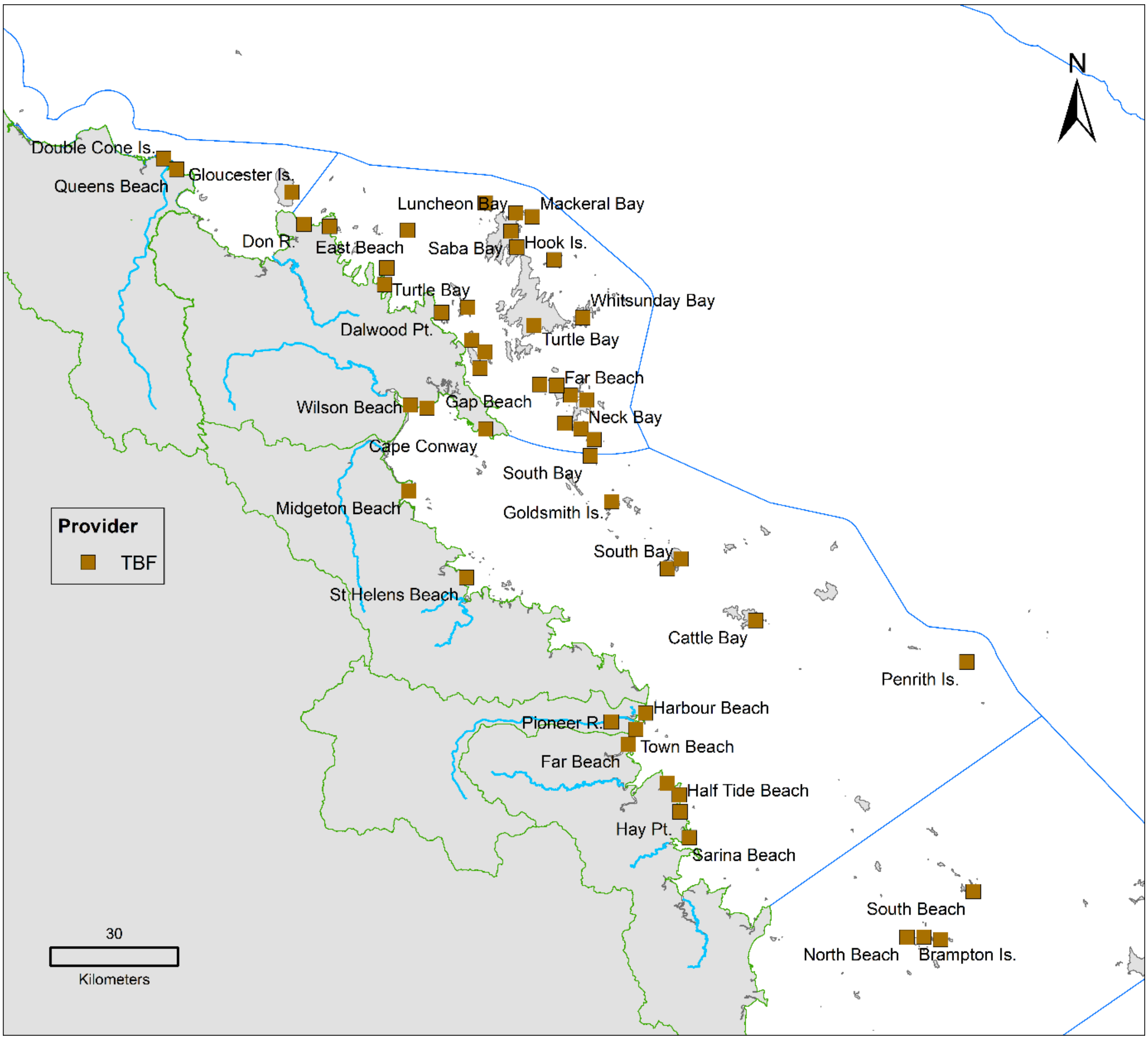


Figure 15. Urban and inshore litter survey sites for the MWI Region for 2020–21. Sites are not rolled into zone-level scores.

2.3.5. Fish Index

Assessments of fish community health were deemed important across all aquatic environments of the MWI Report Card. Potential marine fish indicators and assessment methods are still being explored and therefore are not included in the 2021 Report Card.

2.4. Human Dimensions

Stewardship, defined as "the responsible and sustainable use, and protection of water resources, waterways and catchments to enhance the social, cultural, environmental and economic values of the region", is represented as the level of effective environmental management practice implemented across the region. Actions that local landholders and organisations implement to benefit ecosystems (such as improved land management practices) have a direct link to water quality in the region. Measurements of these activities can be used to demonstrate how on-ground responses undertaken by stakeholders in the region can impact waterway health. Agricultural stewardship is intended to be included in the report card, following a review of the Management Practice Adoption (MPA) targets. Both agricultural and non-agricultural management activities are highlighted in the Partnership's stewardship report, which has been released since 2018.

2.4.1. Agricultural Stewardship

The MWI Report Card aligns its agricultural stewardship reporting with the GBR Report Card, which is reported through the Paddock to Reef (P2R) program[17]. Through P2R, the QLD State and Federal Governments direct investment towards the adoption of best practice farm management systems, with the aim of achieving the Reef 2050 Water Quality Improvement Plan's targets and improving the quality of water flowing into the GBR[18]. Farm management practice benchmarks are reviewed every five years, and annual change is based on data reported each year. The 2016–17 year is the current benchmark from which improvements are measured and aligns to the GBR Report Card. P2R program management practice and benchmarks were developed for each agricultural industry sector[16] and in each of the five major river basins within the region.

Available environmental management practice frameworks are used to provide the basis for stewardship reporting. In agriculture, frameworks that have been developed, reviewed, and endorsed by industry are currently available for grazing, sugarcane, and horticulture. These are based on P2R reporting that uses "Water Quality Risk Frameworks" (previously "ABCD Frameworks")[16].

As mentioned above, due to a review of Agricultural Management Practice (AMP) targets, agricultural stewardship results were not available for the MWI Region prior to the release of this report. It is anticipated that results will be updated again in the 2022 Report Card.

2.4.2. Urban Water Stewardship Framework

The Urban Water Stewardship Framework (UWSF) is a tool for assessing and reporting on the level of practice applied by local government and industry to manage sediment and nutrient loads. Several activities are measured, including erosion during the construction phase (categorised as developing urban), stormwater run-off during the post-construction phase (established urban), and sewage wastewater treatment plant releases (point source). These activities contribute to sediment and nutrient loads entering the Great Barrier Reef (GBR).

To assess this indicator, data were collected and analysed according to methods outlined in the UWSF Implementation Manual version 2.0 (DES, 2020). Score and rating calculations were generated using OGBR Excel-based UWSF scoring spreadsheet (version 8.0).

As per the framework methodology, the primary mode of data collection was via a facilitated workshop and consensus opinion rating process, with direct reference to primary information sources for activity rating done where possible. In late November and early December 2020, separate workshops were held for each of the three participating local government areas. The workshops were attended by a diverse range of personnel from within each council, including land-use planners, compliance, catchment management, development approvals, civil engineers, asset managers, and wastewater treatment plant (WWTP) operators. Due to the impacts of COVID-19, the workshops were held online and were facilitated by staff from Alluvium Consulting. Notably, due to the nature of natural resource management (NRM) versus Local Government Area (LGA) boundaries, grades resulting from the UWSF means that the MWI Report Card represents different area extents than that reported for other indicators (e.g., the Isaac LGA is shared by both Fitzroy and MWI Report Cards).

There were three workshops undertaken, split into three reporting components (Figure 16):

[17] https://www.reefplan.qld.gov.au/tracking-progress/reef-report-card/2017-2018
[18] https://www.reefplan.qld.gov.au/tracking-progress/paddock-to-reef/management-practices

1. Activities that may contribute to diffuse pollution associated with **Developing Urban** areas.
2. Activities that may contribute to diffuse pollution associated with **Established Urban** areas.
3. Activities that may contribute to **Point Source** pollution (associated with sewage treatment and management).

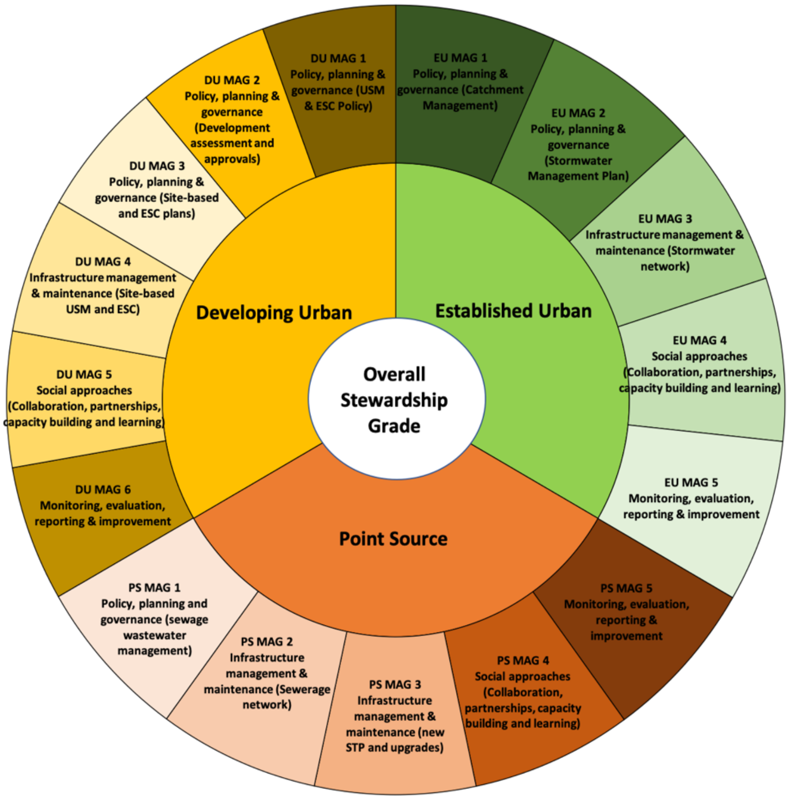


Figure 16. Indicators (outer ring), indicator categories (middle ring), and overall index grade (inner ring) that contribute to the overall UWSF score. The indicator codes are as follows: PS = Point Source, DU = Developing Urban, EU = Established Urban.

A total of 66 activities, linked to the Developing Urban, Established Urban, and Point Source framework components, were assessed at each workshop via online polling and a consensus-based rating method (Figure 17). Separate assessment sessions were held for each framework component to allow focussed discussions among the relevant experts and to reduce local government time and resources for participating in the framework assessment process.

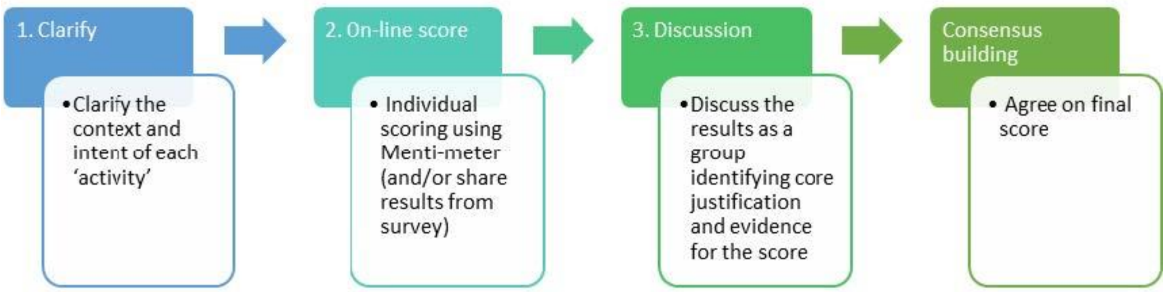


Figure 17. Process diagram for consensus-building in MWI UWSF workshops.

Following the workshops, report card-level results were derived by grouping activity questions into the following framework components:

- **Policy, planning, and governance** (relates to policy setting, planning document, and procedure document content)
- **Infrastructure management and maintenance** (relates to on-ground management activities)
- **Social approaches** (relates to capacity, training, collaboration, and research and development)
- **MERI** (monitoring, evaluation, reporting, and improvement; relates to monitoring and evaluation and how information is used to improve aspects of the above three elements)

Scores for these components (referred to as Management Activity Groups, or MAGs) were derived based on activity responses for each council, which were subsequently used to calculate an overall 'Urban Water Stewardship' grade for each LGA. For reporting purposes, these were averaged across councils and reported as a single UWSF grade for the MWI Region in the 2021 Stewardship Report. The UWSF indicator is anticipated to be updated every two years, with future results published through the HR2RP 2023 Stewardship Report and/or the 2023 Waterway Health Report Card.

2.4.3. Indigenous Cultural Heritage

Indigenous Cultural Heritage assessments are a collaborative set of indicators, led by the MWI Traditional Owner Reference Group (TORG) with support from Reef Catchments, HR2RP, and archaeological consultants. The TORG include representatives from Yuwibara, Koinjmal/Koinmerburra, Barada/Widi, and Ngaro/Gia/Juru Traditional Owners of the Mackay-Whitsunday-Isaac region. The goals of these assessments include providing a means of monitoring selected sites of cultural importance in the MWI Region and highlighting recommended management response actions where appropriate to maintain or improve site health.

Site selection

The 2021 Report Card contains the third update to the MWI Indigenous Cultural Heritage assessments and indicators. Previous assessments were included in the 2015 and 2018 report cards. The geographical region established for cultural heritage assessments surveys is divided into five zones, namely:

- Zone 1. St Helens Beach;
- Zone 2. The Whitsundays (Hook Island, Whitsunday Island and South Molle Island);
- Zone 3. Cape Hillsborough, incorporating Finlayson Point and Haliday Bay;
- Zone 4. Cape Palmerston; and
- Zone 5. The Mackay region.

Sites are prioritised in each assessment based on member recommendation and logistical factors as guided by the TORG. As such, not all sites and regions are visited in each assessment (Table 16).

Table 16. Zones assessed during the MWI Indigenous Cultural Heritage Assessments. Green shading indicates visitation during the assessment, while dotted shading indicates that the site was not visited.

#	Zone Name	2014–15	2017–18	2020–21
1	St. Helens			
2	Islands of the Whitsundays			
3	Cape Hillsborough			
4	Cape Palmerston			
5	Proserpine-Airlie Beach			
6	Lake Elphinstone/Mount Britton			
7	St. Lawrence Zone			

3. Development of Condition Scoring Methods

Ordinal categories are used to describe scores for the condition of indicators, indicator categories, indices, and the overall basin/estuary/zone grade. This follows a five-point grading system: 'very good' (A), 'good' (B), 'moderate' (C), 'poor' (D), and 'very poor' (E).

Numerical scores are aggregated (rolled up by calculating an average) from the indicator level to an overall score for an individual reporting zone in an environment as per Figure 2 (i.e., indicators > indicator categories > index > overall zone score).

The minimum information required to generate scores is as follows:

- ≥ 50% of measured indicators to generate the indicator category score (where relevant), and
- ≥ 60% of indicator categories to generate an index score.
- Overall scores for reporting zones are presented in the Report Card, even if not all indicator categories are available. However, the coaster visualises only components that contribute to the overall grade.

All indicators have specific scoring ranges and bandwidths, described in the following sections, which correspond to the five-point system. Results for indicators that have divergent scoring ranges and bandwidths must be translated into a common scoring range before aggregating. The common scoring range used for reporting is based on that used by the GBR Report Card (Table 17). Where required, indicator scores were standardised into the GBR scoring range by linear interpolation (scaling) within bandwidths. In the following sections, individual indicator scoring and associated formulas for scaling are presented. Once standardised, relevant scores are averaged to aggregate into the higher category.

For presentation purposes in the technical documents and online, scores are shown as integers. The exception to this rule is for coral and seagrass scores, which are presented as rounded scores to ensure alignment with the MMP and QPSMP. Importantly, all significant figures are retained when creating overall scores at each level of aggregation.

Table 17. Overall scoring range, associated grades, and colour codes.

Scoring Range	Condition Grade and Colour Code
81 to 100	Very good
61 to <81	Good
41 to <61	Moderate
21 to <41	Poor
0 to <21	Very poor

3.1. Freshwater Basins and Estuaries

Indicators in freshwater basins and estuaries have closely aligned approaches to determine their condition. The following section describes indicator scoring approaches and associated formulas for indicators in both freshwater basins and estuaries, as condition assessments in these habitats are closely aligned.

3.1.1. Water Quality Index

3.1.1.1. Nutrients, Sediments, and Phys–chem

To calculate a condition score for nutrients, sediments and phys–chem indicators, annual median concentrations of TSS, DIN, FRP, DO, and/or turbidity are compared to local guideline values. Annual median concentrations are calculated from monthly samples, where a monthly median concentration is calculated when multiple samples were taken within the same month[19].

Only annual medians that meet or are better than the guideline value achieve a 'good' or a 'very good' score (

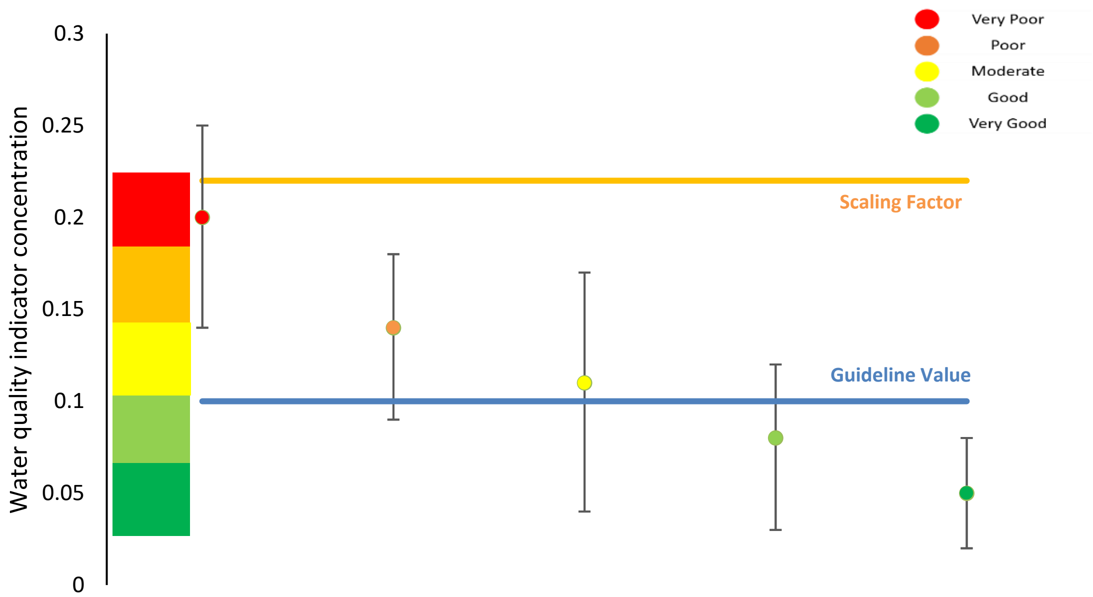


Figure 18). Medians that do not meet the guidelines achieve a 'moderate', 'poor', or 'very poor' grade, depending on where the median falls between the guideline value and a scaling factor (SF). This approach is very similar to the MMP system used in the marine inshore waters, where the cut-off between 'good' and 'moderate' grades is where the indicator's annual median concentration (or mean) is equal to or better than the guideline value.

The approach to calculating a condition score (from 1 to 100) and translating this to the report card five-point grading is:

1. If the measured concentration of an indicator is less than the limit of reporting (LOR), then use a value of 0.5 × LOR,
2. Calculate monthly median concentrations (where relevant),
3. Calculate annual median from monthly medians (where relevant),
4. Compare annual median to the relevant local guideline value,
5. Calculate condition score (0–100) following rules and formulas in Table 18 and Table 19, and
6. Aggregate indicator scores into indicator category scores (where relevant) and the water quality index (following decision rules for minimum information).

[19] Multiple samples are taken during rainfall events at GBRCLMP sites. Using a monthly median removes bias towards event concentrations.

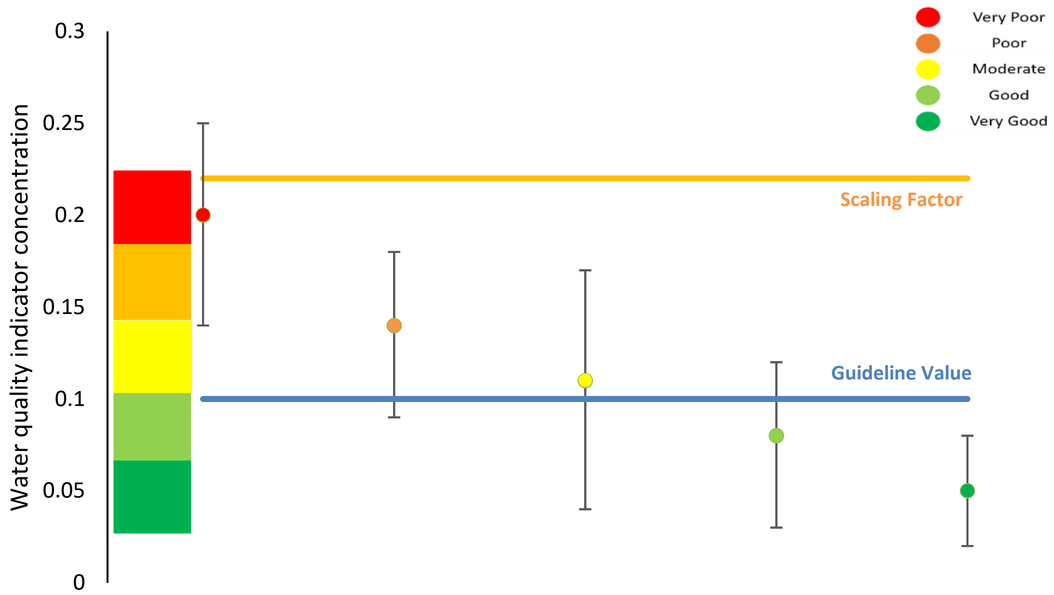


Figure 18. An example of how water quality grades are assigned. Where the middle point represents the annual median, the top whisker—the 80th percentile, and the bottom whisker—the 20th percentile of the data. Only when the median meets or is better than the guideline (in this case, meeting the guideline means the value must be at or 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.

Table 18. Rules, formulas, and scoring ranges for associated grades for TSS, DIN, FRP, chl-*a*, Turbidity, and DO (when comparing to the upper guideline value) in freshwater basins and estuaries of the MWI Report Card.

Rule	Formula	Scoring Range	Grade
Median meets GV and ≥80% of data meets GV	Assigned 90[20]	81 to 100	Very good
Median meets GV, but 80% of data does not meet GV	80.9 – (19.9 × (((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

Where: 80th = 80th percentile of the data; median = annual median; SF = scaling factor based on 90th percentile[21] of available data.

Table 19. Rules, formulas, and scoring ranges for associated grades for DO (when comparing to the lower guideline value (GV)*) in estuaries of the MWI Report Card[10].

Rule	Formula	Scoring Range	Grade
Median meets GV and ≥80% of data meets GV	Assigned 90	81 to 100	Very good

[20] 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; therefore, assumptions/decisions regarding the other 20% of the data (between 80–100%) and how it should be distributed around the GV cannot be made. Thus, a discrete value within the 'very good' range to systems if the 80th percentile meets the GV was assigned. The middle (i.e., 90) of the 'very good' range (Table 18) is used to assign a score for 'very good'.

[21] Scaling Factor for DO is varied to be based on the 99th percentile of all values—further discussion below under 'Scaling Factors (SF)'.

Median meets GV, but 80% of data does not meet GV	80.9 − (19.9 × (((GV − 20th) / (median − 20th))))	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

Where: 20th = 20th percentile of the data; median = annual median; SF = scaling factor based on 90th percentile of available data.
* To meet the lower DO guideline value, % saturation must be higher than the GV. This is inverse to how other indicators meet GV; thus, the formula to calculate grade must also be the inverse.

Guideline Values

Guideline values used for freshwater basins are based on the QLD Water Quality Guidelines 2009 (DES, 2009) and are related to the individual river or creek (Table 20). For the Don River, guideline values used are based on the 'Draft environmental values and water quality guidelines: Don and Haughton River Basins, MWI estuaries, and coastal/marine waters' (Newham et al., 2017). These draft guideline values are listed as 20th, 50th, and 80th percentiles, rather than single values. Annual medians were compared to the middle value of this range of guidelines. This aligns with the approach used to score annual values in the inshore marine environment where 20th, 50th, and 80th percentile guideline values are scheduled. This document is also used for the guideline values for estuaries (21).

Draft guidelines for DIN for the Don Basin and monitored estuaries were not available. Therefore, guideline values were created by summing ammonia nitrogen and NO_x draft guideline values. There is a precedent for this approach in the EPP 2009 'Proserpine River, Whitsunday Island and O'Connell River Basins environmental values and water quality objectives'[22] which, in reference to DIN guideline values, states: "DIN = ammonia nitrogen + NO_x" (page 47). This is reflected in the additive nature of the scheduled water quality objectives for the mid- and lower-estuaries in this document.

Table 20. Water quality indicator categories, associated indicators, and guideline values for freshwater basins in the MWI Report Card.

Indicator category	Indicator	Unit	Don (Don River)	O'Connell (O'Connell River)	Pioneer (Pioneer River)	Plane (Sandy Creek)	Plane (Plane Creek)
Nutrients	DIN	mg/L	0.03	0.03	0.008	0.03	0.008
	FRP	mg/L	0.045	0.006	0.005	0.015	0.008
Sediment	TSS	mg/L	5	2	5	5	3

Table 21. Water quality indicator categories, associated indicators, and guideline values for estuaries in the MWI Report Card. DO guideline values are presented as lower and upper limits.

Indicator Category	Indicator	Unit	Gregory	O'Connell	St Helens/Murray	Vines	Sandy	Plane	Rocky Dam	Carmila

22 https://ehp.qld.gov.au/water/policy/pdf/plans/proserpine-river-ev-wqo.pdf

Nutrients	DIN	mg/L	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
	FRP	mg/L	0.03	0.03	0.03	0.03	0.06	0.06	0.06	0.06
Phys–chem	DO	% sat	70–105	70–105	70–105	70–105	70–105	70–105	70–105	70–105
	Turbidity	NTU	10	10	10	10	Too variable to derive GV			
Chl-*a*	Chl-*a*	µg/L	2	2	2	2	5	5	5	5

Scaling Factors (SF)

To set an SF for freshwater nutrient and sediment indicators (DIN, FRP, and TSS), the historical GBRCLMP data was pooled for each basin, and the 90th percentile was used as the SF. The advantage of this approach is that the SFs were derived from the largest sample size available. For new sites, including the Don and Proserpine GBRCLMP sites, the same SF used for existing sites will be applied to new sites. This will mean the number of SF values across the Report Card will be minimised, making the assessments between basins more consistent.

For the estuarine indicators of turbidity, DIN, FRP, and chl-*a*, the SF is based on the 90th percentile of all values of the relevant indicator collected from estuarine monitoring in the MWI Region. The SF for DO is based on the 99th percentile of all values for DO collected from estuarine monitoring in the MWI Region. This is because the adoption of the 90th percentile would have resulted in the adoption of an SF value of 70% saturation. Most significantly, this is the same as the lower guideline value for DO. This value was unsuitable, as the SF needs to be some distance from the guideline value in order to provide a scoring range that will determine the grade of annual medians that do not meet guidelines. Further, values below 70% saturation occur reasonably frequently in the reference estuary, the Gregory, and therefore, the use of a 90th percentile SF value would put the least impacted estuary in a poor category. Therefore, the SF that was adopted to DO was the 99th percentile (~60% saturation), which avoids giving the Gregory a poor score and still provides a reasonable scoring range.

The Sandy, Rocky Dam, and Carmila Creeks estuaries are strongly tidal-influenced, and this may be apparent in the results. This could affect turbidity values through the increased suspension of sediments by tidal currents. Additionally, at the time of setting SF values, estuarine monitoring in the MWI Region was a newly commenced program, and therefore, only one year of data were available for calculation of the SF. SF values will be re-visited in the future as more data are collected.

Limits of Reporting (LOR)

Rules have been set around how to deal with samples where concentrations of an indicator are below the LOR (Table 22):

- Where a monitoring program reports a LOR that is greater than the guideline value, data from that program where a concentration was reported as <LOR is not used (because this does not allow for valid interpretation of whether guidelines are met within the State of QLD), and
- Where a monitoring program reports a LOR that is less than the guideline value, a value of 0.5 × LOR is applied to data where <LOR is reported in a sample.

When a monitoring program reports a LOR where the magnitude of difference between the guideline value and the LOR is less than two-fold, applying a value of 0.5 × LOR may have the impact of biasing results towards better scores than is true in the field. Therefore, the number of samples where data are reported as <LOR should be considered when reporting confidence of the results when the magnitude of difference between the guideline value and the LOR is less than two-fold.

Table 22. Water quality indicator categories, associated indicators, and LOR values for estuaries in the MWI Report Card. DO guideline values are presented as lower and upper limits.

Indicator Category	Indicator	Unit	LOR
Nutrients	Ammonium Nitrogen (NH_4)	mg/L	0.002
	NOx	mg/L	0.001
	FRP	mg/L	0.002
Phys–chem	DO	% sat	-
	Turbidity	NTU	-
Chl-*a*	Chl-*a*	µg/L	0.100
Sediment	TSS	mg/L	1.000

Aggregation of Scores

Multiple monitoring sites were used to inform water quality scores within the O'Connell and Plane basins. The addition of these sites into the Report Card assessment occurred for the first time in 2018. The following steps were applied for the aggregation of scores in the O'Connell and Plane basins:

1. The total catchment area upstream of the monitoring site was obtained from the QLD Government[6],
2. The adjusted upstream catchment area for each monitoring site was determined. Where multiple monitoring sites are present along the same system, the adjusted catchment area reflects:
    a. The total upstream catchment area from the start of the system, or
    b. The total upstream catchment area as measured from the (first) upstream monitoring station to the next monitoring station,
3. The proportion of total catchment area for each monitoring site was determined and multiplied by the standardised score for each monitoring site,
4. All scores were summed to provide the final basin score.

3.1.1.2. Pesticides

Pesticide indicator scores were developed by the QLD Government's[6] GBRCLMP using the Pesticide Risk Metric (PRM). The aim of this approach is to quantify the ecological risk associated with exposure to a mixture of pesticides. Measured concentrations of up to 22 pesticides (Table 4) in a given sample are converted to a PRM that expresses risk as the percentage of aquatic species that may be adversely affected by the mixture of pesticides. In previous report cards, the PRM had been used to calculate the mixture toxicity for PSII herbicides only, which have a common MoA. From the 2019 Report Card onwards, the PRM approach has been applied to pesticides with multiple MoAs (Table 4). This was calculated using the independent action model of joint action (Plackett & Hewlett, 1952; Warne et al., 2020).

The pesticide mixture toxicity was calculated for all samples collected over the principal pesticide exposure period (i.e., the wet season period between 1st November and 30th April). Where there was more than one sample per day, a daily mean concentration was calculated. The mixture toxicity data (i.e., PRM values) for all water samples collected over the wet season were then summarised as a single value. A multiple imputation technique was used to the daily average PRM for days that were not monitored during the wet season (Donders et al., 2006; Patrician, 2002; Rubin, 1996). This involved fitting a statistical distribution to the observed data for the wet season for the site. Values were then imputed to fill in the missing days in the 182-day period. The resultant data were then divided to obtain the daily PRM and ranked into five risk categories (Table 23). These categories are consistent with the ecological condition categories used in the Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters. All values were rounded to the nearest whole number.

Table 23. Grading description for the pesticides indicator in the freshwater basin assessments.

Risk Categories (% species affected)	% Species Protected	Risk Level	Pesticides Assessment	Scaling of Scores for Aggregation
≤1.0 %	≥99%	Very low risk	Very good	= 81 + ABS((19 − ((score − 0) × (19 / 1))))
>1 to <5%	>95 to <99%	Low risk	Good	= 61 + ABS((19.9 − ((score − 1.01) × (19.9 / 3.99))))
5 to <10%	>90 to 95%	Moderate risk	Moderate	= 41 + ABS((19.9 − ((score − 5.00) × (19.9 / 4.99))))
10 to <20%	>80 to 90%	High risk	Poor	= 21 + ABS((19.9 − ((score − 10.00) × (19.9 / 9.99))))
≥20.0%	≤80%	Very high risk	Very poor	= 0 + ABS((20.9 − ((score − 20.00) × (20.9 / 79.99))))

3.1.2. Habitat and Hydrology

3.1.2.1. In-stream Habitat Modification

The two in-stream habitat modification indicators, impoundment length and fish barriers, were equally weighted to generate the in-stream habitat modification score for freshwater basins (only the fish barriers indicator is used in this category for estuaries). Scoring for each indicator is described below. Final impoundment length and fish barrier scores were standardised within appropriate bandwidths before an average score was generated to describe the overall condition of the in-stream habitat modification indicator.

Impoundment Length (Freshwater Basins only)

The scoring range (Table 24) was derived from 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 and was based on existing studies and the expert opinion of a panel of experienced aquatic ecologists[5]. An assumption of the 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 24. Grading description for the impoundment length indicator in the freshwater basin assessments.

% of Waterway Impounded	Condition Grade	Scaling of Scores for Aggregation
<1.0%	Very good	= 81 + ABS((19 − ((score − 0) × (19 / 0.99))))
1.0–3.99%	Good	= 61 + ABS((19.9 − ((score − 1) × (19.9 / 2.99))))
4.0–6.99%	Moderate	= 41 + ABS((19.9 − ((score − 4) × (19.9 / 2.99))))
7.0–9.99%	Poor	= 21 + ABS((19.9 − ((score − 7) × (19.9 / 2.99))))
≥10.0%	Very poor	= 0 + ABS((20.9 − ((score − 10) × (20.9 / 90))))

Fish Barriers

To score the condition of fish barriers in freshwater basins and estuaries, a scoring range and subsequent score was developed for each of the three indicators (Table 25 to Table 27). Each basin and estuary were allocated a score for each indicator based on these scoring ranges. The final aggregated fish barriers indicator score for each basin and estuary was derived by adding these three scores together (Table 28).

Table 25. Scoring range and subsequent score assigned for the barrier density indicator. Assessed on Stream Order (SO) as indicated[23].

Scoring Range (km/barrier) Freshwater Basins and Estuaries (SO ≥ 3)	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 26. Scoring ranges in freshwater basins and estuaries, and subsequent score assigned for 'stream length to the first barrier as a proportion (%) of total stream length'. Assessed on Stream Order (SO) as indicated.

Scoring Range (%)		Score	Condition Grade
Freshwater Basins (SO ≥ 3)	Estuaries (SO ≥ 3)		
No Barriers	No Barriers	5	Very good
50%–99.9%	80%–99.9%	4	Good
30%–49%	60%–79%	3	Moderate
10%–29.9%	40%–59.9%	2	Poor
0%–9.9%	0%–39.9%	1	Very poor

Table 27. Scoring ranges in freshwater basins and estuaries, and subsequent score assigned for 'stream length to the first low/no passability barrier as a proportion (%) of total stream length'. Assessed on Stream Order (SO) as indicated.

Scoring Range (%) Freshwater Basins (SO ≥ 4)	Scoring Range (%) Estuaries (SO ≥ 4)	Score	Condition Grade
≥95.1%	No low pass barriers (100%)	5	Very good
70.1%–95%	90.1%–99.9%	4	Good
60.1%–70%	80.1%–90%	3	Moderate
50.1%–60%	60.1%–80%	2	Poor
0%–50%	0%–60%	1	Very poor

Table 28. 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	= 81 + ABS((19 + ((score − 15) × (19 / 1))))
11–13	Good	= 61 + ABS((19.9 + ((score − 13) × (19.9 / 2))))
8–10	Moderate	= 41 + ABS((19.9 + ((score − 10) × (19.9 / 2))))
5–7	Poor	= 21 + ABS((19.9 + ((score − 7) × (19.9 / 2))))
3–4	Very poor	= ABS((20.9 + ((score − 4) × (20.9 / 1))))

3.1.2.2. Flow

The flow indicator scores the daily flow record for the reporting year at a given flow assessment site. There are ten measures that contribute to this score (Table 29). Each measure assesses observed flow data against the reference distribution from pre-development modelled flow for each flow

[23] In estuaries only, barriers were assessed on waterways that intersected the Fisheries Queensland 'Estuary Extent' Layer, regardless of Stream Order.

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 ten flow measures were 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 associated ecological assets are cease-to-flow (CTF) (amphibians, riffles, and waterholes), low flows (some spawning fish, reptile and amphibian species, and 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 presented in the Report Card Flow Indicator Project report (Stewart-Koster et al., 2018).

Landscape changes resulting from human activities, including vegetation clearing, removal of wetlands, levelling, modification of channel morphology, and removal or addition of waterway channels, may affect the characteristics of flood waters, including their duration, extent, and frequency. Consequently, whilst flow volumes during flood events may be similar to pre-development levels, the actual hydrological characteristics of the flood and inundation events, and hence their ecological functioning, may be altered.

Table 29. The ten flow measures used for the flow indicator, the season to which they apply, and the hydrologic definition of the measure. CV = coefficient of variation.

Flow Measure	Season	Hydrologic Definition
Low flow duration	July–Jan	Total duration of flows that remain equal to or below the 10th percentile 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 10th percentile threshold during the reporting period (annual).
Low flow variability (CV dry season)	July–Dec	CV (standard deviation/mean) of daily flow for dry season.
Driest six months (ratio dry/total)	July–Dec	Proportion of annual discharge contributed during the months of July–December.
CTF duration	All year	Total duration of where flow ceases during the reporting period (annual).
CTF 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 that remain equal to or above the 50th percentile 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 50th percentile threshold during the reporting period (annual).
High flow duration	All year	Total duration of flows that remain equal to or above the 90th percentile threshold for the reporting period (annual)
High flow frequency	All year	Total count of flows that remain equal to or above the 90th percentile threshold for the reporting period (annual)

The scoring for each flow measure is based upon the percentile range representative of standard deviations from the mean (Table 30).

Table 30. 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 95.37% 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 30th percentile value was selected as the most appropriate summary statistic for representing the range of the ten flow measures and reporting a score for each site. The other summary statistics were the mean, mode, and 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 scale):

1. Determine the 30th percentile value from the ten flow measures (each scores from 1 to 5) for each flow assessment site.
2. Apply the following formula for scores of <2: (20.9 + ((30th percentile – 1.9) × (23.2))). To provide a value of 0 to 20.9 for scores of <2 graded 'very poor'.
3. Apply the following formula for scores of 2 to <5: ((30th percentile × 20) – 19). To provide a value between 21 and 80 for scores 2 to <5 and are graded 'poor', 'moderate', or 'good'.
4. Apply the following formula for scores of 5: 80 + ((M_{min} – 1) × 5) where M_{min} is the lowest scoring measure (1 to 5) for the flow assessment site.
   To provide a value of between 80 to 100 for scores of 5, using the lowest contributing flow measure score as a scale. This 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'.

The 30th percentile score, standardisation formula, and standardised scoring range with grade colour code are presented in Table 31.

Table 31. Standardisation formulae for 30th percentile scores of flow assessment sites.

Scoring Range 30th Percentile Score	Grade	Scaling of Scores for Aggregation
5	Very good	= 80 + ((minimum flow measure score – 1) x 5)
4 to <5	Good	= (score x 20) – 19
3 to <4	Moderate	= (score x 20) – 19
2 to <3	Poor	= (score x 20) – 19
1 to <2	Very poor	= 20.9 + ((score – 1.9) x (23.2°))

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

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 were determined.
- The adjusted upstream catchment for each assessment site (stream gauge) was determined, which is the total 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 were summed to provide the final basin score.

Flow Indicator Example:

The 2019 to 2020 rainfall for the Pioneer Basin and the annual flow records for Finch Hatton Creek and Dumbleton Weir Tailwater are presented in Figure 19. Finch Hatton is located upstream in the upper catchment, whilst Dumbleton Weir Tailwater (TW) is downstream in the lower catchment of the Pioneer River. Differences in the flow records between the sites include the effect of impoundments on river flow of three weirs: Dumbleton, Marian, and Mirani. A major dam, Teemburra, is also located on this watercourse. This example visually presents how the assessment of flow records using the indicator differ between a site that has minimal alteration from pre-development flows (Finch Hatton) and one that has substantial alteration from flows (Dumbleton Weir TW) for the 2019–20 reporting period.

The flow at Finch Hatton Creek for 2020–21 reporting period scored a five or four (out of five) for nine of the ten flow measures, determining that much of the flow was not substantially altered from pre-development flow. The overall freshwater flow score at Finch Hatton Creek was four, calculated from the 30th percentile of the ten flow measures. The standardised report card value of this score was 61 ('good'). The flows at Dumbleton Weir TW were substantially altered from pre-development flows (i.e., a score of one out of five) for the following four measures: cease to flow duration and frequency, low flow duration, and coefficient of variation for the dry season. The flow record at Dumbleton Weir TW shows abrupt changes to flow as a result of the in-stream habitat modifications, including weir impoundments and water releases for consumption purposes. The overall Dumbleton Weir TW score was one, with the standardised report card value of this score of zero ('very poor'). The example demonstrates how the flow indicator assesses the degree of change from reference for different characteristics of the flow regime.

The example includes alterations to flow that are easy to visualise from an annual flow record. However, the ten flow measures can 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 fishery productivity (Stewart-Koster et al., 2018). The results of the flow indicator for Dumbleton Weir TW identify that alteration of flows may be impacting waterway health for the attributes linked to low and medium flows.

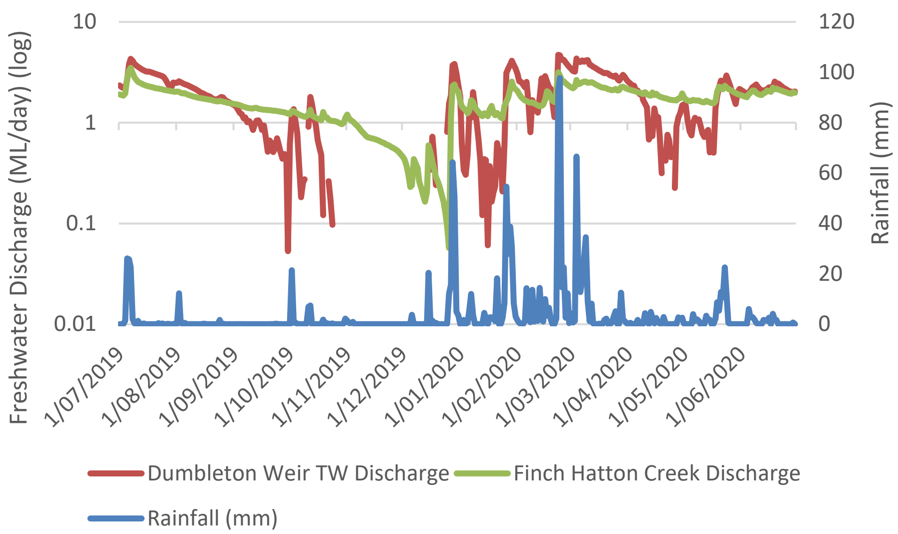


Figure 19. Observed daily discharge (ML/day) for the Dumbleton Weir Tailwater (TW) and Finch Hatton Creek sites in the Pioneer Basin, presented on a log scale. This is plotted against daily rainfall (mm) for the Pioneer Basin. Missing data represent periods of no flow at Dumbleton Weir TW.

3.1.2.3. Riparian, Wetland, and Mangrove/Saltmarsh Extent

The condition score for the extent of riparian, wetland, and mangrove/saltmarsh extent vegetation was determined by calculating the percentage of vegetation loss since pre-clearing to 2013–14 (freshwater riparian extent) and 2016–2017 (remaining vegetation extent indicators) for each basin or estuary and assigning the result a grade (Table 32).

Table 32. Grading description for the riparian, wetland, and mangrove/saltmarsh extent indicators in freshwater basin and estuary assessments.

Scoring Range	Grade	Scaling of Scores for Aggregation
≤5.0%	Very good	= 81 + ABS((19 – ((score – 0) × (19 / 4.99))))
>5.0–15.0%	Good	= 61 + ABS((19.9 – ((score – 5.01) × (19.9 / 9.99))))
>15–30.0%	Moderate	= 41 + ABS((19.9 – ((score – 15.01) × (19.9 / 14.99))))
>30–50%	Poor	= 21 + ABS((19.9 – ((score – 30.01) × (19.9 / 19.99))))
>50%	Very poor	= ABS((20.9 – ((score – 50.01) × (20.9 / 49.99))))

3.1.3. Fish (Freshwater Basins only)

The model developed for the calculation of indigenous species richness was reviewed by local experts to ensure validity. The model provides a means to compare fish species richness across basins to a reference. This reference was based on species richness at the ‘least disturbed’ site that had recent available data, which in the MWI Region was Repulse Creek. This approach does not compare to a pre-development baseline, so it can only be considered as a comparison of current fish community condition between basins.

The primary baseline for assessing the species richness of sites within the MWI region was a regression line describing the relationship between the species richness of the 10% most specious samples, primarily in relation to variables describing the natural variation in fish species richness across the MWI region (D. Moffatt, pers. comm. 19/04/2022).

The regression line was derived using 90th percentile quantile regression, and the variables used to characterise streams were (1) stream size (accumulated run-off weighted catchment area), (2) stream slope, (3) maximum stream slope downstream, and (4) annual temperature range as inputs. The regression line was derived from the fish catch from 370 samples at 252 different locations and explained about 50% of the observed variation. In areas where there were insufficient data to derive a reliable regression line, e.g., the Don Basin, a line was fitted by eye using the single environmental variable explaining the greatest proportion of variation in species richness (D. Moffatt, pers. comm. 19/04/2022).

Based on ongoing indicator development and feedback from a variety of fish experts (both local and QLD Government), several methodological updates were made to the 2021 freshwater fish assessments, including:

- The Don Basin was included in the assessment for the first time.
- The indicator categories were changed from 'Native' and 'Pest' fish to 'Indigenous' and 'Non-indigenous' fish.
- Derived updated or new (Maximum Species Richness) baselines to accommodate new data and assessment areas.

Fish communities are assessed every three years, reflecting the lifespan of many local freshwater fish species and budgetary constraints. Although the method updates in the 2021 Report Card reflect the third round of fish assessments, the fish assemblage indicator is still under development. Future updates will include species distribution models (currently being developed by the QLD Government[6] in collaboration with local experts), ecological integrity insights, and greater detection of individual species present.

A qualitative rating scheme for indigenous species richness (POISE) was developed (Table 33), where the 'very good' category was based on available data for the Repulse Creek sites ('minimally disturbed' site with available data) and the 'poor' was based on the 90th percentile of the results for recent times. Anything less than the 90th percentile is considered 'very poor'. The rating scheme for the non-indigenous fish model output (PONI) differs slightly to that for indigenous species richness (Table 34).

Species distribution models are currently being developed by the QLD Government[6] to complete development of the fish assemblage indicator.

Table 33. Rating scheme for condition of indigenous species richness using the POISE model for freshwater fish communities.

Native Species Richness	Grade	Scaling of Scores for Aggregation
0.80 to 1	Very good	= 81 + ABS((19 + ((score − 1) × (19 / 0.2))))
0.67 to <0.80	Good	= 61 + ABS((19.9 + ((score − 0.7999) × (19.9 / 0.1329))))
0.53 to <0.67	Moderate	= 41+ ABS((19.9 + ((score − 0.6669) × (19.9 / 0.1339))))
0.40 to <0.53	Poor	= 21 + ABS((19.9 + ((score − 0.5329) × (19.9 / 0.1329))))
0 to <0.40	Very poor	= ABS((20.9 + ((score − 0.3999) × (20.9 / 0.3999))))

Table 34. Rating scheme for the modelled non-indigenous fish condition indicator (PONI) for freshwater fish communities.

Non-indigenous Fish	Grade	Scaling of Scores for Aggregation
0 to 0.03	Very good	= 81 + ABS((19 − ((score − 0) × (19 / 0.025))))

>0.03 to 0.05	Good	= 61 + ABS((19.9 − ((score − 0.0251) × (19.9 / 0.0249))))
>0.05 to 0.1	Moderate	= 41 + ABS((19.9 − ((score − 0.051) × (19.9 / 0.049))))
>0.1 to 0.2	Poor	= 21 + ABS((19.9 − ((score − 0.101) × (19.9 / 0.099))))
>0.20 to 1	Very poor	= ABS((20.9 − ((score − 0.201) × (20.9 / 0.799))))

3.2. Inshore and Offshore Marine Zones

3.2.1. Inshore Water Quality

3.2.1.1. Nutrients, Chlorophyll-a, and Water Clarity

For indicators in the nutrients, chl-*a*, and water clarity categories, annual medians or means were calculated (as per the guidelines of the relevant zone) for each site, and condition scores were calculated using the relevant guideline value and the procedure below.

Guideline values were obtained from the relevant documents, as described below:

- Whitsunday and Central Zones—Environmental Protection (Water) Policy 2009 Proserpine River, Whitsunday Island and O'Connell River Basins Environmental Values, and the Environmental Protection (Water) Policy Pioneer River and Plane Creek Basins Environmental Values and Water Quality Objectives[24].
- Northern Zone—guidelines for Central QLD (DES, 2009; GBRMPA, 2010) were used as local guidelines are currently in draft form (Draft environmental values and water quality guidelines: Don and Haughton River Basins, Mackay-Whitsunday estuaries, and coastal/marine waters[25]).
- Southern Zone—Central QLD and Environmental Protection (Water) Policy Pioneer River and Plane Creek Basins Environmental Values and Water Quality Objectives.

Once guidelines are developed, the local guidelines will be used for scoring.

Our first two Report Cards (2014 and 2015) used only the relevant guidelines from (GBRMPA (Great Barrier Reef Marine Park Authority), 2010). The shift towards using locally relevant QLD guidelines (where available) reflects a move toward reporting on the ‘interim site-specific water quality index’, based on guideline values refined using site-specific, long-term water quality data collected at MMP sites (Waterhouse et al., 2017a) rather than GBR-wide (GBRMPA (Great Barrier Reef Marine Park Authority), 2010) guidelines. While the MWI Report Card has not employed the same guideline values as the MMP, the adopted guideline values (scheduled guidelines noted above) are similar (see Table 35 for relevant inshore water quality guideline values used in the 2020 Report Card).

Prior to calculating annual medians or means and comparing them to the guidelines, the LOR (or limit of detection (LOD) was explored as per Table 36, and the same rules applied as described for freshwater basins and estuaries.

[24] https://www.legislation.qld.gov.au/LEGISLTN/SLS/2013/13SL158.pdf
[25] http://www.ehp.qld.gov.au/water/policy/pdf/don-haughton-mackay-whitsunday-main-report.pdf

Table 35. Water quality guideline values for relevant water quality indicators at inshore marine monitoring sites in the MWI Report Card. Also listed are the programs associated with each site, source documents for the guideline values listed, associated basin/region/water area, water type (OC = open coastal, EC = enclosed coastal), and management intent (SMD = slightly to moderately disturbed, HEV = high ecological value, MD = moderately disturbed) outlined in the source documents. Underlined values are compared to means; other single value guidelines are compared to medians. Where a range of three values are listed, the middle value is compared to medians.

Zone	Sites	Documents	Basin/region/ water area	Water Type	Management Intent	NO_x (µg/L)	PN (µg/L)	PP (µg/L)	Chl-*a* (µg/L)	TSS (mg/L)	Secchi (m)	Turb (NTU)
Northern	All sites (Abbot Point)	1 & 2	Don 121	OC	SMD	3	20	2.8	0.45	2	10	1
	WHI1 Double Cone Island (MMP)	3	SD2381	OC	HEV	0–1–2	12–13–15	1.8–2.4–2.8	0.25–0.36–0.54	0.9–1.4–2.3	10	0.7–1.1–2.1
Whitsunday	WHI4 Pine Island (MMP)	3	SD2381	OC	HEV	0–1–2	12–13–15	1.8–2.4–2.8	0.25–0.36–0.54	0.9–1.4–2.3	10	0.7–1.1–2.1
	WHI5 Seaforth Island (MMP)	3	SD2381	OC	HEV	0–1–2	12–13–15	1.8–2.4–2.8	0.25–0.36–0.54	0.9–1.4–2.3	10	0.7–1.1–2.1
	WHI6 O'Connell River mouth (MMP)	3	SD2381 (EC)	EC	HEV	2–4–10			0.8–1.3–2			
	WHI7 Repulse Is. dive mooring (MMP)	3	SD2381	OC	HEV	0–1–2	12–13–15	1.8–2.4–2.8	0.25–0.36–0.54	0.9–1.4–2.3	10	0.7–1.1–2.1
	AMB1 (Mackay & Hay Point)	4	SD2382	OC	HEV		<20	<2.8	<0.45	<2.0	>10	<1
	AMB2 (Mackay & Hay Point)	4	MD2343	OC	MD		<20	<2.8	<0.45	<2.0	>10	D = 1–2–8; W = 5–12–33
	AMB3B (Mackay & Hay Point)	3 & 4	OC landward of plume line	OC	SMD		<20	<2.8	<0.45	<2.0	>10	<1
Central	AMB5 (Mackay & Hay Point)	4	MD2341 (port open waters)	OC	MD		<20	<2.8	<0.45	<2.0	>10	D = 1–2–8; W = 5–12–33
	AMB6 (Mackay & Hay Point)	4	MD2343	OC	MD		<20	<2.8	<0.45	<2.0	>10	D = 1–2–8; W = 5–12–33
	AMB8 (Mackay & Hay Point)	3 & 4	OC landward of plume line	OC	SMD		<20	<2.8	<0.45	<2.0	>10	D = 1–2–8; W = 5–12–33
	AMB10 (Mackay & Hay Point)	3 & 4	OC landward of plume line	OC	SMD		<20	<2.8	<0.45	<2.0	>10	<1
	AMB12 (Mackay & Hay Point)	3 & 4	HEV2383	OC	HEV	0–0–1	14–18–24	1.6–2.1–3	≤0.45	1.1–1.6–2.4	10	<1
	CAM1 (Aquila Island)	2&4	SD2383	OC	HEV	3	<20	<2.8	<0.45	<2.0	>10	<1
Southern	CAM2	2& 4	SD2383	OC	HEV	3	<20	<2.8	<0.45	<2.0	>10	<1
	CAM3	2&4	SD2383	OC	HEV	3	<20	<2.8	<0.45	<2.0	>10	<1

Documents:

1. Great Barrier Reef Marine Park Authority, 2010. Water quality guidelines for the Great Barrier Reef Marine Park. Revised edition 2010, Townsville.
2. Central Queensland guidelines in Department of Environment and Science, 2009. Queensland Water Quality Guidelines 2009, Version 3.
3. Department of Environment and Science, 2009. Environmental Protection (Water) Policy Proserpine River, Whitsunday Island and O'Connell River Basins Environmental Values and Water Quality Objectives.
4. Department of Environment and Science, 2009. Environmental Protection (Water) Policy Pioneer River and Plane Creek Basins Environmental Values and Water Quality Objectives.

Table 36. Indicator LORs and LODs for different marine water quality monitoring programs used by the MWI Report Card.

Indicator Category	Indicator	LOR: SIP and NQBP (JCU)	LOD: MMP (AIMS)
Nutrients	Particulate nitrogen (PN) *(= TN – TDN)*	NA	<1.0 µg/filter
	Total nitrogen (TN)	<10 µg N/L	
	Total dissolved nitrogen (TDN)	<10 µg N/L	<0.28 µg/L
	Particulate phosphorus (PP) *(= TP – TDP)*	NA	<0.09 µg/L
	Total phosphorus (TP)	<1 µg P/L	
	Total dissolved phosphorus (TDP)	<1 µg P/L	0.62 µg/L
	Oxidised nitrogen (NO_x) *(= NO_2 + NO_3)*	NA	<0.28 µg/L (NO_x)
Chl-*a*	Chl-*a*	<0.2 µg/L	<0.004 µg/L
Water Clarity	TSS	<0.2 mg/L	<0.15mg/filter
	Secchi disk depth	NA	NA
	Turbidity	0.005 NTUe	

The following steps were used to calculate indicator scores (see Lønborg et al., 2016; Waterhouse et al., 2017b).

1. For indicators where failure to meet a guideline is defined as the annual (mean or median) concentration being *higher* than a guideline value:

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

   For indicators where failure to meet a guideline is defined as the annual (mean or median) concentration being *lower* than a guideline value (e.g., secchi disk depth):

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

   Where:
   AM is the annual median or mean of the measured indicator
   GV is the guideline value
2. Ratios were capped to bind the water quality index to the range of −1 to 1 to ensure all indicators were on the same scale.
3. For turbidity, where a wet and dry season score is calculated, these scores were averaged to give an annual turbidity score.
4. The nutrients indicator category score was calculated as the average of NO_x, particulate phosphorus (PP), and particulate nitrogen (PN) scores (where available and following rules for minimum information (as per Section **Error! Reference source not found.**, pg. 52)).
5. The water clarity indicator category was calculated as the average of secchi, TSS, and turbidity scores (where available and following rules for minimum information (as per Section **Error! Reference source not found.**, pg. 52)).
6. Nutrients, water clarity, and chl-*a* scores were translated to the report card five-point grading scale (Table 37).

Table 37. Inshore water quality grades, scoring ranges, and scaling for aggregation.

Score Range	Condition Grade and Colour Code	Scaling of Scores for Aggregation
>0.5 to 1	Very good	= 100 − (19 − ((score − 0.51) × (19 / 0.49)))
0 to 0.5	Good	= 80.9 − (19.9 − ((score − 0.01) × (19.9 / 0.49)))
<0 to −0.33	Moderate	= 60.9 − (19.9 − ((score − (−0.33)) × (19.9 / 0.32)))
<−0.33 to −0.66	Poor	= 40.9 − (19.9 − ((score − (−0.66)) × (19.9 / 0.32)))
<−0.66 to −1	Very poor	= 20.9 − (20.9 − ((score − (−1)) × (20.9 / 0.34)))

3.2.1.2. Pesticides

Pesticides in the inshore marine zone were reported using the PRM for the fourth consecutive year, replacing the PSII-HEq (PSII Herbicide Equivalent Concentration) method (Grant et al., 2018), which only assessed a maximum of 13 herbicides (5 in 2015 and 13 in 2016–2018). This aligns with that for freshwater basins (Section **Error! Reference source not found.**), the Reef 2050 Water Quality I mprovement Plan pesticide targets, and the Australian and New Zealand Water Quality Guidelines (ANZG, 2018). The PRM approach considers pesticides with different MoAs (Table 11), which exert their toxicity by different means, increasing the number of chemicals that can be incorporated to inform water quality assessments. As a result, the impacts to the marine environment through land-based run-off are captured for a greater number of pollutants.

Concentration data was converted into a single number that represents the toxicity of the mixture of pesticides in each passive sampler or water sample. This was done to express the overall risk to aquatic ecosystems in simple numeric terms (given as a percentage of species affected). The PRM for pesticides with different MoAs was calculated using the independent action model of joint action (Plackett & Hewlett, 1952). Further details on how the PRM calculations were made are provided in (Warne et al., 2020).

Corresponding to the percentage of species affected calculated for each passive sampler, the percentage of species protected were allocated to given risk categories as done for freshwater basins and estuaries (Table 23). These categories are consistent with the ecological condition categories used in the Australian and New Zealand Water Quality Guidelines ANZG 2018[26]. The average maximum PRM concentration recorded within the zone was used as the pesticide result. All values were rounded to the nearest whole number.

3.2.2. Offshore Water Quality

Offshore water quality is not currently reported while technical staff and the TWG work towards finding new data sources for this region.

3.2.3. Coral

Condition assessment of the coral indicators for the inshore zones followed the MMP method (Table 38):

Coral cover: This indicator simply scores reefs based on the level of coral cover, with high coral cover being the desirable state for coral reefs. For each reef, the proportional cover of all genera of hard (order Scleractinia) and soft (subclass Octocorallia) corals are combined.

[26] https://www.waterquality.gov.au/anz-guidelines/resources/key-concepts/level-of-protection

Macroalgae cover: This indicator is the percentage cover of macroalgae as a proportion of the total cover of all algal forms (inshore regions only) as a representation of these opportunistic colonisers outcompeting corals.

Density of juvenile hard corals: Counts of juvenile hard corals were converted to density per m^2 of space available for settlement. The genus *Fungia* (mushroom/disc corals) were excluded.

Change in coral cover (Cover change): This is derived from the comparison of the observed change in coral cover between two visits and the predicted change in cover derived from a multi-species form of a Gompertz growth equation (Thompson et al., 2021). Due to differences in growth rates, GBR reefs were divided into eight groups based on community types. Models were developed for each group of reefs and separately for fast growing corals of the family Acroporidae, as well as the combined grouping of all other slower growing hard coral taxa. Some reefs are surveyed in alternate years. The coral change index is based on the mean of available estimates of change over the previous four-year period.

Community composition: The basis of the indicator is the scaling of cover for constituent hard coral genera (subset of 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 chl-*a*. Composition is scored relative to a baseline observed over the first years that a site was monitored.

Benthic cover and density of juvenile hard coral data collected under the NQBP monitoring programs in the Central and Northern Zones were analysed using the MMP approach. This involved aggregating site-level juvenile density and benthic cover estimates, up to the reef level mean. Mean hard coral and soft coral cover for each reef are summed to produce the overall 'coral cover'. Mean total algae cover at each site was used to convert juvenile abundance to the indicator juvenile density. Inshore zone scores are the mean of reef-level scores for each indicator.

Given the difference in data collection methods, a weighted approach was used to combine coral cover data collected by RCA with that from the MMP. Data from only the most recent survey was used (as done for score calculations using MMP and LTMP data). RCA coral cover data was first converted into coral cover scores as per the method used by AIMS:

Coral cover score = Percentage coral cover / 75

Scores were then weighted based on survey precision relative to that of the MMP, which was calculated as a function of sampling frequency. Precision was assessed using a simulation of randomly sampled point series, with known proportions and improved precision, expressed as confidence intervals around the mean. This random simulation showed that improvement in precision for each monitoring program could be determined based on sample size (number of observations). The calculation for this simulation is as follows:

Sample size = No. observations taken every metre × No. transects × transect length (m) × No. of sites sampled within the same reef

Precision estimates were then used to calculate weighting values, which were then applied to the RCA coral cover data. For more detailed information on how the weighting of RCA data was conducted, see (Whitehead, 2020). Coral indicators for the inshore and offshore zones were scored in a similar way. Observations for each indicator were scored on a continuous scale following (Thompson et al., 2016). (Table 38). 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)). The values for the reefs in each reporting zone are then averaged and converted to a scale of 0 to 100 (Table 39).

Table 38. Threshold values for the condition assessment of coral, where indicators that are reported in inshore zones only are identified. CI = confidence interval.

Community Attribute	Score	Thresholds
Cover—Combined hard and soft coral cover	Continuous between 0.0 and 1.0	1 at 75% cover or greater
		0 at zero cover
Change—Rate of increase in hard coral cover (preceding four years)	1.0	Change > 2x upper 95% CI of predicted change
	Continuous between 0.6 and 0.9	Change between upper 95% CI and 2x upper 95% CI
	Continuous between 0.4 and 0.6	Change within 95% CI of the predicted change
	Continuous between 0.1 and 0.4	Change between lower 95% CI and 2x lower 95% CI
	0.0	change < 2x lower 95% CI of predicted change
Macroalgae—Proportion of algae cover classified as macroalgae (inshore only)	Continuous between 0.0 and 1.0	≤ reef specific lower bound and ≥ reef specific upper bound
Juvenile—Density of hard coral juveniles (<5 cm diameter)	1.0	> 13 juveniles per m^2 of available substrate
	Continuous between 0.4 and 1.0	4.6 to 13 juveniles per m^2 of available substrate
	Continuous between 0 and 0.4	0 to 4.6 juveniles per m^2 of available substrate
Composition—Composition of hard coral community (inshore only)	1.0	Beyond 95% CI of baseline condition in the direction of improved water quality
	0.5	Within 95% Confidence intervals of baseline composition
	0.0	Beyond 95% CI of baseline condition in the direction of declined water quality

Table 39. Scoring ranges for aggregated coral results and scaling formula to aggregate coral index with other indices to produce overall score.

Condition Grade and Colour Code	Score Range	Scaling of Scores Aggregation
Very good	>0.8	= 'score' × 100
Good	>0.6–0.8	= 'score' × 100
Moderate	>0.4–0.6	= 'score' × 100
Poor	>0.2–0.4	= 'score' × 100
Very poor	0–0.2	= 'score' × 100

3.2.4. Inshore Seagrass

3.2.4.1. Marine Monitoring Program

The MMP seagrass monitoring data are rolled up into the GBR Report Card scoring range (Table 17) (McKenzie & Collier, 2015). The scoring thresholds and their relation to the GBR Report Card scoring ranges are provided for the two MMP seagrass indicators in Table 40–**Error! Reference source not found.**. An overall score for each site is then calculated by averaging the two seagrass indicator scores, where all indicators are equally weighted.

Table 40. Seagrass 'abundance' scoring thresholds in relation to condition grades (low = 10^{th} or 20^{th} percentile guideline). Source: (McKenzie et al., 2015).

Category	Score	Score Range	Condition Grade
75–100	100	80 to 100	Very good
50–75	75	60 to <80	Good
Low–50	50	40 to <60	Moderate
<Low	25	20 to <40	Poor
<Low by >20%	0	0 to <20	Very poor

Table 41. 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.

<table>
<tr><th>Resilience group</th><th>Scoring range</th><th>Resilience group grade</th><th>Scoring range</th><th>Standardised scoring range</th><th>Condition grade</th></tr>
<tr><td rowspan="3">Reproductive high resistance</td><td rowspan="3">70–100</td><td>Persistent reproductive and high resistance</td><td>85–100</td><td rowspan="2">81–100</td><td rowspan="2">Very Good</td></tr>
<tr><td rowspan="2">Reproductive high resistance</td><td rowspan="2">70–100</td></tr>
<tr><td rowspan="2">61–80</td><td rowspan="2">Good</td></tr>
<tr><td rowspan="4">Non-reproductive high resistance</td><td rowspan="4">30–70</td><td rowspan="2">Reproductive history and high resistance</td><td rowspan="2">50–70</td></tr>
<tr><td rowspan="2">41–60</td><td rowspan="2">Moderate</td></tr>
<tr><td rowspan="2">Non-reproductive history and high resistance</td><td rowspan="2">30–50</td></tr>
<tr><td rowspan="2">21–40</td><td rowspan="2">Poor</td></tr>
<tr><td rowspan="3">Low resistance sites</td><td rowspan="3">0–30</td><td rowspan="2">Reproductive and low resistance</td><td rowspan="2">5–30</td></tr>
<tr><td rowspan="2">1–20</td><td rowspan="2">Very Poor</td></tr>
<tr><td>Non-reproductive, low resistance</td><td>0–15</td></tr>
</table>

3.2.4.2. Queensland Ports Seagrass Monitoring Program

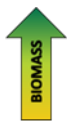
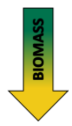
The QPSMP uses a condition index developed for seagrass monitoring meadows based on changes in mean above-ground biomass, total meadow area, and species composition relative to a baseline (**Error! Reference source not found.**). The baseline is ideally calculated using a ten-year average. S eagrass meadows near Abbot Point have been monitored since 2008, and meadows near Mackay and Hay Point have been monitored since 2005 (although no surveys were conducted in 2008 or 2013). Baseline conditions were therefore calculated using all data available and are updated annually until the full 10 years is reached.

The index provides a means of assessing current meadow condition and likely resilience to disturbance. Seagrass condition for each indicator is scored from zero to one and assigned an A–E grade (A. Carter et al., 2019). Scores are multiplied by 100 to align to the MMP and regional report card scale.

To derive a condition score, a meadow classification system defines threshold ranges for the three indicators, in recognition that for some seagrass meadows, these measures are historically stable, while in other meadows, they are relatively variable. Baseline conditions for species composition were determined based on the annual percent contribution of each species to average meadow biomass of the baseline years. Meadows are classified as either single species dominated (one species comprising ≥80% of baseline species) or mixed species (no one species comprises ≥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 (A. Carter et al., 2019).

Each meadow/site score is defined as the lowest grade/score of the three indicators within that meadow where this is driven by biomass or area. Where species composition is the lowest score, it contributed 50% of the overall meadow score, with the next lowest indicator (area or biomass) contributed the remaining 50%.

Table 42. 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		

3.2.4.3. 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 meadow/site remain consistent with MMP and QPSMP reporting. There is no overlap between QPSMP and MMP locations in the Whitsunday Zone, but both programs have seagrass monitoring in the Central and Northern Zones.

Overall scores for each monitoring site/meadow are averaged to generate an overall score for each reporting zone. Final zone scores are graded based on the regional report card scoring ranges previously described, regardless of the program (Table 17). Final scores were calculated in this way (compared to taking an average of the overall indicator scores for each zone) due to the score calculation differences between programs. For a full description and worked example of the combined display approach refer to (A. Carter et al., 2016b).

3.2.5. Litter

3.2.5.1. Baseline Data

The total litter collected at each site within a reporting year is compared to the annual average for that zone collected across the four-year baseline (data from 1st July 2014 until 30th June 2018). Baseline data was used to establish a reference distribution and will be used as the permanent baseline against which data will be compared. Data was scaled from zero to one for the Report Card, with close to zero equating to "highly littered/very poor", and close to one being a "near pristine/very good" state.

The litter indicator scoring method was designed to show any change (increase or decrease) compared to the baseline. For example, if the mean for a financial year is lower than the mean from the four-year baseline, the indicator will be graded as an 'A' to 'C' but would be 'D' or 'E' if there was more litter than previous years (or 'the mean from the baseline period'). For more detailed methods on how the scores for the litter index were generated, refer to 'Litter Score and Grade Proposal for Townsville' (Whitehead & Venables, 2019).

Although the scoring system and thresholds are consistent between the four partnerships, it is not appropriate to directly compare grades/scores between regional report cards. This is because grades/scores for each report card are based on a four-year baseline, which is unique to the dataset in each region. Thus, a 'moderate pressure' score for one partnership is not equal to a 'moderate pressure' score for another partnership. Comparability is only relevant in terms of site improvement or deterioration (e.g., the number of sites that showed less rubbish and thus had a better score than the previous year and vice versa).

3.2.5.2. Statistical Model

Observed debris counts were highly variable, with the Poisson distribution leading to overdispersion. As such, a negative binomial model ($C \sim NB(\mu, \theta)$) was employed, where C is the count, μ is the mean, and ϑ the variance parameter. The expected value may be defined as $\mathrm{E}(C) = \mu$ and variance parameter ($\mathrm{Var}(C) = \mu + \frac{\mu^2}{\theta}$). Under log-link, the log of the mean (μ) is linearly related to the explanatory variables, defined as:

(1) $$\log(\mu) = \beta_0 + \beta_1 x_1 + \beta_2 x_{2+\cdots+\, \beta_p x_p}$$

where $x_1, x_{2,} \ldots\ x_p$ are explanatory variables and $\beta_0, \beta_1, \beta_{2,\ldots}\beta_p$ are regression coefficients. A general linear model was employed, using fixed effects of log(effort) and debris type (plastic bag, plastic bottle, and single-use). Random effects were chosen for year, the administrative zone and site, in addition to random intercept adjustments for zone by year and site by year. A random effect term was also included for correlated random perturbations for the three debris type intercepts within Site.

Count ~ 0 + Type/log(Hours) + (1|Year) + (1|Zone/Year) + (1|Site/Year) + (0 + Type|Site)

3.2.5.3. Effort Standardisation and litter scoring

To achieve a robust, homogeneous basis for litter scores, the model is used to predict the expected mean count for each of the three debris items, producing a standardised unit of effort per site, namely, the expected counts per first hour of sampling. The expected counts for the three items are then converted into a single generic item count, using a weighted mean of the three log counts, and the result is converted to the natural count scale. The weighted means for each of the three items are the components of the leading (i.e., first principal) eigenvector (normalised to 1) from the variance component matrix of the model.

The generic item counts are then used to produce an empirical continuous distribution function, resulting in 'litter scores' per site (0, 1). Additionally, a smoothed curve of the approximating distribution (i.e., survivor function) was used to define fixed break points to discretise scores, with quartiles used as cut-offs (

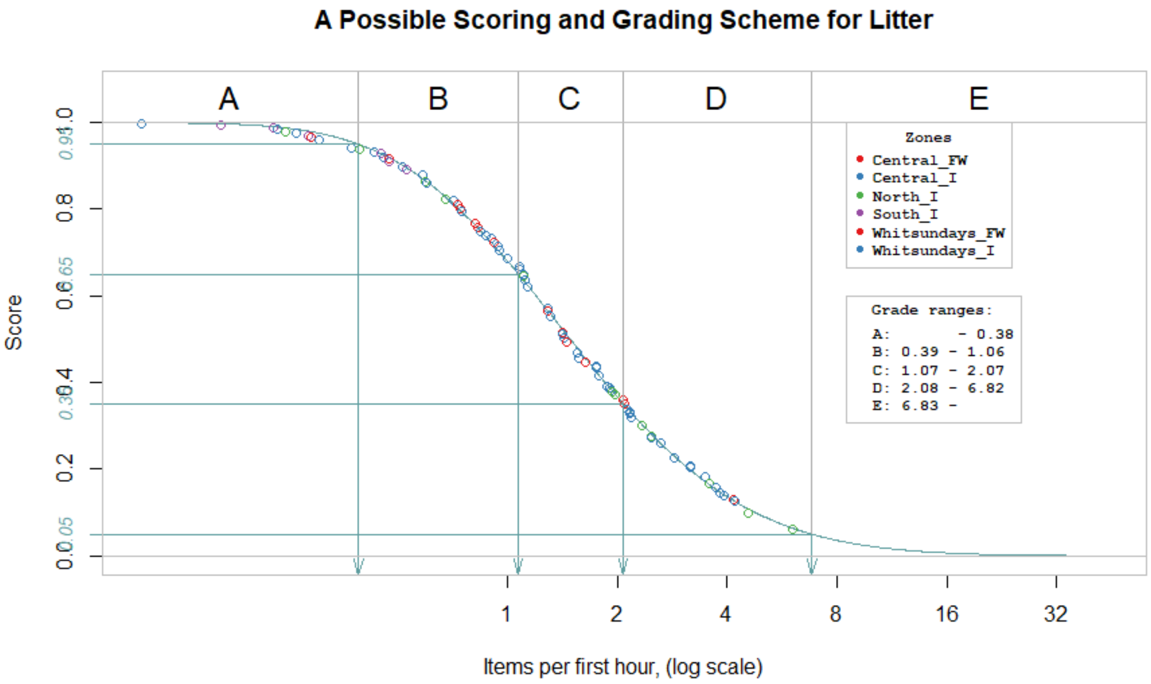


Figure 20).

3.2.5.4. Comparison with an empirical approach for effort standardisation

A model fitting approach was used to standardise effort, which we compare to an empirical approach. For comparability, the slopes of the fixed effects for each item type from the statistical model (described in Section 2.3) were used as exponents to standardise effort for each item type. Item counts (per type) were standardised in the log scale (Equation 2).

(2) $$\log C^* = \log\left(C + \frac{1}{2}\right) - \beta_I \log E$$

Where $\beta_I$is the fixed effect slope for the item type and E is effort. The standardised counts, in log scale, are then averaged per type, site, and year. Counts are then averaged per item type, using first principal component weights, and subsequently transformed back to the natural scale to produce 'generic item counts', equivalent to those produced within the model-based approach.

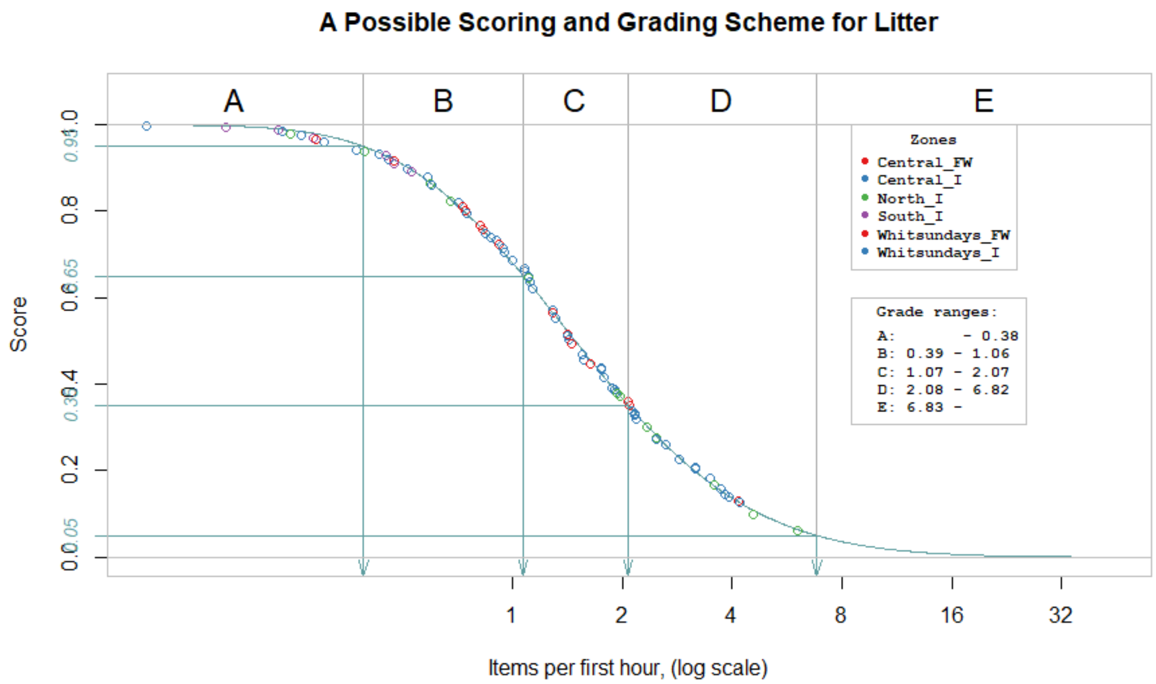


Figure 20. Transformation of standardised collection rates to scores and grades (CPUE vs. scores).

3.3. Human Dimensions

3.3.1. Urban Water Stewardship Framework

For the UWSF, activities were rated using unique assessment criteria, accompanied by guidance notes to explain the intended basis for activity evaluation and any relevant indication or information sources. All activities were rated on a four-point 'ABCD' scale, with score ranges given for each rating category (Table 43). That same system was used for evaluating the practice level when 'rolling up' the scores from individual activities to Management Activity Groups (MAGs) to components and the overall regional grade.

The process of aggregating scores to each MAG level was as per (DES, 2020). It involved averaging across relevant activities and/or activity groups. Where a 'non-applicable' answer was given for an activity, this was accounted for by adjusting the weightings of the remaining activities in the MAG as per (DES, 2020). This process was only required for one particular local government area and was relevant to seven activities, affecting only one Developing Urban MAG, one Established Urban MAG, and two Point Source MAGs.

Table 43. Test Score and rating categories for the Urban Water Stewardship Framework.

Terminology	Practice standard			
Practice Level Rating	A	B	C	D
Practice level description	Innovative and/or Aspirational	Current Best Practice	Minimum Standard	Superseded

Water quality risk framework	Lowest risk	Moderate–low risk	Moderate risk	High risk
Score Range	>17.5	12.5–17.4	5.0–12.4	<5.0

3.3.2. Indigenous Cultural Heritage

3.3.2.1. Scoring and assessment grade development

For the purposes of the 2018 report card, the cultural values indicators, measures, and scoring system were refined, streamlined, and simplified compared to the 2015 report card. The measures used in the 2018 report card provided a more balanced and culturally appropriate approach, with greater emphasis on Traditional Owner values and perspectives than was the case during the assessment for the 2015 report card (Markwell and Associates, 2018). Specifically, the methodology was amended to:

- Increase the focus of Traditional Owner perspective (stories, significance, and associations) of their heritage;
- Apply an expanded definition of Aboriginal heritage values (sites/places/landscapes) throughout the project, which was defined and agreed by TORG members;
- Expand the quantity of sites assessed and the number of zones visited; and
- Establish "baseline" data for the sites, including GPS locations, physical condition of the site, threats to the site, and management options to preserve and protect the cultural values of the site/location/landscape.

Whilst refinements occurred to the cultural heritage values, measures and scoring system, indicators, and zoning remained the same as reported in the 2015 report card. The revised approach aligns to the emerging Indigenous Heritage program design forming under the Reef 2050 Integrated Monitoring and Reporting Program (RIMMReP).

As representatives of the TORG, the Yuwibara Koinjmal/Koinmerburra, Barada/Widi, and Ngaro/Gia/Juru Traditional Owners had an active role in all stages of the data collection and reporting process. For previous methods employed for cultural heritage surveys, refer to the Development of Methods for the Mackay-Whitsunday-Isaac report card Stewardship and Cultural Heritage report[27].

For the purposes of this report, the indicators for each of the zones visited were scored in the field based on the scoring system in **Error! Reference source not found.**. Broad grade/value ranges (A to E a nd very high to very low) in this scoring system matched those used in 2015, but the attribution of + or – to letter grades was better defined in the 2018 assessments (**Error! Reference source not found.**). This did not impact reporting, as the report card does not report + or – along with a letter grade.

Table 44. Scoring system for indigenous cultural heritage.

Score	Grade	Value
4.51–5	A	Very High

[27] https://healthyriverstoreef.org.au/wp-content/uploads/2018/12/development-of-methods-for-the-mackay_stewardship-and-cultural-2015.pdf

4.1–4.5	B+	High
3.51–4	B−	
3.1–3.5	C+	Medium
2.51–3	C−	
2.1–2.5	D+	Low
1.51–2	D−	
1–1.5	E	Very low

To calculate each indicator score, evidence was collected from a broad range of sources, including Traditional Owner knowledge and perspectives on sites, scientific data, and online resources, such as the Queensland Department of Aboriginal and Torres Strait Islander Partnerships (DATSIP) register.

3.3.2.2. Indicator Development

For the purposes of this assessment, indicators were developed at the zone level and enable a holistic assessment of the heritage values, sites, cultural landscape, and management activities within each zone. For the purposes of this assessment, indigenous cultural heritage for each zone is assessed as a combination of five indicators:

1. Spiritual/social value of the zone;
2. Scientific/archaeological value of sites within the zone;
3. Physical condition of sites within the zone;
4. Protection of sites; and
5. Cultural maintenance activities within the zone.

Measures used for each of the indicators are presented in **Error! Reference source not found.**. In the d evelopment of the 2018 report card, the cultural value indicators were streamlined, refined, and simplified, and they provided a more balanced and culturally appropriate picture, with greater emphasis on Traditional Owner values through the inclusion of a direct measure, 'Importance of site to Traditional Owners' into the Spiritual/Social value indicator (**Error! Reference source not found.**). I ndicators remained the same as the 2015 report card (where cultural heritage indicators were developed and reported for the first time), with similar measures to allow for comparison across report cards.

For more information on the development of the cultural heritage indicators and methods, refer to the Development of Methods for the Mackay-Whitsunday-Isaac report card Stewardship and Cultural Heritage report[28].

Table 45. Cultural heritage indicators in the Mackay-Whitsunday-Isaac report card and what was measured to assess them.

Indicator	Measure
Spiritual/Social Value	Traditional Owner knowledge about the site and zone
	Importance of site to Traditional Owners
Archaeological Value	Representativeness—how well sites represent or support the story and traditional land use
	Uniqueness—how rare or distinct identified sites are
	Potential to answer research questions for Traditional Owners and

[28] https://healthyriverstoreef.org.au/wp-content/uploads/2018/12/development-of-methods-for-the-mackay_stewardship-and-cultural-2015.pdf

	archaeologists
Physical Condition	Visible impact of threats from: • Environment, e.g., storm surges; inundation and erosion; for art sites—fading of motifs, insect nests, water flow across art, mineral staining, etc. • Animals, e.g., burrowing, trampling, animal waste • Humans, e.g., tracks, vehicles, paths, trampling, boating activities
	Impact of threats on cultural values—stability or deterioration as a result of visible impact of threats from environment, animals, and humans
Protection of Sites	Registration of sites with the Queensland Department of Aboriginal and Torres Strait Islander Partnerships (DATSIP)
	Management of threats to sites
	Control of access to sites (e.g., through boardwalks, information signage, and fencing)
	No obvious threats (physical protection not needed)
Cultural Maintenance	Documented on-going management arrangements (e.g., Management Plans, Council MOUs, and QPWS MOUs, etc.)
	Engaging and collaborating with stakeholders to fulfil joint cultural values aims (e.g., regular meetings, committees, etc.)

4. Development of Progress to Targets Scoring Methods

To provide information on how the MWI Region is tracking toward targets set for certain aspects, progress to targets will be presented in future report cards and associated documentation. This will enable progress on a year-to-year basis to be assessed and allow comparison across years and trends to be established.

4.1. Calculating Progress to Targets

In order to provide a score on how the region is progressing toward meeting its targets, the following information will be required:

- Baseline condition (i.e., a starting point),
- Current condition, and
- Target condition.

The calculation of the results of the progress to targets in each report card will use the following equation:

$$\text{Progress to target} = ((X-Z) / (X-Y)) \times 100$$

Where:
X is the baseline
Z is the current condition
Y is the target

Determining appropriate targets requires a specific body of work to identify which indicators should have targets and what the targets (and associated timeframes) should be. Where possible, the targets established for the Report Card will align with available targets used in the GBR Report Card and other relevant programs to provide consistency.

5. Confidence, Limitations, and Recommendations

5.1. Confidence Associated with Results

The regional report cards use the 2015 GBR Report Card as the basis for communicating confidence (Australian and Queensland Governments, 2015). 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 ("criteria") that contribute to confidence. 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 key difference in how the regional report cards use the 2015 GBR Report Card method for communicating confidence is how confidence criteria are weighted. Criteria that are seen to have more importance for the MWI Region have been given a higher weighting when determining the overall confidence.

5.1.1. Methods

Report card confidence levels are determined using the five criteria explained below (Table 46).

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 criterion is weighted 0.36 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. This criterion minimises compounded errors. The score is weighted 0.71 for this criterion so as not to outweigh the importance of the representativeness criterion.

Representativeness

This criterion shows the confidence in the representativeness of monitoring/data to adequately report against relevant indicators. It takes into consideration the spatial and temporal resolution of the data as well as the sample size. This criterion is considered the most important when considering confidence in the MWI Report Card and as such is given a weighting of 2.

Directness

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

Measured Error

The purpose of this criterion is to incorporate an estimate of uncertainty when an indicator is measured. This score is weighted 0.71 for this criterion so as not to outweigh the importance of the representativeness criterion.

Table 46. Scoring matrix for each criterion used to assess confidence.

Maturity of methodology (weighting 0.36)	**Validation** (weighting 0.71)	**Representativeness** (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

5.1.2. Scoring

For all indicators where a condition score was reported, each criterion is scored 1 (lowest) to 3 (highest) (Table 46). The score of each criterion is weighted accordingly, and the total confidence score is calculated by adding all weighted scores of the five criteria. The final score is assessed against a 1 to 5 qualitative confidence ranking (Table 47). The final scores and the associated confidence rankings have been adjusted from the previous report cards to reflect the MWI specific weightings applied to the criteria. The confidence ranking (out of 5) is then presented in the Report Cards.

5.1.2.1. Scoring Confidence Criteria in the MWI Report Card

When scoring confidence for indicators in the MWI Region, confidence of an indicator was considered separately for the different reporting zones. This was because for some indicators, there were different sample sizes, programs, or divergent methods contributing to the condition scores of an indicator depending on the zone.

The representativeness criterion was 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 the temporal scale representativeness was low (i.e., 1), the score used for representativeness was low (i.e., 1).

Occasionally, data from different programs were used to derive condition scores for an indicator in the same reporting zone. For example, in the Central Zone, NQBP and MMP programs provided water quality data, but there was a difference in confidence in the data provided by the two programs. To score confidence in such a situation, where two or more methods/programs/datasets contribute to an overall indicator score in the same reporting zone, the following decision rule was applied:

When data are partitioned equally between the two methods/programs/datasets, confidence is scored conservatively (i.e., the lower of two scores is applied where relevant),

When data are not partitioned equally between the methods/programs/datasets, confidence is scored by using the score for the dominant method/program/dataset.

Based on these rules, in the Central Zone, confidence is scored by considering the Ports program because it has nine sampling sites compared to the MMP's two sampling sites.

5.1.2.2. Final Confidence Scores for Presentation in the MWI Report Card

Once each criterion is scored, the appropriate weighting is applied, and these scores are added together to give a final score. An overall ranking for confidence for each indicator in each zone is applied based on the final score (Table 47). For presentation purposes, confidence scores are aggregated into a single score for freshwater basin, estuarine, and inshore and offshore marine indices.

Indicator Level

When confidence scores for an indicator are different across only two reporting zones, confidence is scored conservatively (i.e., the lowest total score of the pair is used) to determine the overall rank of the indicator,

When confidence scores for an indicator are different across three or more zones, the median of all the total confidence scores between the reporting zones is used to apply the overall rank of the indicator.

For example, in the Don Basin, confidence in the fish barrier indicator was lower than confidence in this indicator across the other four basins because there were differences in ground truthing between the Don and the other basins. Therefore, the freshwater fish barriers indicator score used was the median of the final confidence score and associated ranking.

Indicator Category and Index Level

When confidence scores for an indicator or indicator category are different, the median of all the total confidence scores between the indicator or indicator category is used to apply the overall rank of the indicator category or index.

Table 47. Overall confidence score, associated ranking, and how ranking is displayed in the Report Card.

Final Confidence Score Range	Ranking	Display in Report Card
>11.7 to 13.5	Five	VERY HIGH ●●●●●
>9.9 to 11.7	Four	HIGH ●●●●○
>8.1 to 9.9	Three	MODERATE ●●●○○
>6.3 to 8.1	Two	LOW ●●○○○
4.5 to 6.3	One	VERY LOW ●○○○○
<4.5	Zero	NO DATA ○○○○○

5.1.2.3. Confidence in Human Dimensions Indicators

The results for Urban Water Stewardship (Table 48) and Indigenous Cultural Heritage in the report card were rated in terms of the confidence based on the same methods used for other report card indicators. For Indigenous Cultural Heritage reporting, the representativeness criterion was assessed by considering the number of sites recorded as part of the assessment compared to the number listed in the DATSIP register and any known but unlisted sites for the reporting zone.

Table 48. Confidence associated with Urban Water Stewardship Results for the 2020–21 monitoring period. Confidence criteria are scored 1 to 3 and then weighted by the value identified in parentheses as per the UWSF implementation manual (DES, 2020). Final scores (6–18) are additive across weighted confidence criteria. Summary rationales are given below each criterion.

	Maturity of methodology (x0.4)	Validation (x0.7)	Representativeness (x4.0)	Directness (x0.7)	Measured error (x0.7)	Final	Rank
UWSF 2020–21	2	1	2	1	1	**11**	**2**
Rationale	UWSF ratings based on ISP-endorsed method	No reference to use of primary data for UWSF activity ratings (pre and during workshop)	Spatial (3): All 3 LGAs in RRC region included in assessment Temporal (1): This is the first year the finalised UWSF assessment method was done in the region (even though a pilot was done in the Whitsunday SC the year before)	The UWSF assessment process was applied at the LGA urban area urban footprint scale (i.e., not to particular areas within an LGA) and based on the most common scenario (i.e., not to a particular case).	No measure of error quantified		

5.2. Limitations and Recommendations

The quality and accuracy of report card results have improved since the pilot release in 2014. However, it is important to highlight and acknowledge the limitations of our existing approach.

Current Limitations

Spatial representativeness of freshwater basins is still low, with only one or two sites per basin. Additional monitoring throughout all basins is a critical step to improving confidence in basin scale reporting.

The **Proserpine Basin was not given a water quality score** in the 2021 Report Card following a review of the available water quality data that suggested the monitoring site was influenced by tidal action and therefore was not fully representative of the freshwater environment. It is anticipated that this tidal action may also impact the observed concentration of nutrients (DIN and FRP). As a result, sediment and nutrient condition were not reported for the Proserpine Basin in the 2021 Report Card. HR2RP is investigating alternative sites in the Proserpine Basin that could be used for future water quality monitoring.

The **method produced for assessing multiple freshwater sites** was reviewed during the production of the 2020 Report Card. While it was determined that there are limitations to the method currently used for assessing multiple freshwater sites, it is the best option available given HR2RP's resources and data availability. However, refinements to this methodology may be incorporated in the development of future report cards.

Flow was incorporated into the 2021 Report Card for the fourth consecutive year. Considerable work has been undertaken between the 2018 and 2021 Report Card releases to explore opportunities to fill flow data gaps in basins and estuaries with additional sites and pre-development data currently under investigation. Questions remain on the validity of the model in response to the data available, especially during periods of low or now flow. **A review of the flow indicator tool** was recommended at the 2020 ISP and TWG meetings and has yet to be progressed.

Low confidence in estuarine pesticide data has been highlighted since the 2014 Pilot Report Card. In 2017, the Partnership established and funded a supplementary pesticide monitoring program, with monitoring commencing in the 2017–18 wet season. The monitoring program was scoped with the intention of improving the temporal representativeness of sampling through increasing the number of monitoring events from less than 6 to approximately 18 in the current assessment. The results obtained through this monitoring program were reported for the first time in the 2019 Report Card. This year's results further our understanding of pesticide concentrations in MWI estuaries.

Marine pesticides sampling across zones is not standardised in terms of the contaminants recorded, and thus cannot be directly compared. Furthermore, representation across time and space is not equal between zones. For example, in the 2021 reporting cycle, in the northern zone there was one passive sampler deployed that was removed before the onset of the rainy season, whereas in the central zone there were 14 deployments across four sites.

A knowledge gap was identified in previous Report Cards for the Southern Zone. Baseline water quality, seagrass, and coral monitoring was commissioned by the Partnership in 2017, and a long-term monitoring program has been established for these indicators. The 2018 Report Card saw the release of a water quality score for the Southern Zone for the first time. The 2019 Report Card reported on pesticides and coral for the first time. With the release of seagrass scores in the 2021 Report Card, the **Partnership continues to fill knowledge gaps in the Southern Zone**.

Seagrass reporting does not allow for direct comparison across marine reporting zones. Improved integration of the different seagrass indicator programs is being addressed by the seagrass working group as part of the Reef Integrated Monitoring and Reporting Program (RIMReP, directed by GBRMPA).

There are limitations around the **understanding of riparian, wetland, and mangrove/saltmarsh habitats**. The Partnership is currently working with the TWG and riparian and wetland data providers/experts to improve report card indicators for wetland and riparian extent and ensure comparability over time, most recently during the production of the 2019 Report Card.

Future Improvements

Exploration of estuary and marine fish indicators (including the potential use of citizen science),

- Exploring the option to use eReefs modelling as part of condition assessments,
- Expansion of water quality monitoring in offshore zones by integrating data from (see pg. **Error! Bookmark not defined.**),
- Expansion of water quality monitoring in freshwater basins to include the upper and middle sections of catchments, and
- Moving towards the inclusion of reporting progress-to-targets.

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7. Appendices

Appendix A—Data Sources

Table A1. Data sources for each index reported in the 2020 MWI Healthy Rivers to Reef Report Card.

Environment	Basin/Estuary/ Marine Zone	Index (Indicator Category)	Program	Data Source
Freshwater Basins	Don Basin Proserpine Basin O'Connell Basin Pioneer Basin Plane Basin	Water Quality (including pesticides)	GBRCLMP	Pesticide data available through the Water Quality & Investigations Pesticide Reporting Portal Current Contact: Dr Reinier Mann—Science Leader, DES (reinier.mann@des.qld.gov.au)
		Riparian Extent	Built-for-purpose	Current contact: Partnership Staff (technical@healthyriverstoreef.org.au)
		Fish Barriers		
		Impoundment Length		
		Wetland Extent		
		Fish	Regional Report Card Monitoring Program	Current Contact: David Moffatt—Principal Environment Officer, DES (david.moffatt@des.qld.gov.au)
		Flow	Streamflow data—Water Monitoring Information Portal (QLD Government) Rainfall data—SILO (QLD Government) and BoM	Streamflow Online Database Rainfall Online Databases for SILO and BoM
Estuarine	Gregory River O'Connell River St Helens/Murray Creek Vines Creek Sandy Creek Plane Creek Rocky Dam Creek Carmila Creek	Water Quality (including pesticides)	DES Estuary Monitoring Program	Current Contact: Dr Michael Newham—Senior Scientist, DES (michael.newham@des.qld.gov.au)
		Pesticides (additional monitoring)	Regional Report Card Monitoring Program	Current contact: Partnership Staff (technical@healthyriverstoreef.org.au)
		Riparian Extent		
		Mangrove and Saltmarsh Extent	Built-for-purpose	
		Fish Barriers		
Inshore Marine	Northern	Water Quality (including pesticides)	NQBP Abbot Point Ambient Water Quality Monitoring Program	Annual Reports

Table A1. Data sources for each index reported in the 2020 MWI Healthy Rivers to Reef Report Card.

Environment	Basin/Estuary/ Marine Zone	Index (Indicator Category)		Program	Data Source
					Current contact: Nicola Stokes—Senior Environmental Advisor, NQBP (environment@nqbp.com.au)
		Coral		NQBP Abbot Point Coral Monitoring Program	Online Database
		Seagrass		NQBP Abbot Point Seagrass Monitoring Program	Online Database
				Seagrass Watch	Online Database
	Whitsunday	Water Quality		GBR MMP for Inshore Water Quality	Annual Reports Turbidity and Chlorophyll-*a* Online Database Current contact: Dr Renee Gruber—Biological-Chemical Oceanographer, AIMS (r.gruber@aims.gov.au)
		Coral		GBR MMP for Inshore Coral Reefs	Annual Reports Online Database Current contact: Angus Thompson—Coordinator Inshore Reef Benthic Monitoring, AIMS (a.thompson@aims.gov.au)
				RCA	Annual Reports Current contact: Jenni Calcraft—Great Barrier Reef Project Coordinator, RCA (jenni@reefcheckaustralia.com)
		Seagrass		GBR MMP for Inshore Seagrass (including Seagrass Watch)	Annual Reports Seagrass Watch Online Database Current contact: Len McKenzie—Principal Research Officer, JCU (len.mckenzie@jcu.edu.au)
	Central	Water Quality	Pesticides	GBR MMP for Inshore Pesticides	Annual Reports Current Contact: Dr Reinier Mann—Science Leader, DES (reinier.mann@des.qld.gov.au)

Table A1. Data sources for each index reported in the 2020 MWI Healthy Rivers to Reef Report Card.

Environment	Basin/Estuary/ Marine Zone	Index (Indicator Category)	Program	Data Source
		Nutrients, Water Clarity, Chlorophyll-*a*	GBR MMP for Inshore Water Quality	Annual Reports Turbidity and Chlorophyll-*a* Online Database Current contact: Dr Renee Gruber—Biological–Chemical Oceanographer, AIMS (r.gruber@aims.gov.au)
			NQBP Mackay and Hay Point Ambient Water Quality Monitoring Program	Annual Reports Current contact: Nicola Stokes—Senior Environmental Advisor, NQBP (environment@nqbp.com.au)
		Coral	NQBP Mackay and Hay Point Coral Monitoring Program	Online Database
		Seagrass	NQBP Mackay and Hay Point Seagrass Monitoring Program	Online Database
			GBR MMP for Inshore Seagrass (including Seagrass Watch)	Annual Reports Seagrass Watch Online Database Current contact: Len McKenzie—Principal Research Officer, JCU (len.mckenzie@jcu.edu.au)
	Southern	All indices	Partnership-funded SIP	Current contact: Partnership Staff (technical@healthyriverstoreef.org.au)
		Seagrass	Seagrass Watch	Online Database
	All inshore and urban sites	Litter	AMDI Database	Online Database
Offshore Marine	Offshore	Water Quality	BoM	Current contact: Partnership Staff (technical@healthyriverstoreef.org.au)
		Coral	AIMS LTMP	LTMP Annual Reports and Database Current contact: Angus Thompson—Coordinator Inshore Reef Benthic Monitoring, AIMS (a.thompson@aims.gov.au)

Table A1. Data sources for each index reported in the 2020 MWI Healthy Rivers to Reef Report Card.

Environment	Basin/Estuary/ Marine Zone	Index (Indicator Category)	Program	Data Source
			RCA	Annual Reports Current contact: Jenni Calcraft—Great Barrier Reef Project Coordinator, RCA (jenni@reefcheckaustralia.com)

GBRCLMP = Great Barrier Reef Catchment Loads Monitoring Program, DES = Department of Environment and Science, NQBP = North Queensland Bulk Ports, MMP = Great Barrier Reef Marine Monitoring Program, RCA = Reef Check Australia, UQ = University of Queensland, SIP = Southern Inshore Monitoring Project, BoM = Bureau of Meteorology, AMDI = Australian Marine Debris Initiative, AIMS = Australian Institute of Marine Science, JCU = James Cook University, LTMP = AIMS Long-term Monitoring Program, Great Barrier Reef Marine Park Authority = GBRMPA, RAP = Representative Areas Program.

Appendix B—Litter Metric

7.1.1. Appendix B1: Filtering Methods

Document prepared and supplied by Jordan Gacutan (University of New South Wales (UNSW), Sydney)

Data filtering methods for the litter metric in regional report cards

Prepared for: Regional report card partnerships—the Dry Tropics Partnership for Healthy Waters, Partnership for Wet Tropics Waterways, and MWI Healthy Rivers to Reef Partnership.

On behalf of: Tangaroa Blue Foundation and UNSW, Sydney

Summary:
The following brief provides an overview of the methods used to process the Australian Marine Debris Initiative (AMDI) Database (henceforth **'raw data'**) to a '**custom dataset'**, as in input for the model described in (Whitehead & Venables, 2019).

Rationale:

- Support continued monitoring of litter to detect changes due to source reduction/policy implementation within GBR catchments.
- Standardise litter reporting across regional report card partnerships, supported by the AMDI Database.
- Implementation of AMDI in reporting and decision-making.
- Support the United Nations Sustainable Development Goals [14.1.1, marine plastic pollution].

Description
This project extends the statistical model and analyses presented in the report "Litter Score and Grade Proposal for Townsville". The existing model has been implemented for the Dry Tropics Partnership for Healthy Waters reporting region. The model and required data processing have been extended to the Wet Tropics and MWI reporting regions.

In December 2020, Tangaroa Blue Foundation and UNSW, Sydney were asked to provide a data pipeline to process raw data from the AMDI Database for use in a statistical model. The pipeline facilitates the extraction and processing of data for future reporting needs. Tasks to be performed by UNSW are described in the '**data sharing agreement**' between Tangaroa Blue Foundation, UNSW, and each Partnership.

The data pipeline involves filtering (1) data quality, (2) spatially to the reporting area, and (3) model use, described in Figure B1. Treatment of **ReefClean** data is described in Section 1.

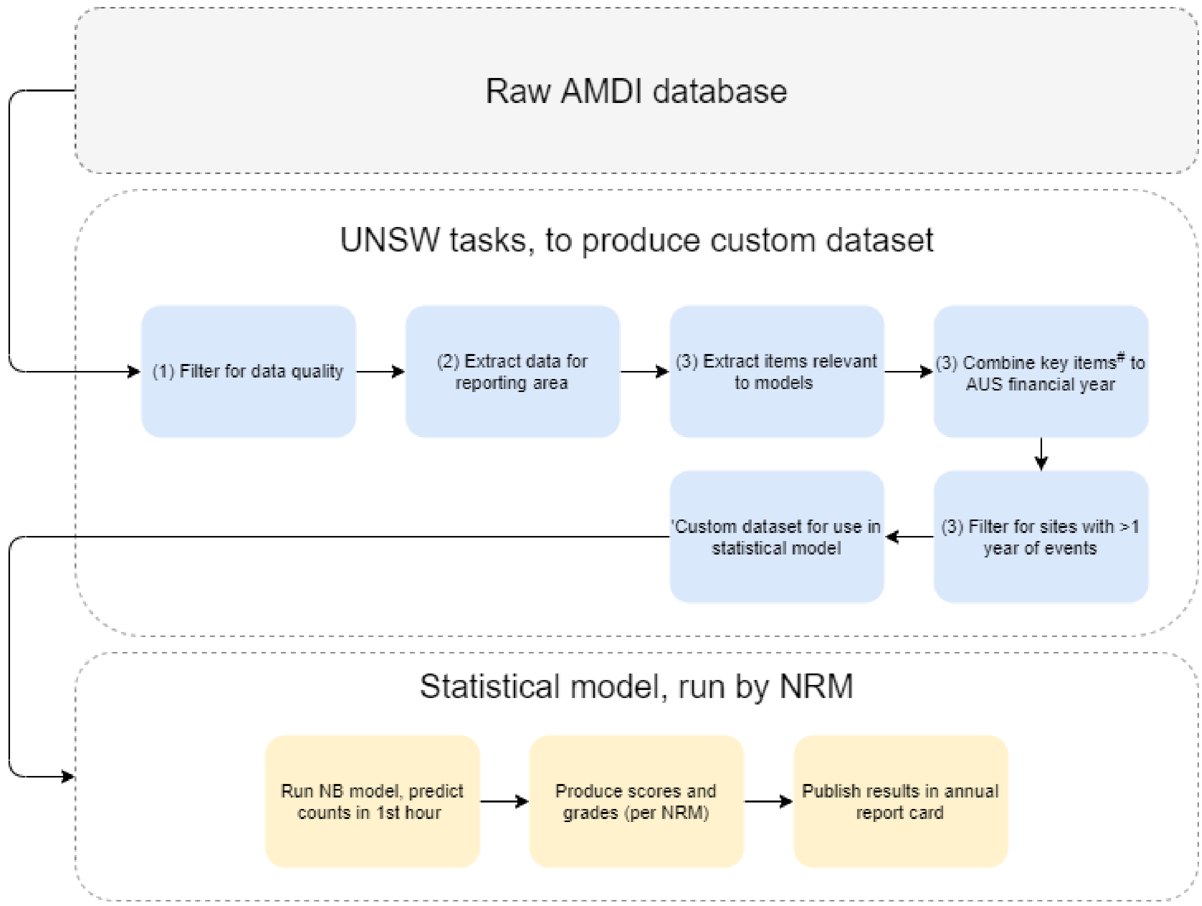

Figure B1. Data pipeline for the project to extract key items (#) (plastic bags, plastic bottles, single-use cutlery, and cigarettes) from the Australian Marine Debris Initiative (AMDI) Database for annual use in a statistical model for the production of litter scores and grades. NRM = Natural Resource Management area pertaining to the partnership reporting region, NB = Negative binomial.

1) Filter for data quality

Filtering for data quality is taken from methods and related scripts of the publication, 'Continental patterns in marine debris revealed by a decade of citizen science' (Gacutan et al., 2022). The filters used are presented in Table B1.

ReefClean data was identified and processed separately, aggregating all transects and debris collected in surrounding areas, to align with data from community clean-ups stored within the AMDI Database. Loss of resolution was justified by model needs.

Table B1. Data quality filters used to process the Australian Marine Debris Initiative (AMDI) Database. Filters are in sequential order.

Cleaning theme	Tool used	Cleaning step	Examples / Description
Original database	DB Browser for SQL lite	Original database (Downloaded January 2021)	N/A
Limit to Australia	ArcMap 10.6	Remove foreign entries	Hawaii/Tonga/NZ/PNG/Timor Leste
	ArcMap 10.6/Nearmap	Remove Australian external territories	Christmas island/Norfolk Island/Cocos Islands
Limit timeframe	DB Browser for SQL lite	Filter for Jan 2009–Dec 2018	-

Table B1. Data quality filters used to process the Australian Marine Debris Initiative (AMDI) Database. Filters are in sequential order.

Clean by event entries	DB Browser for SQLite/R	Remove duplicate sites	-
		Clean-up time <0.25 hours	Non-exhaustive clean-up.
		One volunteer, <1 kg	A single volunteer collecting less than 1 kg indicates a non-exhaustive or informal clean-up
Clean by event entries	R/Excel	One volunteer, >10 hours	Single volunteer cleaning more than 10 hours (indicates multiple days/weeks/months collecting)
		Not a clean-up	Daily walk / hike / Anecdotal as described in notes
		Estimated/incomplete	Stated in event notes
		Anecdotal (stated in notes)	Stated in event notes
		Clean-up over multiple days/weeks/ month	Stated in notes, hours reported > 24
		Data quality poor	Number of volunteers/time/date or other details missing.
		Single item reported	Stated in event notes
		Timor Leste	Incorrectly entered as Australian site w/incorrect coordinates
		Remove fishing line bin entries	Fishing bin Initiative hosted in the AMDI Database
Event clean (Ratios of variables used to clean database)	R	bags/volunteer >8	Volunteers collected more than 8 bags each (accuracy of data)
		Weight/volunteer >10 & wt /bag >10	Volunteers collected more than 10 bags weighing 10 kg each (accuracy of data)
		Hours per volunteer >10 (i.e., each volunteer worked + 10 hrs)	Indicates poor data quality or multiple clean-ups over a longer timeframe
Clean events by item entries	R	Single item	Single item reported at the event (not in notes)
		Components <10	Less than 5 item categories reported
		Estimated (div 10, integers)	Entries with integers divisible by 10 (estimated item categories >50%)

2) Extract data for reporting areas:

Processed data were classified according to partnership reporting areas and ‘water type’, as defined in Environmental Protection (Water) Policy 2009 (Qld, s. 12). Reporting areas and water types were classified by provided spatial data. Provided data and **custom dataset** were manipulated in ArcMap 10.7.

Table B2. Provided shapefiles used to classify data by each partnership’s reporting needs.

Shapefile name	**Providing organisation**
Townsville boundary for Jordan.kmz	Dry Tropics Partnership for Healthy Waters
FW_report_zones_dis.shp 20160201_Wet_Tropics_Estuaries.shp Inshore_Zones_Dissolve.shp	Partnership for Wet Tropics Waterways

Amended_Marine_Region.shp	
HR2R_ReportingZones_v4_15March2016.shp	MWI Healthy Rivers to Reef Partnership

3) Manipulate extracted data for use in model:

To align with model structure, the following steps were performed:

a) Policy relevant items (plastic bags, plastic bottles, single-use items) were extracted.
b) Events were classified per financial year. Multiple events per site per year were classified as 'Replicates'.
c) To avoid model collapse, sites with less than one financial year were filtered from analysis.

The resulting data were then provided to each regional report card partnership.

7.1.2. Appendix B2: MWI Sample Sites 2015–2021 FYs

Table B3. Locations where data have been collected in the Mackay-Whitsunday-Isaac Region from the 2015–2021 financial years.

Zone	Site Type	Site	2021 Survey		Past Surveys (FYs)					
			Vol. No.	Vol. Hours	2020	2019	2018	2017	2016	2015
Northern	Inshore	**Don River Mouth, Bowen***	45	24	1	1				
		Queens Beach, Bowen*	36	18	1	1				
		Gloucester Island, Eastern Side	15	12			1		1	
		Gordon Beach*	-	-		1			1	
		Horseshoe Bay, Bowen	-	-					1	
Whitsunday	Urban	Proserpine Town*	-	-	1					
		Urban Surrounds, Airlie Beach	-	-		1	1	1	1	
		Urban Surrounds, Cannonvale	-	-			1		1	
		Cannonvale Beach	-	-		1				
	Inshore	Bluff Point North East Side, Pioneer Bay*	-	-	1					
		Border Island	6	9	1		3		1	
		Coral Beach, Airlie Beach*	6	9	1					1
		Dalwood Point Bay	12	3						
		Dingo Beach*	6	6	1					
		Eagle Bay, Shaw Island	-	-	1		1			
		East Beach	12	3						
		Gap Beach	33	3						
		George Point	6	9	1	4			2	
		Hook Island, East	6	9	1	1				
		Luncheon Bay, Hook Island*	24	6	1					
		Mackerel Bay, Hook Island*	51	36	1	1			1	
		Pigs Head Bay	21	4.5						
		Saba Bay, Hook Island*	42	21	1	3	1			3

Table B3. Locations where data have been collected in the Mackay-Whitsunday-Isaac Region from the 2015–2021 financial years.

Zone	Site Type	Site	2021 Survey		Past Surveys (FYs)					
			Vol. No.	Vol. Hours	2020	2019	2018	2017	2016	2015
		Solway Circuit, Whitsunday Island	-	-	1	2				
		Southeast Bay, Long Island*	6	9	1		1		1	1
		South End of Runway, Hamilton Island	-	-	1			2	2	
		Southern Tip, Whitsunday Island*	18	9	1					
		Turtle Bay, South Molle Island*	36	27	1	1				
		Turtle Bay, Whitsunday Island*	18	21	1	1	2		2	
		Airlie Beach	-	-			1		1	2
		Armit Island	-	-			1		1	
		Billbob Bay, Shaw Island	6	9		1	1			
		Blue Pearl Bay, Hayman Island*	6	9		2				
		Bluff Point	-	-					1	
		Coral Seas Boardwalk, Airlie Beach	-	-		1				
		Double Cone Island	6	9					1	
		Driftwood Bay, Hamilton Island	-	-						1
		East Neck Bay, Shaw Island	30	7.5						
		Genesta Bay	-	-			1		1	1
		Grassy Island	-	-			1		1	
		Grimstone Point, Central Beach, Western Side	-	-			1	1		
		Grimston Point East	36	21						
		Grimstone Point, Northern Beach, Western Side	6	9		2	1		3	1
		Gumbrell Island	-	-			1		1	
		Haselwood Island, Southern End	-	-		1			1	1
		Hook Island	-	-				1	3	
		Keyser Island	12	3						
		Maher Island	-	-					1	
		Maher Island East	-	-			2			
		Neck Bay, Shaw Island	-	-			1			
		Northern Pine Bay, South Molle Island	-	-						
		Pandanus Bay, Long Island	6	9		1				1
		Pine Bay, South Molle Island	-	-						2
		Plantation Bay, Lindeman Island	-	-					1	
		Roma Point, South Molle Island	-	-		1	2			
		Shute Harbour	-	-			1	1	2	
		Shute Harbour, Slipway*	-	-		1				
		South Molle Island	-	-		1			4	

Table B3. Locations where data have been collected in the Mackay-Whitsunday-Isaac Region from the 2015–2021 financial years.

Zone	Site Type	Site	2021 Survey		Past Surveys (FYs)					
			Vol. No.	Vol. Hours	2020	2019	2018	2017	2016	2015
Central		**South Bay**	63	16.5						
		White Bay	78	25.5						
		Whitsunday Island, South of Hook Pass	-	-				5	1	
	Urban	Mackay City Centre	-	-	1	12	40			
		Mackay Industrial Precinct	-	-	1	1	1			
		Pioneer River, Glenella Connection Road North Mackay*	57	30	1	2				
		Sarina Townsite	-	-	1	3				
		Bucasia Beach	-	-		2	1			
		River Street Park, Mackay*	-	-		3	1			
	Inshore	Armstrong Beach*	-	-	1					
		Cattle Bay	12	6						
		Conway Beach*	69	46.5	1	1				
		Half Tide Beach, Hay Point*	75	37.5	1	11	2	1		
		Harbour Beach, Mackay*	123	46.5	1	9	3	1	7	
		Lamberts Beach, Mackay	-	-	1	1	2			
		Louisa Creek Beach, Hay Point*	42	24.75	1					
		Town Beach, Mackay*	9	3	1	1	1		1	
		Wilson Beach, Conway*	24	12	1	1				
		Blacks Beach	-	-		3	1			
		Blacksmith Island, Whitsundays	-	-		1		1		
		Brampton Island, Multiple Sites	-	-		1	1			
		Cape Conway	6	9					1	1
		Dinghy Bay West, Brampton Island	12	3				1		1
		Eimio Beach	-	-		1	2			
		Far Beach, Mackay	30	45			1			
		Goldsmith Island, Whitsundays	6	9		1	1	1		
		Hay Point	18	27			1	2		
		McEwens Beach	-	-			1		6	
		Midgeton Beach	6	6						
		Penrith Island	21	12						
		Sarina Beach	6	9			1		1	
		South Bay	12	6						
		St Helens Beach	6	4.5						
Southern	Inshore	**Avoid Island, The Percy Group**	6	9	1		2	1		
		Clairview Beach North*	-	-	1	1				
		Davidson Bay	21	15						
		North Beach	51	18						
		South Beach	18	3						

Table B3. Locations where data have been collected in the Mackay-Whitsunday-Isaac Region from the 2015–2021 financial years.

Zone	Site Type	Site	2021 Survey		Past Surveys (FYs)					
			Vol. No.	Vol. Hours	2020	2019	2018	2017	2016	2015
		Treble Island	21	12						