HEALTHY RIVERS TO REEF PARTNERSHIP
MACKAY-WHITSUNDAY-ISAAC

METHODS FOR THE MACKAY-WHITSUNDAY-ISAAC 2019 REPORT CARD

ENVIRONMENTAL INDICATORS

Authorship statement

The Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership (henceforth referred to as 'the Partnership') Methods for the Mackay-Whitsunday-Isaac 2019 Report Card technical report was compiled by the Partnership's Technical Officers, Alysha Lee, Jessica Gillespie, Talen Rimmer and Elly Pratt.

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1. Executive Summary

The Mackay-Whitsunday-Isaac 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 the Region's waterways. The Partnership's 2014 Pilot report card was released in October 2015. The 2019 report card (reporting on data from 2018-2019) is the sixth report card released by the Partnership.

The purpose of this document is to provide detailed information on the methods used to produce the Mackay-Whitsunday-Isaac 2019 report card. This includes condition assessments of the environmental indicators in freshwater basins, estuaries, inshore and offshore marine environments, in addition to agricultural stewardship results. Specifically, this document describes:

- The indicator selection process;
- The data collection methods; and
- The scoring methods.

The report card assesses different ecosystem health (environmental) indicators to report on overall condition of the Region's waterways. Scores for indicators are aggregated together depending on the aspect of the environment they assess (Figure i), and follow three key themes: water quality, habitat and fish.

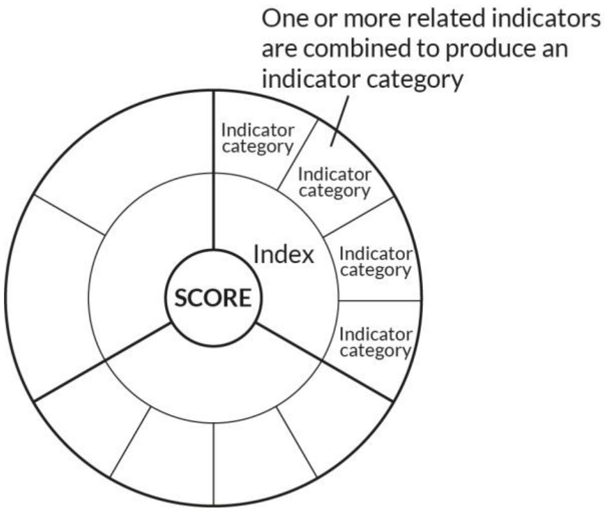

Figure i. Terminology used for defining the level of aggregation of indicators and how they are displayed in coasters in the report card.

The indicators for freshwater basins are grouped within the water quality, habitat and hydrology and fish indices. The water quality index includes sediment (total suspended solids), nutrients (dissolved inorganic nitrogen and filterable reactive phosphorus) and pesticides as the indicator categories. Water quality data for freshwater basins is provided by the Great Barrier Reef Catchment Loads Monitoring Program. The habitat and hydrology index includes indicators relating to habitat modification (impoundment length and fish barriers), flow, riparian extent and wetland extent. Importantly, wetland methods were updated for the 2019 report card based on newly available mapping data from the Queensland Herbarium, and thus results from the 2013 assessment have been updated in the 2019 results document. Freshwater basin zones reported in the Mackay-Whitsunday-Isaac report card are the Don Basin, Proserpine Basin, O'Connell Basin, Pioneer Basin and Plane Basin.

The indicators for estuaries are grouped within the water quality, habitat and hydrology and fish indices. The water quality indicator includes physical and chemical indicators (dissolved oxygen and turbidity), nutrient indicators (dissolved inorganic nitrogen and filterable reactive phosphorus) and pesticide indicators. Water quality data for freshwater basins is provided by the Great Barrier Reef Catchment Loads Monitoring Program, the Department of Environment and Science (DES) Estuary Monitoring Program, and a Partnership-funded Estuary Pesticide Monitoring Program. The habitat and hydrology index includes fish barriers, flow, riparian extent and mangrove and saltmarsh extent. There is currently no fish index for estuaries in the Region. Developing a fish index is a priority for the Partnership and requires further identification of indicators and appropriate methodology before monitoring can take place. The eight estuaries reported in the Mackay-Whitsunday-Isaac 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.

The indicators for the inshore marine environment are grouped within the water quality, coral, seagrass and fish indicators. The water quality index includes water clarity (total suspended solids, turbidity and secchi depth), nutrients (oxidised nitrogen, particulate phosphorus and particulate nitrogen) and pesticide indicators. The coral index includes coral cover, macroalgae cover, rate of coral cover increase, density of juvenile corals and community composition indicators. Finally, the seagrass index includes above-ground biomass, meadow area and species composition, and/or percentage cover, tissue nutrient status and reproductive effort indicators. Data for water quality, coral and seagrass are provided through the Great Barrier Reef Marine Park Authority Marine Monitoring Program (MMP), North Queensland Bulk Ports (NQBP) Abbot Point/Mackay Hay Point Marine Monitoring Program and the Partnership-funded Southern Inshore Monitoring Program. The inshore marine environment is divided into four zones, from north to south: the Northern, Whitsunday, Central and Southern inshore marine zones. The offshore marine reporting zone is not divided any further and extends from the State jurisdiction boundary to the Eastern boundary of the GBR Marine Park.

The indicators for the offshore marine environment are grouped within the water quality, coral and fish indices. The water quality index includes water clarity (total suspended solids) and chlorophyll-*a* indicators, which are measured using remote sensing data. The coral index includes coral cover, rate of coral cover increase and density of juvenile coral indicators. The inshore and offshore marine environment are reported separately in the Mackay-Whitsunday-Isaac report card, with the State Jurisdiction boundary separating the inshore and offshore reporting areas. The offshore marine reporting zone extends from the State Jurisdiction boundary to the Eastern boundary of the Great Barrier Reef Marine Park. Data for the water quality index was collected from the Bureau of Meteorology (BoM) dashboard. Data for coral was collected from the Long-Term Monitoring Program (LTMP) and Representative Areas Program (RAP).

Stewardship is 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'. Agricultural management practice adoption assessments align to agricultural stewardship reported through the GBR water quality report card [1] and provides a snapshot in time of the

[1] https://www.reefplan.qld.gov.au/tracking-progress/reef-report-card

percentage (%) of area managed using best management practice systems. Agricultural stewardship practices for sugarcane, horticulture and grazing were reported for the 2019 report card.

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Terms and Acronyms

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	AM is annual median or mean of measured indicator
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 (including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part). It includes diversity within species and between species, and diversity of ecosystems
Chl-*a*	Chlorophyll-*a*: A measure of overall phytoplankton biomass. It is widely considered a useful proxy to measure nutrient availability and the productivity of a system
DDL	Declared Downstream Limit
DES	Department of Environment and Science, Queensland (formally the Department of Science, Information Technology and Innovation)
DIN	Dissolved Inorganic Nitrogen
DNRME	Department of Natural Resources, Mines and Energy, Queensland
DO	Dissolved Oxygen
Ecosystem	A dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit
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 is defined by GBRMPA (2010).
Fish (as an index)	Fish community health is assessed and included in the ecosystem health assessments (coasters). Inclusion in the report card will contributes to an assessment of the health of local fish communities
Fish barriers (as an indicator)	Fish barriers relate to any barriers which prevent or delay connectivity between key habitats which has the potential to impact migratory fish populations, decrease the diversity of freshwater fish communities and reduce the condition of aquatic ecosystems (Moore 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
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 Values
HEV	High ecological value: the management intent (level of protection) to achieve an effectively unmodified condition.
Impoundment (also impoundment length)	An indicator used in the 'in-stream habitat modification' indicator for freshwater basins in the Region. This index reports on the proportion (%) of the linear length of the main river channel 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)
In-stream habitat modification (as an indicator)	This basin indicator category is made up of two indicators; fish barriers and impoundment length
LAT	Lowest astronomical tide
LOR	Limit of reporting
LTMP	Long-Term Monitoring Program
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. Increased macroalgae on a coral reef is often undesirable, indicating reef degradation (Diaz-Pulido and McCook 2008)
MD	The management intent (level of protection) to achieve a moderately disturbed (MD) condition.
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	Marine Monitoring Program: the Great Barrier Reef Marine Park Authority's Marine Monitoring Program, which provided water quality data for the Central and Whitsunday reporting zones in the report card
ms-PAF	Multiple Substances-Potentially Affected Fraction
NO_x	Oxidised Nitrogen (nitrate and nitrite)
NQBP	North Queensland Bulk Ports Corporation Ltd
Offshore (reporting zone)	Offshore 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
Pesticides (as an indicator)	Formerly limited to the PSII herbicides (Ametryn, Atrazine, Diuron, Hexazinone, Tebuthiuron, Bromacil, Fluometuron, Metribuzin, Prometryn, Propazine, Simazine, Terbuthylazine, Terbutryn). Now incorporating up to 22 herbicides and insecticides with different modes of action. A list of the relevant analytes are provided in Table 5.
Pesticide Risk Metric	Refers to the multisubstance Potentially Affected Fraction (ms-PAF) 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
PONSE	Proportion of Native (fish) Species Expected
Ports	NQBP port authority
PP	Particulate Phosphorus
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
RE	Regional Ecosystem
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 card released to date. This indicator uses mapping resources to determine the extent of the vegetated interface between land and waterways in the Region
RPF	Relative potency factors
SD	The management intent (level of protection) to achieve a slightly disturbed (SD) condition.
Secchi	Secchi depth (m) – measure of water clarity
SF	Scaling factor
SMD	The management intent (level of protection) to achieve a slightly to moderately disturbed (SD) condition.
TSS	Total Suspended Solids

2. Introduction

2.1. Purpose of this document

The purpose of this document is to provide detailed information on the methods used to produce the Mackay-Whitsunday-Isaac 2019 report card. This includes condition assessments of the environmental indicators in freshwater basins, estuaries, inshore and offshore marine environments, along with agricultural stewardship results. Specifically, this document describes:

- The indicator selection process;
- The data collection methods; and
- The scoring methods.

2.2. Background

The Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership (the Partnership) was established in October 2014. The primary focus of the Partnership is to produce an annual report card on the health of the Region's waterways.

The report card includes assessments of the freshwater environment, the estuarine environment and the marine environment (to the eastern boundary of the Great Barrier Reef Marine Park). Different indicators are assessed to provide the overall scores for the environmental zones throughout the Mackay-Whitsunday-Isaac Region (herein the 'Region'). Social, cultural and economic information relevant to waterways and the marine environment is also provided, along with an assessment of stewardship in relation to waterways. Stewardship is reported for the agricultural, tourism, ports, heavy industry, aquaculture and urban sectors of the Region.

Significant review was undertaken between the release of the 2014 pilot report card and the first full 2015 report card. Further refinement of analyses and scoring methods was incorporated into the 2016 and 2018 report card in order to align more methods with other report cards in the Great Barrier Reef Region. A five-year (2017-2022) program design has now been established as a framework to guide the development of the Mackay-Whitsunday-Isaac Healthy Rivers to Reef report card and its future scope and will be reviewed again after the release of the 2022 report card. The 2019 report card is the sixth report card released by the Partnership. For more detail on the Mackay-Whitsunday-Isaac report card and Partnership, refer to the 'Mackay-Whitsunday-Isaac Report Card Program Design 2017 to 2022' document (MWHR2RP 2018)[1].

2.3. Terminology

The report card assesses different ecosystem health (environmental) indicators to report on overall condition of the Region's waterways. Scores for indicators are aggregated together depending on the aspect of the environment they are assessing and follow three key themes: water quality, habitat and

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

fish. The terminology used in this document for defining the level of aggregation of indicators is as follows:

- The overall score is generated by the aggregation of indices or by a single index score;
- Index/indices (e.g. water quality) are generated by the aggregation of indicator categories;
- Indicator categories (e.g. nutrients) are generated by one or more indicators; and
- An indicator is measured (e.g. particulate nitrogen concentration).

In the report card, overall scores and scores for indices are represented in the format of a coaster (Figure 1). Presentation of the coasters can be with or without the outer ring (i.e. indicator categories).

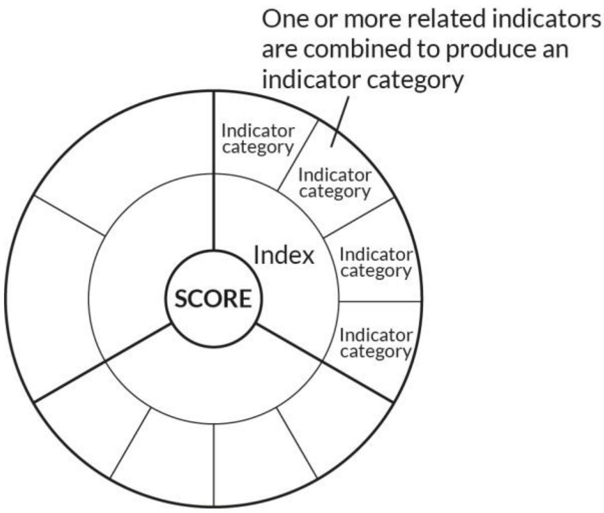

Figure 1. Terminology used for defining the level of aggregation of indicators and how they are displayed in coasters in the report card.

3. Data collection methods

The sections below provide an overview of the data collection methods for the environmental indicators and agricultural stewardship reported in the Mackay-Whitsunday-Isaac 2019 Report Card. The indicator selection process and descriptions of the environmental indicators are detailed in the Mackay-Whitsunday-Isaac Report Card Program Design 2017 to 2022 document (MWHR2RP 2018).

The report card assesses and scores the condition of freshwater basins, estuaries and the inshore and offshore marine environment separately, but assesses the same three key themes (indices) across these reporting areas: water quality, habitats (reported as 'habitat and hydrology', 'coral' or 'seagrass' indices) and fish. The indicators assessed within each of these indices are outlined in Table 1. Also listed are any relevant indicator category groupings.

Table 1. Environmental indicators, indicator categories (where not relevant NA is listed) and indices used to assess the condition of waterways in the Mackay-Whitsunday-Isaac Region.

Index	Indicator category	Indicator	Freshwater	Estuary	Inshore marine	Offshore marine
Water quality	Sediment/Water clarity	Total suspended solids (TSS)	●		●	●
		Turbidity *		●	●	
		Secchi depth			●	
	Physical-chemical	Dissolved oxygen (DO)		●		
	Nutrients	Dissolved inorganic nitrogen (DIN)	●	●		
		Filterable reactive phosphorus (FRP)	●	●		
		Particulate nitrogen (PN)			●	
		Particulate phosphorus (PP)			●	
		Nitrogen oxides (NO_x)			●	
		Chlorophyll-*a* (Chl-*a*)		●	●	●
	Pesticides	Pesticides – multi substances potentially affected fraction (ms-PAF)	●	●	●	
Habitat and hydrology	In-stream habitat modification	Impoundment length	●			
		Fish barriers (3 indicators are used) *	●	●		
	Flow	Flow (10 indicators are used)	●	●		
	NA	Riparian extent	●	●		
	NA	Wetland extent	●			
	NA	Mangrove and saltmarsh extent		●		
Coral	*NA*	Coral cover			●	●
	NA	Macroalgae cover			●	
	NA	Rate of coral increase			●	●
	NA	Density of juvenile coral			●	●
	NA	Community composition			●	
Seagrass	*NA*	Seagrass abundance			●	
	NA	Seagrass tissue nutrients			●	
	NA	Seagrass reproductive effort			●	
	NA	Seagrass biomass			●	
	NA	Seagrass meadow area			●	
	NA	Seagrass species composition			●	
Fish	*NA*	Pest fish	●			
	NA	Native richness	●			
	NA	Fish assemblage	●			
	NA	TBC		●	●	●

* For reporting in the estuaries, turbidity is grouped with DO to form the physical-chemical category; fish barriers is not grouped with another indicator.

3.1. Freshwater basins

The freshwater basin zones reported in the Mackay-Whitsunday-Isaac report card are the Don Basin, Proserpine Basin, O'Connell Basin, Pioneer Basin and Plane Basin. The boundaries of these zones are based on the corresponding basins determined by the Queensland Department of Natural Resources, Mines and Energy (DNRME). The basins can be seen in Figure 7.

The indicators, relevant indicator categories, and overall indices that are assessed for the basins are outlined in Figure 2. For indicator descriptions, refer to the Mackay-Whitsunday-Isaac Report Card Program Design 2017 to 2022 (MWHR2RP 2018) document. The frequency of reporting for each metric, including the updated indicators, can be found in Table 2, below.

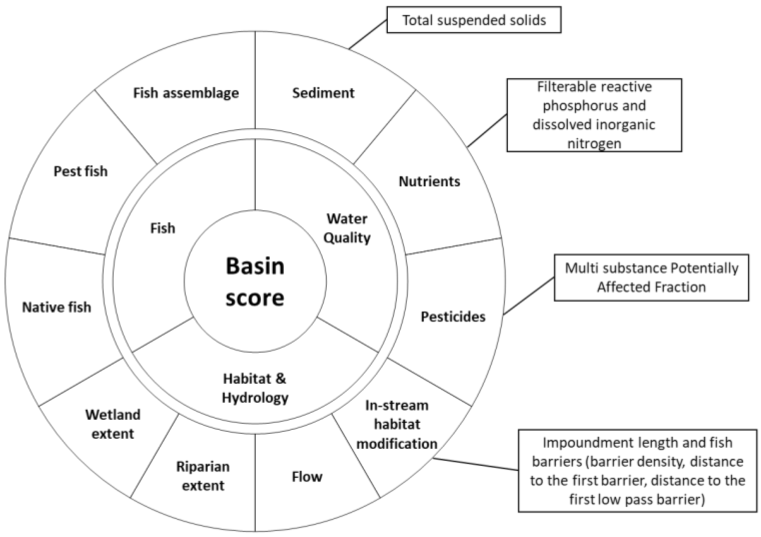

Figure 2. Indicator categories (outer ring) and indices (inner ring) that contribute to overall basin scores. Where multiple indicators are aggregated to determine the indicator category, these are listed in break-out boxes.

Table 2. Indicator categories (outer ring) and indices (inner ring) that contribute to overall basin scores, frequency of reporting and update status for the 2019 report card.

Index	Indicator Categories:	Indicator	Frequency of Reporting	Updated in 2019?
Water quality	Sediment	TSS	Annually	Yes
	Nutrients	DIN, FRP	Annually	Yes
	Pesticides	ms-PAF	Annually	Yes
Habitat and Hydrology	In-stream habitat modification	Fish barriers, Impoundment Length	4 Yearly	Yes
	Flow	10 indicators	Annually	Yes
	Riparian ground cover	Extent	4 Yearly	No (repeated from 2014)
	Freshwater wetlands	Extent	4 Yearly	Yes

Fish	Fish	Native fish, pest fish, assemblage	3 Yearly	No (data repeated from 2018)

3.1.1. Water quality index

Indicators used to report on the water quality index in freshwater basins are: total suspended solids (TSS), dissolved inorganic nitrogen (DIN [1]), filterable reactive phosphorus (FRP) and pesticides, reported as a multi-substance potentially affected fraction (ms-PAF). FRP and DIN are grouped together to form the nutrients indicator category.

3.1.1.1. Sediment, nutrients and pesticides

The water quality data used to report on the condition of basins in the Mackay-Whitsunday-Isaac report card were collected through the Great Barrier Reef Catchment Loads Monitoring Program (GBRCLMP), led by the Department of Environment and Science (DES). Sampling was conducted in accordance with the Queensland Government's Monitoring and Sampling Manual (Department of Environment and Science 2009). Data were obtained through analysis of water samples collected using manual grab sampling techniques and the use of automatic samplers. Samples for all water quality indicators were collected concurrently. For full details on sampling procedure, transport and laboratory analysis refer to Huggins et al. (2017).

Data from samples collected between July 1st 2018 and June 24th 2019 were used to calculate water quality condition scores for the 2019 report card. For this time period, data was available from seven end-of-system GBRCLMP sites within the Region (an improvement to the six available for the 2017 report card) (Figure 7). These sites were:

- 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
- Pioneer Basin: Pioneer River at Dumbleton Pump Station
- Plane Basin: Sandy Creek at Homebush and Plane Creek at Sucrogen Weir

Intensive sampling (up to hourly) occurred during high flow events and monthly sampling was undertaken during ambient (low or base-flow) conditions. A summary of the monitoring program for the 2018-2019 reporting year is provided in Table 3 and Table 4, below.

Table 3. Water quality monitoring within the Mackay-Whitsunday-Isaac basins, where n denotes the number of samples analysed for pollutants of concern (Dissolved Inorganic Nitrogen, Filterable Reactive Phosphorus and Total Suspended Solids). Where differences in the number of samples collected between parameters occurs, they are highlighted. Where no monitoring data was available, cells have been highlighted in grey.

[1] DIN is comprised of oxidised nitrogen (NO_x) and ammonia nitrogen (NH_3) forms. NO_x is the sum of the nitrate (NO_3) and nitrite (NO_2). It is the bioavailability of NH_3 and NO_x to aquatic plants that makes it important to report both forms of nitrogen collectively as DIN.

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)
2018	July	2	1	1	1	2	2	2
	August	1	1	1	1	1	1	1
	September	1	1	1	1	1	1	1
	October	1						
	November	1	4	2	4	4	4	4
	December	1	17	6	7	14	14*	20**
2019	January	15	22	39	28	41	21	38
	February	18	14	14	20	14	16	26
	March	8	2	9	5	13	10	16
	April	4	6	9	17	11	10	11
	May	1	1	1	1			
	June	1	1	1	1	1	1	1
TOTAL		54	70	84	86	102	80	120

*15 samples analysed for Nutrients (DIN, FRP), 14 samples analysed for TSS. Laboratory noted the sample bottle lid was loose and had low sample volume, the bottle was removed and not submitted for analysis. The most conservative value is listed within Table 1.

**21 samples analysed for Nutrients (DIN, FRP), 20 samples analysed for TSS. Laboratory noted the bottle had low sample volume, insufficient to undertake analysis. It was removed and not submitted for analysis. The most conservative value is listed within Table 1.

Table 4. Water quality monitoring within the Mackay-Whitsunday-Isaac basins, where n denotes the number of samples analysed for pesticides. Where no monitoring data was available, cells have been highlighted in grey.

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)
2018	July							
	August							
	September							
	October							
	November							
	December	3	12	7	6	10	11	16
2019	January	11	19	25	22	29	17	26
	February	10	11	13	13	9	11	14
	March	8	4	8	4	11	9	16

	April	5	7	9	11	10	10	11
	May	1	1	1	1			
	June							
TOTAL		38	54	63	57	69	58	83

Two additional sites were incorporated into the water quality scores in the 2018 report card, and again in the 2019 report card: the O'Connell at Stafford's Crossing and Plane Creek at Sucrogen Weir. 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.

Water quality in the Don River was reported for the third consecutive year. 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 short after rainfall events. This is different to the other rivers reported in the Region, which are typically perennial in nature. As a result, the sampling size used to inform water quality scores in the Don basin is expected to vary based on the prevailing hydrological conditions. In the 2019 report card, ambient conditions were successfully captured with sufficient sampling events occurring across the wet and dry season; the results obtained from a total of 54 ambient and event samples were used to derive an indicator score for DIN, FRP and TSS (Table 3). This was broadly comparable to the sampling size for the Don basin the previous year, which comprised 41 samples.

For the Proserpine Basin, sediment and nutrient condition were not reported for the 2019 report card. Upon reviewing the sites' water quality data, there was evidence that the site was located within the estuary. Therefore, the concentration of sediments (TSS) are influenced by tidal action and are therefore not fully representative of the freshwater environment. It is anticipated that tidal action may also impact the observed concentration of nutrients (DIN and FRP), however further investigation is required to delineate the influence of tidal exchange on different water quality parameters at this site. As a result, sediment and nutrient condition were not reported for the Proserpine Basin in the 2019 report card.

Pesticides were still reported using data from the Proserpine site. This is because the site was considered to provide a reasonable estimate of pesticide pressures in the freshwater catchment, where tidal inflow of marine waters was not likely to dilute the magnitude of the pesticide risk score substantially. Furthermore, it was determined that a pesticide risk score calculated from samples taken above the tidal zone would not necessarily provide a more accurate picture of the pesticide pressures in the catchment, as it would likely miss some land-based inputs. For the preliminary review involved in this decision-making process, see Appendix D of the Mackay-Whitsunday-Isaac 2018 Environmental Results report[1].

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

Pesticide indicator scores were developed using the Pesticide Risk Metric (PRM) approach. 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 different pesticides in a given sample are converted to a Pesticide Risk Metric that expresses risk as the percentage of aquatic species that may be adversely affected by the mixture of pesticides.

Pesticide condition in freshwater catchments for the 2019 report card was based on the monitored concentrations of up to 22 pesticides (Table 5). In previous regional report cards, the PRM had been used to calculate the mixture toxicity for PSII herbicides only. PSII herbicides share a common mode of action (MoA), and therefore, the PRM could be calculated using the concentration addition model of joint action (Bliss 1939; Plackett and Hewlett 1952; Könemann 1981). For the 2019 report card, the PRM approach was applied to pesticides with multiple MoAs (Table 5). The PRM for pesticides with different modes of action was calculated using the independent action model of joint action (Plackett and Hewlett 1952). Further details on how the Pesticide Risk Metric calculations were made are provided in Warne et al. (2019). The pesticide mixture toxicity was calculated for all samples collected over the wet season. Where there was more than one sample per day a daily mean concentration was calculated.

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

For the 2017 report card onwards, PRM values were used to determine pesticide grades. All values were rounded to the nearest whole number. All pesticide concentration data and calculated pesticide risk metric data were provided by the Queensland Government's Great Barrier Reef Catchment Loads Monitoring Program.

Table 5. Pesticides included in pesticide risk metric. Not all of the listed pesticides were necessarily detected in collected water samples.

Reference pesticide	Pesticide type	Mode of Action
Chlorpyrifos	Insecticide	Acetylcholine esterase (AChE) inhibitor
Fipronil	Insecticide	Gamma-aminobutyric acid (GABA) gated chloride channel blocker
Imidacloprid	Insecticide	Nicotinic receptor agonist
Haloxyfop	Herbicide	Acetyl-coenzyme A carboxylase (ACCase) inhibitor
Imazapic	Herbicide	Acetolactate synthase (ALS) inhibitor
Metsulfuron-methyl	Herbicide	
Pendimethalin	Herbicide	Microtubule synthesis inhibitor

Metolachlor	Herbicide	Acetolactate synthase (ALS) inhibitor
Ametryn	Herbicide	PSII inhibitor
Atrazine	Herbicide	
Terbuthylazine	Herbicide	
Tebuthiuron	Herbicide	
Simazine	Herbicide	
Diuron	Herbicide	
Terbutryn	Herbicide	
Hexazinone	Herbicide	
Metribuzin	Herbicide	
2,4-D	Herbicide	Auxin mimic (Phenoxy-carboxylic acid auxins)
MCPA	Herbicide	
Fluroxypyr	Herbicide	Auxin mimic (Pyridine-carboxylic acid auxins)
Triclopyr	Herbicide	
Isoxaflutole	Herbicide	4-hydroxyphenylpyruvate dioxygenase (4-HPPD) inhibitor

3.1.2. 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.

3.1.2.1. In-stream habitat modification

Impoundment length

This indicator was selected with the intention to describe how much 'natural' channel habitat remained, compared with 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. All data for impoundment indicator was assessed in 2017-18. Impoundment is updated every four years, with the impoundment indicator updated for the 2018 report card as per its reporting cycle. As a result, impoundment scores presented in the 2019 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 Department of Natural Resources and Mines (now DNRME, Department of Natural Resources, Mines and Energy) Queensland 1:100,000 ordered drainage network, Google Earth imagery, Queensland Globe spatial layers (Dams, Weirs and Barrages, Referable Dams and Reservoirs) and local knowledge, including from DNRME regional hydrographic staff. 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 of the Mackay-Whitsunday-Isaac Region migrate between freshwater and estuarine habitats at some stage during their life cycle (Moore 2016). 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 2015).

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 3).

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.[1]

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 Queensland Department of Natural Resources, Mines and Energy (DNRME). 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 Mackay-Whitsunday-Isaac 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 regions waterways. On-ground validation of priority potential barriers was undertaken to determine the authenticity of barriers and collate important barrier characteristics (Moore 2016).

The '**barrier density**' indicator was assessed by calculating the total stream length (km) of 'Major' and 'High' category waterways in a basin and dividing the total stream length by the total number of barriers on these streams within this basin (Figure 3).

The '**proportion of stream length to the first barrier**' indicator was assessed by quantifying the distance (stream length) upstream from the DDL to the first barrier on all 'Major' and 'High category waterways in a basin (Figure 3). The total basin stream length was divided by the overall connected basin stream length to determine the proportion of stream length upstream of the DDL not impacted by barriers.

The '**proportion of stream length to the first low/no "passability" barrier'** indicator was assessed by quantifying the distance (stream length) upstream from the DDL to the first low/no "passability" barrier for 'Major' waterways only (Figure 3). The total basin stream length was divided by the overall connected basin stream length to determine the proportion of stream length upstream of the DDL not

[1] 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.

impacted by no/low “passability” barriers. A low “passability” barrier was defined as a barrier that never or rarely ‘drowns out’[1] (<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.

The fish barriers score is updated every four years in accordance with the reporting cycle. Following the 2014-2015 assessment, data for the fish barrier indicators was collected and assessed in 2018-2019.

In the Proserpine, O’Connell, Pioneer and Plane Basins, fish barriers were assessed utilising known barriers (identified using spatial imaging, local knowledge and ground truthing) that were identified and assessed for the Mackay-Whitsunday-Isaac Region Freshwater Fish Barrier Prioritisation (Moore 2015b).

In the preceding assessment (2014-2015) of the Don basin, fish barriers were provisionally assessed using the Burdekin Dry Tropics Natural Resource Management Group Region Fish Passage Study (Carter et al. 2007). Due to the age of the BDT NRM fish passage study, and 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. Instead, expert opinion was used to assess the ‘proportion of stream length to the first no/low “passability” barrier’ indicator. In the current 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. This resulted in improved data accuracy of the fish barrier index, through ground-truthing, in the Don basin.

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

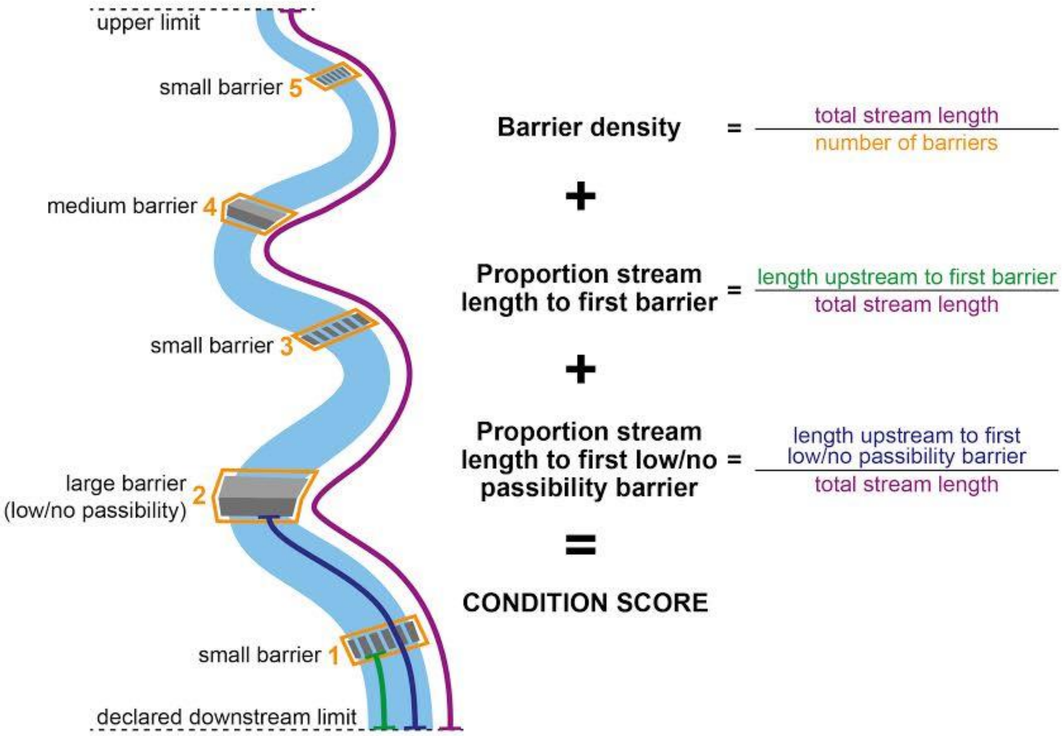

Figure 3. Diagram of the three fish barrier indicators and how they are calculated.

3.1.2.2. Flow

The flow indicator follows a reference condition approach where a waterway with a highly modified flow regime, resulting in large deviations from an unregulated reference condition, will score poorly, and a waterway with an unmodified flow regime, resulting in a similar flow regime to a referenced condition, will score well. Flow metrics used to score the flow indicator for basins assess deviations of the observed flow data from the reference pre-development flow data.

The flow assessment was conducted for all available basin flow monitoring sites within the 2019 report card. For a site to be assessed for flow, the following criteria was required: i) an operational stream gauging station that provides daily stream flow data; and ii) time series modelled pre-development daily flows to provide the reference condition. Observed daily flows (ML day^{-1}) were obtained from stream gauging stations managed by Queensland Department of Natural Resources, Mines and Energy (DNRME) and reported via the Queensland Government Water Monitoring Information Portal (water-monitoring.information.qld.gov.au/). Pre-development time series (100+ years, date ranging typically from 1890-2008) of daily flows (ML day^{-1}) were obtained from Queensland Government hydrologic models (Integrated Water Quantity and Quality Model (IQQM)) which were developed for Queensland basin water resource plans.

The flow assessment sites (with station names) used in the 2019 report card are presented in Table 6, below.

Table 6. Flow assessment sites with DNRME gauging stations used for the flow indicator within each basin.

Basin and flow assessment site	Gauging station number
Pioneer Basin	
Cattle Creek at Gargett Blacks Creek at Whitefords Finch Hatton Creek at Gorge Road Pioneer River at Mirani Weir TW Pioneer River at Dumbleton Weir TW	125004B 125005A 125006A 125007A 125016A
Plane Basin	
Sandy Creek at Homebush	126001A

The annual flow pattern in any given river will vary naturally with the prevailing rainfall conditions. To account for differences of rainfall between years, historical daily rainfall data (100+ years) were obtained from the Queensland SILO program for the catchments (silo.longpaddock.qld.gov.au) and the Bureau of Meteorology (BoM) (http://www.bom.gov.au/). 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. Missing gaps in rainfall data were 'patched' using the River Analysis Package (RAP) developed by the Cooperative Research Centre for Catchment Hydrology at Monash University Melbourne. Sites used to characterise climate from rainfall using Patched Points or Drilled Data from the SILO website for each basin are presented in Table 7.

Table 7. Rainfall site details used to present catchment rainfall for flow indicator sites.

Site	Station name/ location	Station number	Latitude	Longitude	Elevation (m)
Pioneer Basin					
PB1 S	Mackay Alert	33303	-21.1397	149.1883	11
PB2 S	Dumbleton Rocks Alert	33300	-21.1439	149.0753	0
PB3 S	Mirani Post Office	33052	-21.1500	148.8667	50
PB4 S	Finch Hatton Cook St	33026	-21.1436	148.6322	105
PB5 S	Sarichs Alert	33299	-21.2725	148.8203	47.8
PB6 P	Upper Pioneer catchment	N/A	-21.30	148.65	392.9
Plane Basin					
PB1 S	Plane Creek Sugar Mill	33059	-21.43	149.22	16
PB2 S	Eton Sunwater	33134	-21.27	148.97	30
PB3 S	Koumala Hatfields Road	33038	-21.63	149.24	30
PB4 S	Carmila Beach Road	33186	-21.92	149.44	23
PB5 S	Orkabie West Hill	33095	-21.80	149.36	22
PB6 S	Belgamba	33188	-22.03	149.49	30
PB7 S	Upper Plane Catchment	N/A	-21.2	148.9	51.7
PB8 P	Lower Plane Catchment	N/A	-21.20	149.15	7.5

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

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

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

For a given basin, each year of the hydrological record was then ascribed a 'rainfall type'. As such, the flow measures used to produce the indicator scores each have reference distribution for each rainfall type at each flow assessment site. The rainfall type for the reporting year (2018-2019) was determined by comparing the rainfall record to the historical rainfall data. Generation of rainfall types and determining rainfall type of the reporting year was conducted using the flow indicator tool developed in fulfilment of the regional report cards flow indicator project (Stewart-Koster et al. 2018)[1].

3.1.2.3. 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 Queensland Wetland Mapping Programme data. The present extent of riparian forest is defined by those areas with a foliage projective cover of at least 11% (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 ecosystems (based on regional ecosystem mapping version 9) to estimate the amount of riparian forest remaining in the five basins. The method assumes that the pre-development riparian forest regional ecosystems were 100% forested.

The riparian extent indicator is updated in broad accordance with mapping updates produced by the Remote Sensing Centre, Department of Environment and Science. Consequently, the period of update is generally every 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. As a result, score were due to be updated for the 2018 report card. However, the data collected during 2017-2018 is subject to considerable change, including amendments to the satellite imagery and data processing, in order to improve the resolution and accuracy of vegetation mapping. Updated mapping is scheduled to be released in mid-2020, after the development of the 2019 report card. Additionally, revised mapping and the methods for calculating riparian extent will need to be reviewed to ensure they are compatible. Therefore, it is anticipated this information will be available in the 2020 report card.

3.1.2.4. Wetland extent

The assessment of wetland extent uses similar methods to those employed in the GBR report card. The source data is the same for the GBR report card and the Mackay-Whitsunday-Isaac report card,

[1] For the complete report for the report card's flow indicator project, see Stewart-Koster et al. 2018 report by contacting info@healthyriverstoreef.org.au.

however only palustrine systems are reported in the five drainage basins for the Mackay-Whitsunday-Isaac report. Palustrine systems were defined as wetlands with more than 30% emergent vegetation cover, or less than eight hectares.

Wetland extend is defined as the aerial extent of a wetland. The condition of wetland extent was determined through a comparison of current extent against pre-development extent of vegetated freshwater swamp (palustrine) systems using the Queensland Regional Ecosystem (RE) mapping version 11. The regional ecosystem mapping is derived by delineating pre-development regional ecosystems 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 change in wetland extent due to 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 Government and Queensland Government, 2018).

The wetland extent indicator was updated in the 2019 report card, based on mapping information collected in 2017-2018. Wetland extent is updated every four years, in accordance with the frequency of reporting for this indicator and was last assessed in 2013-2014. Scores were scheduled to be updated in 2018, however, due to changes in the source data used to calculate wetland extent, exploration of impacts to the assessment were not able to be achieved prior to the release of the 2018 report card. Including refinements such as fixing errors and remapping to a finer scale, data are not directly comparable to those previously reported inhibiting any interpretation in change between years. To rectify this, wetland extent scores were back-calculated for the 2013 assessment using updated mapping. This information is provided in Appendix A.3 of the Mackay-Whitsunday-Isaac Environmental Results 2019 [1] report. The 2019 report card scores and back-calculated scores supersede previously published scores pertaining to wetland extent through the Mackay-Whitsunday-Isaac regional report card.

Report Card Update
For the 2019 report card, updated wetland mapping was utilised to calculate scores for the wetland extent indicator. As a result of these refinements, previous wetland extent scores were back-calculated. The 2019 report card wetland extent scores supersede previously published scores.

2.1.3 Fish index

The fish community index is based on the condition of native and pest fish, as assessed through the two respective indicators. Field monitoring surveys, data collection and analysis were conducted through DES.

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

The indicators for fish community condition in freshwater basins are assessed by comparing observed data to modelled data to report on two out of three indicators:

- **Native richness**: The number of native fish species actually recorded in catches divided by the number expected to occur based on modelling (Proportion Observed Native Species compared to Expected, PONSE);
- **Pest fish**: The proportion of fish catch that consists of individuals of alien species; and
- **Fish assemblage**: This indicator is currently under development and was not reported in the 2018 report card.

Site selection was a multi-step process. 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 heavy 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 adopted into the survey program. Fish surveys were conducted using predominantly backpack electrofishing techniques, during October 2017 and June 2018. In some instances, boat mounted electrofishing techniques were used to assess sites unsuitable for wading (e.g. deeper water).

The model developed for the calculation of native 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 Mackay-Whitsunday-Isaac Region was Repulse Creek. This approach does not compare to a pre-development baseline, so can only be considered as a comparison of current fish community condition between basins.

Fish communities are assessed every three years. This frequency was chosen to reflect the lifespan of many local freshwater fish species and budgetary constraints. As a result of this reporting frequency, 2018 report card results were updated for the first time since the 2015 report card. The results presented in the 2018 report card are repeated in the 2019 report card.

Species distribution models are currently being developed by DES to complete the fish assemblage indicator development project. It is expected the fish assemblage indicator will be finalised and reported in the next assessment (2021 report card, released in 2022). Review of species distribution models will be conducted in collaboration with local experts.

Future fish community assessments will consider translocated fish under the pest fish umbrella. Currently, fish native to Queensland but not endemic to the region's waterways, and identified outside their natural distribution, are included within the native richness assessment.

3.2. Estuaries

The eight estuaries reported in the Mackay-Whitsunday-Isaac 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. The locations of these rivers and creeks can be seen in Figure 7.

The indicators, relevant indicator categories and overall indices that are assessed for the estuaries are pictured in Figure 4. Refer to the Mackay-Whitsunday-Isaac Report Card Program Design 2017 to 2022 (MWHR2RP, 2018) document for indicator descriptions. The frequency and types of indicators can be seen in Table 8.

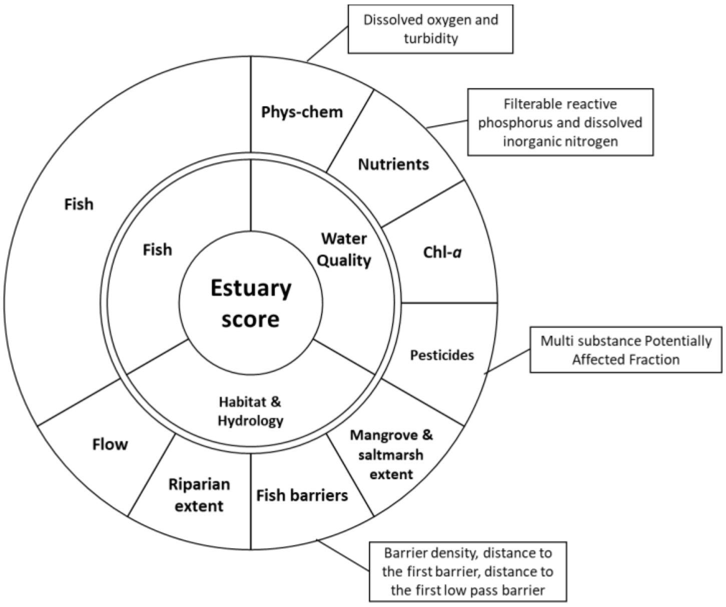

Figure 4. Indicator categories (outer ring) and indices (inner ring) that contribute to overall estuary scores. Where multiple indicators are aggregated to determine the indicator category, these are listed in break-out boxes.

Table 8. Indicator categories (outer ring) and indices (inner ring) that contribute to overall basin scores, frequency of reporting and update status for the 2019 report card.

Index	Indicator Categories:	Indicator	Frequency of Reporting	Updated in 2019?
Water quality	Phys-chem	Turbidity; DO	Annually	Yes
	Nutrients	DIN (constructed from NOx and ammonia); FRP	Annually	Yes
	Chlorophyll-*a*	Chlorophyll-*a*	Annually	Yes
	Pesticides	ms-PAF	Annually	
Habitat and Hydrology	Flow	Fish barriers, Impoundment Length	Annually	Yes
	Riparian Vegetation	10 indicators	4 Yearly	Yes

	Mangrove and saltmarsh	Extent	4 Yearly	Yes
	Fish barriers	Extent	4 Yearly	Yes
Fish	Fish	TBC	TBC	N/A (surveys not yet undertaken)

3.2.1. Water quality index

Indicators used to report on the water quality index in estuaries are: DIN, FRP, turbidity, dissolved oxygen (DO), chlorophyll-*a* (chl-*a*) and pesticides reported as a multi-substance potentially affected fraction (ms-PAF). FRP and DIN are grouped together as the nutrients indicator category and turbidity and DO are grouped together as the physical-chemical (phys-chem) indicator category.

3.2.1.1. Nutrients, 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 DES, with supplementary data being added through the Great Barrier Reef Catchment Loads Monitoring Program (GBRCLMP), and a Partnership-led pesticide monitoring program. For the DES estuary monitoring program, monitoring commenced in October 2014 and is conducted once per month in one, two or three sites in each of the eight estuaries (Table 9). Sampling sites are located at varying distances upstream of the mouth of the estuary (Table 9; Figure 7). Distance of sampling sites are reported as adopted middle thread distance[1]. Hereafter, monitoring sites associated with this program will be referred to as 'mid-river' sites.

To better understand the health of the region's waterways, a supplementary monitoring program was established and funded by the Partnership in an effort to increase the temporal representativeness of pesticide data. Pesticide monitoring commenced in November 2018 and was conducted twice per month from a single site in seven of the region's estuaries. Monitoring sites were selected based on their proximity to existing mid-river sites, and limitations associated with land-based monitoring (site accessibility and risk to safety due to crocodiles). Hereafter, monitoring sites associated with this program will be referred to as 'land-based sites'. The estuaries and associated water quality monitoring sites assessed are outlined in detail in Appendix B.1 of the Mackay-Whitsunday-Isaac Environmental Results 2019[2].

While the Murray and St Helens Creeks are reported as one estuary, it was necessary to monitor sites upstream of both creeks. For the O'Connell estuary only, pesticide and nutrients data were reported using the freshwater basin GBRCLMP water quality monitoring site, the location of which is described in Table 9. As a result, estuary pesticide monitoring is not conducted in the O'Connell at mid-river or corresponding land-based sites.

[1] 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
[2] https://healthyriverstoreef.org.au/report-card/report-card-download/

Table 9. 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. Notably, water quality monitoring data for Murray Creek and St Helens Creek are combined to produce one score for the 'St Helens/Murray Creek estuary'.

Monitoring sites	Sites (km from estuary mouth)	Nutrients (n)	Phys-chem (n)	Chlorophyll-*a* (n)
Gregory River	5.1	11*	11*	11*
	9.9	11*	11*	11*
O'Connell River	7.5	11ɣ	12	12
St Helens Creek	7.5	0	12	0
	8.9	12	12	12
Murray Creek	10	0	12	0
	12.5	12	12	12
	16.5	12	12	12
Vines Creek	2	12	12	12
Sandy Creek	4.5	12	12	12
	13.5	12	12	12
Plane Creek	6	11**	11**	11**
	9	12	11^	12
Rocky Dam Creek	8.9	12	12	12
	12.9	12	12	12
Carmila Creek	3.4	12	12	12

* Water quality samples were not collected during December 2018 in the Gregory River estuary, due to access limitations (rock blockages) associated with high rainfall. A pesticide sample was taken further upstream.

**Water quality samples were not collected during March 2019 in the Plane Creek River at 6.0 km from estuary mouth site, due to inclement weather; the field team was not able to launch the boat to reach the monitoring point.

^Flow was strong at the land site (Plane Creek, 9.0 km from estuary mouth), in March 2019, that multiparameter meter probe was damaged and so no field readings were obtained.

ɣ grab samples for nutrient (NOx, NH3, FRP) analysis were mistakenly not collected in October 2018, therefore no monitoring data is available for this time.

Data samples collected between the 1st of July 2018 and the 28th of June 2019 were used to calculate water quality condition scores for estuaries in the 2019 report card. Notably, pesticide monitoring routinely occurs across the wet season for a period of six months. This contrasts the monitoring program for residual water quality parameters, where ambient sampling activity occurs once per month, for the duration of the monitoring year. A summary of the pesticide monitoring program is provided in Table 10, below. To ensure the conditions at each monitoring event are comparable, sampling was conducted on the ebb of neap tides, to minimise the effect of tidal variation. All water quality samples were collected, stored, and transported in accordance with the Queensland Government's Monitoring and Sampling Manual (DES 2009).

Laboratory analyses for chl-*a* and nutrients were conducted in-house at the DES Science Division Chemistry Centre (Ecoscience Precinct, Dutton Park, Queensland). 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. To derive DIN from estuary data oxidised N is summed with ammonia N.

Further, to maintain consistency in the quality of results, pesticide samples across the ambient and supplementary monitoring program were both submitted to the Queensland Health Forensic and

Scientific Services Laboratory for analysis. This laboratory is accredited by the National Association of Testing Authorities (NATA) for the chemical and physical analysis of water, including for the assessment of toxicants such as pesticides.

Table 10. Water quality monitoring within the Mackay-Whitsunday-Isaac estuaries, where n denotes the number of samples analysed for pesticides. 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
2018	July									
	August									
	September									
	October									
	November	3		3	3	3	4	3	3	3
	December	3	5	3	3	3	5	3	4	3
2019	January	2	22	3	3	3	10	3	3	3
	February	3	13	3	3	3	9	3	2	3
	March	4	4	3	3	3	9	3	3	3
	April		11	2	2	2	8	2	3	2
	May	1	1	2	2	1	4	1	1	1
	June									
TOTAL		16	56	19	19	18	49	18	18	18

*pesticide data in the O'Connell River estuary is derived from samples collected through the Great Barrier Reef Catchment Loads Monitoring Program (GBR CLMP).

** pesticide data in the Sandy Creek estuary is derived from samples collected through a standalone monitoring program, led by the Water Quality and Investigations team, Department of Environment and Science.

3.2.2. Habitat and hydrology index

Indicators used to report on the habitat and hydrology index in estuaries were riparian extent, mangrove/saltmarsh extent, and fish barriers. Insufficient information was available to report on the condition of flow within estuaries.

3.2.2.1. 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 m of the bank of the estuarine environment. The area assessed was from the estuary mouth, upstream to the tidal limit. The tidal limit was determined based on vegetation species distribution observed *in situ* and expert opinion relating to these species. The actual spatial area assessed along the length of each estuary was recorded so that the same spatial layer for each assessment could be used in subsequent assessments allowing for comparability of report cards over time.

The data prepared by DES was obtained through Google Earth and the Queensland Herbarium's Regional Ecosystem (version 11) mapping. The extent of riparian area within the 50 m buffer was compared to pre-development extent to determine the percentage of loss.

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 Regional Ecosystems of Queensland, Version 9.0 (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 were assessed in 2019, based on mapping which depicts condition in 2017. Riparian extent is updated every four years and was due to be updated for the 2018 report card. However, due to changes in the source data for riparian extent, exploration of impacts to methods were not able to be achieved prior to the 2018 report card. Additionally, as a result of updates to the source mapping, including refinements such as fixing errors and mapping to a finer scale, 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. This information is provided in Appendix B.3 of the Mackay-Whitsunday-Isaac Environmental Results 2019 report[1]. The 2019 report card scores and back-calculated scores supersede previously published scores pertaining to riparian extent through the Mackay-Whitsunday-Isaac regional report card.

3.2.2.2. 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-development condition.

The spatial data was prepared by DES and derived from the Queensland Herbarium's Regional Ecosystem (version 9) data. The 2013 aerial extent and pre-development data layers were compared and the proportion of loss since pre-development presented.

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

The procedure for the spatial estimation of the percentage loss (pre-development to 2013) of the four selected important riparian categories of mangrove, samphire, tussock and melaleuca (REs 8.1.1, 8.1.2, 8.1.3 and 8.1.5) in the dominant Regional Ecosystem data was:

1. Start with the defined area of each estuary.
2. Select all the dominant Regional Ecosystem (RE1) data for the proportion of the four selected riparian important categories of mangrove, samphire, tussock and melaleuca (8.1.1, 8.1.2, 8.1.3 and 8.1.5) with these defined areas used as a "cookie cutter" to extract from the three Herbarium data sets of pre-development, 1997 and 2013 Remnant Regional Ecosystems of Queensland.
3. Calculate the percentage loss from the difference in pre-development to 2013 combined area of the mangrove, samphire, tussock, and melaleuca in the dominant Regional Ecosystem data.

All data for mangrove/saltmarsh extent results were assessed in 2019, based on mapping which depicts condition in 2017. Wetland extent is updated every four years and was due to be updated for the 2018 report card. However, due to changes in the source data for riparian extent, exploration of impacts to methods were not able to be achieved prior to the 2018 report card. Additionally, as a result of updates to the source mapping, including refinements such as fixing errors and mapping to a finer scale, data are not directly comparable to those previously reported inhibiting any interpretation in change between years. To rectify this, riparian extent results have been hindcasted for the 2013 assessment using updated mapping. This information is provided in Appendix B.3 of the Mackay-Whitsunday-Isaac Environmental Results report[1]. The 2019 report card sores and hindcasted scores supersede previously published scores pertaining to riparian extent through the Mackay-Whitsunday-Isaac regional report card.

3.2.2.3. Flow

Data collection methods for estuary flow follow that described for basins (section 3.1.4.3). Due to availability of pre-development or observed flow data, flow for estuaries was not reported for the 2019 report card.

Future direction

Considerable work has been undertaken between the release of the 2018 and 2019 report cards to explore opportunities to fill data gaps and is currently progressing in collaboration with the report card's Technical Working Group (TWG) and Bureau of Meteorology (BoM). A review of the flow indicator tool developed for regional report cards is expected to go through a review process for future report cards with the TWG and aquatic ecology experts to identify further refinements to the tool and methods, including rainfall seasonality's applied within the tool.

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

3.2.2.4. Fish barriers

All data for fish barrier results was assessed in 2018-2019. Fish barrier scores are updated every four years and were last updated in 2014-2015.

Assessment of fish barriers in the estuarine environment was undertaken using the same indicators and scoring ranges described for freshwater basins. Barriers were assessed in the named creeks associated with the estuaries (Gregory, O'Connell, Murray & St Helens, Vines, Sandy, Plane, Rocky Dam, and Carmila) and 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 Queensland 'Estuary Extent' Layer regardless of the size of the waterway (Figure 5).

The elevation threshold (18.8 m above the DDL) itself was selected based on Fisheries Queensland 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 Queensland'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.

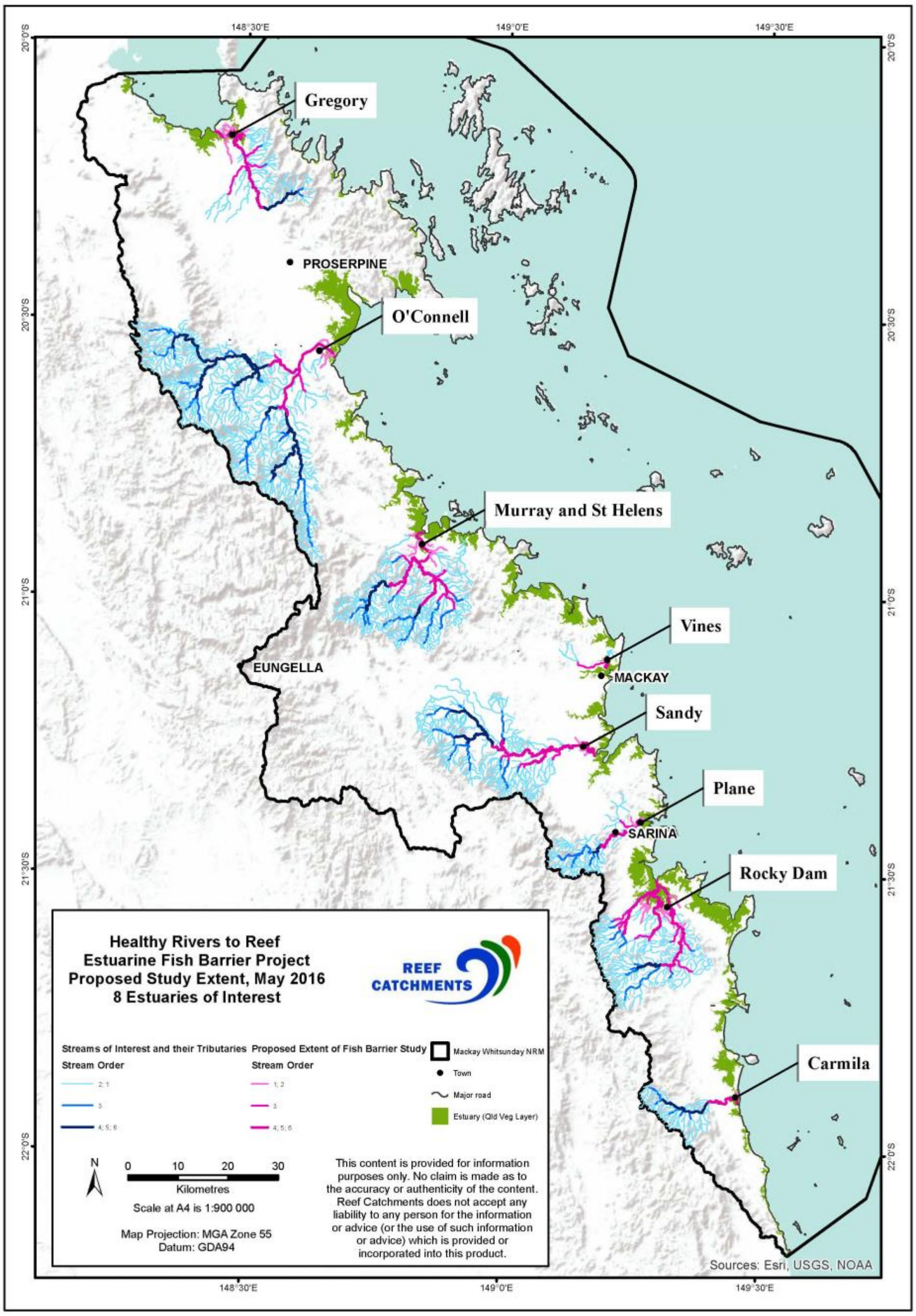

Figure 5. Extent of estuary assessment of fish barriers. Only pink/magenta waterways are included in the estuary barrier assessment; blue waterways are excluded as they do not intersect the estuary layer, are not 'Major' or 'High' impact tributaries and/or are higher than 18.5 m above DDL. NB the major river near Mackay is the Pioneer River, however it is not assessed for estuary condition, thus does not feature on this map.

3.2.3. Fish index

Assessments of fish community health were deemed important across all aquatic environments of the Mackay-Whitsunday-Isaac report card. The development of estuarine fish indicators and methods is still progressing and was not included in the 2019 report card.

3.3. Inshore and Offshore marine environments

The inshore and offshore marine environment are reported separately in the Mackay-Whitsunday-Isaac report card, with the State jurisdiction boundary separating the inshore and offshore reporting areas. The inshore marine environment is further divided into four zones, from north to south: the Northern, Whitsunday, Central and Southern inshore marine zones. The offshore marine reporting zone is not divided any further and extends from the State jurisdiction boundary to the Eastern boundary of the GBR Marine Park. The locations of these zones can be seen in Figure 7.

The indicators, relevant indicator categories and overall indices that are assessed for the inshore and offshore zones are pictured in Figure 6. Refer to the Mackay-Whitsunday-Isaac Report Card Program Design 2017 to 2022 (MWHR2RP 2018) document for indicator descriptions. The frequency and types of indicators can be seen in Table 11.

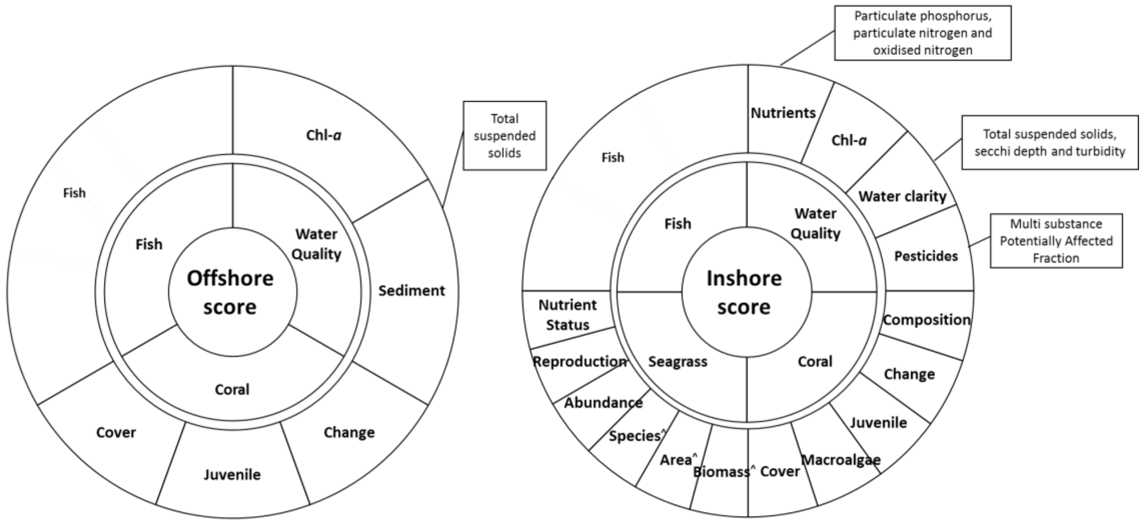

Figure 6. Indicator categories (outer ring) and indices (inner ring) that contribute to overall inshore (right) and offshore (left) marine scores. Where multiple indicators are aggregated to determine the indicator category, these are listed in break-out boxes.

Table 11. Indicator categories (outer ring) and indices (inner ring) that contribute to overall basin scores, frequency of reporting and update status for the 2019 report card.

Index	Indicator Categories:	Indicator	Frequency of Reporting	Updated in 2019?
Water quality	Nutrients	Particulate phosphorus; particulate nitrogen; oxidised nitrogen	Annually	Yes
	Chlorophyll-*a*	Chlorophyll-*a*	Annually	Yes
	Water clarity	Total suspended solids; Secchi depth; turbidity	Annually	Yes

	Pesticides	ms-PAF	Annually	Yes
Coral	Composition	Composition	Annually	Yes
	Change	Change	Annually	Yes
	Juvenile	Juvenile	Annually	Yes
	Macroalgae	Macroalgae	Annually	Yes
	Cover	Cover	Annually	Yes
Seagrass	Biomass	Biomass	Annually	Yes
	Area	Area	Annually	Yes
	Species	Species	Annually	Yes
	Abundance	Abundance	Annually	Yes
	Reproduction	Reproduction	Annually	Yes
	Nutrient status	Nutrient status	Annually	Yes

3.3.1. Water quality index

Indicators used to report on the water quality index in inshore and offshore marine zones are: Total Suspended Solids (TSS), Secchi depth, turbidity, Particulate Phosphorus (PP), Particulate nitrogen (PN), Nitrogen Oxides (NOx), chlorophyll-*a* (chl-*a*) and pesticides reported as a multi-substance potentially affected fraction (ms-PAF). For the inshore marine zones, TSS, Secchi depth and turbidity are grouped together as the water clarity indicator category and PP, PN and NOx are grouped together as the nutrients indicator category.

3.3.1.1. Inshore marine nutrients, chlorophyll-*a*, water clarity and pesticides

Three existing marine water quality monitoring programs in the Mackay-Whitsunday-Isaac Region provided data for the 2019 report card in the Northern, Whitsunday and Central inshore marine zones. These programs included the Abbot Point ambient marine water quality monitoring program, the Mackay and Hay Point ambient marine water quality monitoring program and the Inshore Marine Water Quality Monitoring, led by the Australian Institute of Marine Science as part of the Marine Monitoring Program (MMP).

The comprehensive baseline water quality monitoring programs at Abbot Point and the Ports of Mackay and Hay Point were commissioned by North Queensland Bulk Ports Corporation Ltd (NQBP) in order to develop a long-term understanding of the marine water quality characteristics for the Region and to capture changes that may be related to Port activities (Waltham et al*.* 2015).

In the Southern inshore zone, water quality monitoring forms part of the Southern Inshore Monitoring Program. This program is funded by the Partnership and highlights the Partnership's commitment to improving understanding of the region's waterways. Water quality data collected from this program aligns closely with the Abbot Point and Mackay/Hay Points ambient monitoring program.

Inshore water quality scores are based on data collected during the 2018-19 reporting period from the MMP, Abbot Point and Mackay and Hay Point monitoring programs, and the Southern inshore program. Data from grab samples, in situ water quality loggers and passive samplers were used where available. The relevant program, number of sampling events (grab samples), water type and indicators measured are summarised for each site in each inshore reporting zone in Table 13.

Grab sample data were reported for surface samples only and were used to report NOx, PP, PN, Chl-*a*, TSS and pesticides. Water quality logger data from all three programs were used to report turbidity.

Pesticide condition for the 2019 report card was based on the monitored concentrations of up to 19 pesticides (Table 12) in passive sampler devices over the reporting year. This differs from pesticide condition in the catchments, which is based on multiple grab samples over the wet season (see Section 3.2.4.2). Passive samplers provide a single time integrated concentration for each sampler representing the entire deployment time (typically two to four weeks). While grab samples have the potential to identify acute, rapid, irregular peaks in pesticide concentration, this is only the case if taken at the opportune time. All data from passive samplers were obtained from the MMP and Southern inshore marine monitoring program. Pesticide grab sample data from the NQBP program was presented for reference only.

All water quality data were collected in accordance with the Queensland Water Quality Monitoring and Sampling Manual (Department of Environment and Science 2009). The water type at each monitoring location is defined by the Environmental Protection (Water) Policy 2009 for Central Queensland.

Details on sample sites, sampling methodology and laboratory analysis can be found in the relevant reports for Abbot Point (Waltham et al. 2018), MMP (Lønborg et al. 2016; Gallen et al. 2016) and Mackay and Hay Point (Waltham et al. 2015) water quality monitoring programs.

Table 12. Pesticides detected in passive sampler devices that could be assessed using the pesticide risk metric method for multiple pesticides. Not all of the listed pesticides were necessarily detected in collected water samples. Pesticides listed in italics were not used in development of score but are expected to be incorporated in future report cards.

Reference pesticide	Pesticide type	Mode of Action
Chlorpyrifos	Insecticide	Acetylcholine esterase (AChE) inhibitor
Fipronil	*Insecticide*	*Gamma-aminobutyric acid (GABA) gated chloride channel blocker*
Imidacloprid	Insecticide	Nicotinic receptor agonist
Haloxyfop	Herbicide	Acetyl-coenzyme A carboxylase (ACCase) inhibitor
Imazapic	Herbicide	Acetolactate synthase (ALS) inhibitor
Metsulfuron-methyl	Herbicide	
Pendimethalin	Herbicide	Microtubule synthesis inhibitor
Metolachlor	Herbicide	Acetolactate synthase (ALS) inhibitor
Ametryn	Herbicide	PSII inhibitor
Atrazine	Herbicide	
Terbuthylazine	Herbicide	
Tebuthiuron	Herbicide	
Simazine	Herbicide	
Diuron	Herbicide	
Terbutryn	Herbicide	
Hexazinone	Herbicide	
Metribuzin	Herbicide	
2,4-D	Herbicide	Auxin mimic (Phenoxy-carboxylic acid auxins)
MCPA	Herbicide	
Fluroxypyr	Herbicide	Auxin mimic (Pyridine-carboxylic acid auxins)
Triclopyr	*Herbicide*	
Isoxaflutole	*Herbicide*	*4-hydroxyphenylpyruvate dioxygenase (4-HPPD) inhibitor*

Report Card Update
For the 2019 report card, pesticides were reported for the first time in the Southern inshore marine zone, as part of the Partnership funded monitoring program.

Table 13. Summary of relevant program, number of temporal samples (July 2018 – June 2019), water type (Open Coastal or Enclosed Coastal) and indicators sampled for each site in each reporting zone. 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. Open circles show that data was collected at these sites but no score was calculated because there are no guideline values for these indicators where the site is located.

Site name and relevant reporting zone	Program	Temporal (grab samples)	Water type	Sample type			Indicators sampled							
				Grab	Logger	Passive	PN	PP	NOx	Chl-*a*	TSS	Secchi	Turbidity	Pesticides
Northern inshore zone														
Amb1	AP	6*	OC	■	■		●	●		●	●	●	●	●
Amb 2	AP	6*	OC	■	■		●	●		●	●	●	●	●
Amb 3	AP	6*	OC	■	■		●	●		●	●	●	●	●
Amb 4a	AP	6*	OC	■	■		●	●		●	●	●	●	●
Amb 5	AP	6*	OC	■	■		●	●		●	●	●	●	●
Whitsunday inshore zone														
Double Cone Island	MMP	5	OC	■	■		●	●	●	●	●	●	●	
Pine Island	MMP	5	OC	■	■		●	●	●	●	●	●	●	
Seaforth Island	MMP	5	OC	■	■		●	●	●	●	●	●	●	
Central inshore zone														
AMB1	MHP	5**^	OC	■	■		●	●		●	●	●	●	●
AMB2	MHP	5**^	OC	■	■		●	●		●	●	●	●	●
AMB3B	MHP	5**^	OC	■	■		●	●		●	●	●	●	●
AMB5	MHP	5**^	OC	■	■		●	●		●	●	●	●	●
AMB6	MHP	5**^	OC	■			●	●		●	●	●		●
AMB8	MHP	5**^	OC	■	■		●	●		●	●	●	●	●
AMB10	MHP	5**^	OC	■	■		●	●		●	●	●	●	●
AMB11	MHP	5**^	EC	■			o	o		●	o	●		●
AMB12	MHP	5**^	OC	■	■		●	●	●	●	●	●	●	●
Repulse Islands dive mooring	MMP	5	OC	■	■		●	●	●	●	●	●	●	
O'Connell River mouth	MMP	5	EC	■			o	o	●	●	o	o	o	
Round Flat	MMP		OC			■								●
Sarina	MMP		EC			■								●
Sandy Creek	MMP		OC			■								●
Repulse Bay	MMP		EC			■								●
Southern inshore zone (monitoring program established September 2017)														
Mky_Cam 1	SIP	5"	OC	■	■	■	●	●	●	●	●	●	●	●
Mky_Cam 2	SIP	5"	OC	■			●	●	●	●	●	●		
Mky_Cam 3	SIP	5	OC	■			●	●	●	●	●	●		

* 2 sample for TSS

3.3.1.2. Offshore marine sediment and chlorophyll-*a*

The data for the offshore assessment of water quality was extracted from the Bureau of Meteorology (BoM) dashboard for the 2018-19 year. The score is calculated from the percent of the Mackay-Whitsunday-Isaac offshore area that exceeds the GBRMPA guidelines (GBRMPA 2010) for concentrations of chl-*a* and TSS.

3.3.2. Coral index

The coral indicators used in the Mackay-Whitsunday-Isaac report card are: coral cover, coral change, macroalgae, juvenile density and coral composition.

The indicators closely follow the indicators used in the GBR report card, which are drawn from two coral monitoring programs: the MMP and the Long-Term Monitoring Program (LTMP). In the Whitsunday inshore zone, data for reporting was taken directly from both programs.

There are also coral monitoring programs associated with the Ports of Abbot Point, Mackay and Hay Point, commissioned by NQBP. Data was drawn from these programs to produce scores for four indicators: coral cover, change, macroalgae and juvenile density.

For the first time in the 2019 report card, coral was reported in the Southern inshore zone through the Partnership funded Southern inshore marine monitoring program. Coral indicators and methods used closely align to the MMP. Three indicators were scored in the Southern zone: cover, macroalgae and juvenile density. The coral change and composition indicators both rely on data collected over multiple years. Where relevant, these indicators will be included in the Northern, Central and Southern zones as data becomes available.

Only LTMP coral data were used for reporting coral in the offshore zone where only coral cover, coral change, and juvenile density indicators are reported.

3.3.2.1. Sampling programs and survey methods

The data included in the 2019 report card was collected up to July 2019. Data in July 2019 at some sites in the Whitsunday zone was included for inshore coral zones despite this being slightly outside of the standard financial year reporting period. Importantly, this monitoring now captures the full extent of impact of Tropical Cyclone Debbie which impacted the region in March 2017.

Inshore coral data within the Whitsunday inshore zone was collected from seven reefs by the MMP and an additional three reefs by the LTMP (see Figure 7 for locations). Both these programs have a biennial sampling design, so not every reef included in the survey is sampled every year. Values of each indicator from the most recent surveys are used to calculate the value each year. Since some reefs will have been surveyed in the preceding year, the values for each reporting year are effectively a two-year rolling mean. In the case of the MMP, where acute disturbances such as cyclones are suspected to have impacted reefs during the preceding summer, contingency sampling of some reefs not scheduled for sampling may be conducted to better estimate the impact of that disturbance. For full details refer to Thompson et al. (2019). The most recent sample dates for coral communities included in the 2019 report card are detailed in Table 14 and Table 15.

Table 14. Coral sampling sites for the 2019 report card compared to previous report cards. The MMP program normally surveys reefs across a two-year period, however in response from acute disturbance from Tropical Cyclone Debbie some reefs were sampled out of schedule (+). An * identifies reefs that were surveyed prior to the passage of TC Debbie in March 2017. The NQBP program surveys each reef annually.

Inshore zone	Survey time 2018-2019	Reef	Program	2016	2017	2018	2019
Northern	27-29th May 2019	Camp East	NQBP		●	●	●
		Camp West	NQBP		●	●	●

		Holbourne East	NQBP		●	●	●
		Holbourne West	NQBP		●	●	●
Whitsunday	29- 30th Apr- 1st May 2019	Langford	LTMP		●*		●
		Hayman	LTMP		●*		●
		Border	LTMP		●*		●
	11th Jul-2019	Double Cone (WQ)	MMP	●	+	●	●
	14-16th Jun-2018	Hook	MMP	●		●	
		Daydream (WQ*)	MMP	●	+	●	
		Shute Harbour	MMP	●	+	●	
	10th Jul-2019	Dent	MMP		●		●
		Pine (WQ)	MMP		●	●	●
	29th May-2019	Seaforth (WQ**)	MMP		●		●
Central	13-16th Jun 2019	Keswick	NQBP		●	●	●
		Round	NQBP		●	●	●
		Slade	NQBP		●	●	●
		Victor	NQBP		●	●	●
Southern	27- 31st Jan 2019	Pine Peak	Southern inshore				●
		Pine Islets	Southern inshore				●
		Henderson Island	Southern inshore				●
		Connor Island	Southern inshore				●
	27th May 2019	Temple Island	Southern inshore				●
		Aquila Island	Southern inshore				●

Table 15. Offshore coral sites surveyed as part of the Long-Term Monitoring Program (LTMP) and Representative Areas Program (RAP) for 2018-19 and 2017-18 reporting.

Reef	Sampled 2018/19 Financial Year (LTMP)	Sampled 2017/18 Financial Year (RAP)
SLATE REEF	● 24-Apr-2019	
HYDE REEF	● 25-Apr-2019	
REBE REEF	● 26-Apr-2019	
BORDER ISLAND REEF (NO 1)	● 01-May-2019	
19131S	● 21-Apr-2019	
20104S*	● 18-Feb-2017	
LANGFORD-BIRD REEF	● 30-Apr-2019	
HAYMAN ISLAND REEF	● 29-Apr-2019	
19138S	● 22-Apr-2019	
POMPEY REEF (NO 1)		● 22-Mar-2018
21060S		● 21-Mar-2018
POMPEY REEF (NO 2)		● 02-May-2018
21591S		● 24-Mar-2018
20348S		● 11-May-2018
21062S		● 08-May-2018
20353S		● 18-Sep-2019
21064S		● 12-May-2018
TERN REEF (20309)		● 17-Mar-2018
PENRITH REEF		● 25-Mar-2018

MMP and Abbot Point programs stratify sampling by depth, including transects at both 2 m and 5 m below lowest astronomical tide (LAT). This is because coral community structure and exposure to disturbances differ markedly with depth, especially in inshore areas where the turbidity of waters causes a rapid attenuation of light. The LTMP samples sites at 6 - 9 m depth only (**Error! Reference source not found.** 16). The Mackay and Hay Point program includes sites at a range of depths to conform with the location of coral communities at the chosen sites. All coral reef sites included within the assessment were selected based on expert advice and to meet the purposes of each specific coral monitoring program.

Table 16. Survey methods for relevant coral monitoring programs reporting in the Mackay-Whitsunday-Isaac Region.

Program and survey method	Information provided	Number of reefs or locations	Samples per location	Transects
Abbot Point coral monitoring program (Northern inshore zone)				
Photo point Intercept transect	Percentage cover of corals and other benthic categories.	4	2 at both 2 m and 5 m* depths	5 x 20m
Belt transect	Abundance of juvenile corals < 5cm	4	2 at both 2 m and 5 m* depths	5 x 20m
MMP (Whitsunday inshore zone)				
Photo point Intercept transect	Percentage cover of corals and other benthic categories.	7	2 at both 2 m and 5 m depths	5 x 20m
Belt transect	Abundance of juvenile corals < 5cm	7	2 at both 2 m and 5 m depths	5 x 20m
LTMP (Whitsunday inshore zone)				
Photo point Intercept transect	Percentage cover of corals and other benthic categories.	3	3 (6-9 m depth)	5 x 50m
Belt Transect	Size structure and density of juvenile (<5cm) coral communities.	3	3 (6-9 m depth	5 x 5m
Mackay and Hay Point coral monitoring program (Central inshore zone)				
Line Intercept transect	Percentage cover of corals and other benthic categories.	4	6 (variable depths)	4 x 20m
Belt transect	Abundance of juvenile corals < 5cm	4	6 (variable depths)	4 x 20m
Southern inshore coral monitoring program				
Photo point Intercept transect	Percentage cover of corals and other benthic categories.	6	2 at both 2 m and 5 m depths^	5 x 20m
Belt transect	Abundance of juvenile corals < 5cm	6	2 at both 2 m and 5 m depths^	5 x 20m
LTMP (Offshore zone)				
Photo point Intercept transect	Percentage cover of corals and other benthic categories.	10	3 (6-9 m depth)	5 x 50m
Belt transect	Abundance of juvenile corals < 5cm	10	3 (6-9 m depth)	5 x 55m

*Two reefs in the northern zone are sampled at a single depth only.

^ Two reefs in the Southern zone are sampled at a single depth only of 1m

Inshore coral data for the Ports of Mackay and Hay Point coral monitoring program, relevant to the Central inshore zone, was collected from six sites around four island locations (NQBP, 2018). At each site, cover of benthic reef organisms was assessed using four 20 m line intercept transects. At each site, transects were established between a depth range of 0.5 m – 0.7 m below Lowest Astronomical Tide (LAT) (NQBP, 2018). For full details refer to NQBP (2018). Data included in the 2019 report card was collected from these reefs in June 2019.

Inshore coral data for the Abbot Point coral monitoring program, relevant to the Northern inshore zone, was collected from four reefs around two island locations. Technically, Holbourne Island falls within the offshore reporting zone (and mid-shelf water type), however surrounding reefs include species typical of both inshore and mid-shelf reefs. For the report card, these reefs have been included in the Northern inshore reporting zone. Like the MMP, sampling at Holbourne Island was stratified by depth, including transects at both 2 m and 5 m below LAT. Only 2 m depths were available at Camp Island. Data included in the 2019 report card was collected from these reefs in May 2019.

Inshore coral data for the Southern inshore coral monitoring program, was collected from twelve sites around six island locations. At each site, cover of benthic reef organisms was assessed using five 20 m photo point intercept transects. Transect were replicated at both 2 m and 5 m depths below lowest astronomical tide datum (LAT) at Pine Peak Island, Pine Islets, Henderson Island and Connor Island. At Temple Island and Aquila Island the reef slope transitioned to sand at 1-1.5 m below LAT and as such transects were set at 1 m below LAT only. Data included in the 2019 report card was collected from these reefs in January 2019 and May 2019.

Offshore coral data was collected from permanent sites on sixteen reefs that were surveyed as part of the AIMS LTMP to assess the effects of rezoning the GBR Marine Park in 2004. As mentioned, reefs in these programs are sampled in alternating years, however, the score for each reporting year is calculated based on the rolling mean of data collected over a four-year period. 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, sampling sites are at least 250 m apart, with five 50 m transects (within each site). Transects follow depth contours on the reef slope parallel to the reef crest (at approximately 6-9 m depth). Technically, Penrith Island falls just within the Central inshore zone for the Mackay-Whitsunday-Isaac report card, but the Penrith Island reef is clearly a mid-shelf reef so it has been included with the offshore reefs.

The MMP, LTMP, Abbot Point coral monitoring programs and the Southern inshore coral monitoring program employ the photo point intercept method to record percentage cover estimates of the benthic communities. In contrast, the Mackay and Hay Point program uses the line intercept technique. All programs record juvenile abundance within narrow belt transects from which the density of juvenile corals can be estimated (Table 9). Despite some differences in survey methodology and transect dimensions, similar data was collected across the two monitoring programs (Table 9).

Benthic photo point intercept method

The photo point intercept method was used to gain estimates of the composition of the benthic communities. The method closely follows the AIMS Standard operational procedure number 10 of the LTMP (Jonker et al. 2008).

Juvenile coral surveys

These surveys aimed to provide an estimate of the number of both hard and soft coral colonies that were successfully recruiting and surviving early post-settlement pressures. Importantly, this method aims to record only those small colonies assessed as juveniles, 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. The method closely follows the AIMS Standard operational procedure number 10 of the LTMP (Jonker et al. 2008).

Benthic line intercept method

These surveys record 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.

For further detail on the MMP and LTMP methods, refer to Thompson et al. (2016) and the AIMS Reef Monitoring website[1] and SOPs respectively.

Report Card Update
For the 2019 report card, coral was reported for the first time in the Southern inshore marine zone, as part of the Partnership funded monitoring program.

3.3.3. Seagrass index

The seagrass indicators are based on indicators used in two existing monitoring programs: (1) the MMP used to develop the GBR report card results, and (2) the Queensland Ports Seagrass Monitoring Program (QPSMP). To report on seagrass, data from the QPSMP were used for the Northern inshore zone, data from the MMP were used for the Whitsunday inshore zone, and data from both the MMP and QPSMP were used for the Central inshore zone. No index score was produced for seagrass in the Southern inshore zone for the 2019 report card. A monitoring program for seagrass was established in the Southern inshore zone in 2017, as funded by the Partnership. To report on seagrass condition over time, a baseline or reference condition needs to be ascertained. To achieve this, five years' worth of monitoring data is required. As result, seagrass scores will be reported on in future report cards.

The seagrass indicators used for reporting based on the MMP are described in detail by McKenzie et al. (2015) and include seagrass percent cover, tissue nutrient status (C:N ratio), and reproductive effort (production of spathes, flowers and fruits per unit area). The indicators selected from the QPSMP are described in detail by York and Rasheed (2019) and include mean above-ground biomass, meadow area and species composition.

3.3.3.1. 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 et al. 2015). The meadows monitored within the MMP were selected by the GBRMPA, using expert advice.

Mapping surveys were conducted to select representative meadows, which were those that had a greater extent of seagrass. They were also generally the dominant community type and within GBR average abundances (McKenzie et al. 2015). Sampled meadows were lower littoral (rarely exposed to air) and sub littoral (permanently covered with water). Two sites (transect blocks) were selected at each location to account for spatial heterogeneity. Additionally, the minimum detectable difference had to be 20% (McKenzie et al. 2015). 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.

[1] http://www.aims.gov.au/docs/research/monitoring/reef/sops.html

Monitoring occurred during the late dry (growing) season and late wet season in order to obtain information on the seagrass communities' status pre and post-wet season.

Methods adopted for seagrass monitoring were largely as per McKenzie et al. (2010), specifically:

- Seagrass abundance, as per standardised protocols in McKenzie et al. (2003) and McKenzie (2009);
- Reproductive health – samples processed in accordance with McKenzie et al. (2010); and
- Tissue nutrient status – described in McKenzie et al. (2015).

For further information on site selection and methods, refer to McKenzie et al. (2015), McKenzie *et al*. (2010), and McKenzie (2009).

For the 2019 report card, MMP seagrass monitoring data was reported in the Whitsunday inshore zone at Hydeaway Bay, Hamilton Island, Pioneer Bay, Tongue Bay and Lindeman Island. In the Central inshore zone seagrass monitoring data was reported at Midge Point, St Helens Beach, Sarina Inlet and Newry Bay (Figure 7). Hydeaway Bay, Pioneer Bay and St Helens Beach are long-term monitoring sites of the Seagrass-Watch program. Seagrass-Watch therefore, contributes seagrass monitoring data to the Central inshore zone (in conjunction with the QPSMP described below) and the Whitsunday inshore zone. Seagrass-Watch is also collecting seagrass monitoring data from a site at Clairview in the Southern inshore zone which will be combined with data collected by TropWATER as part of the Southern Inshore Monitoring Program to calculate seagrass health scores in the 2021 report card (currently being collected to establish a baseline).

3.3.3.2. Queensland Ports Seagrass Monitoring Program

The objective of the QPSMP is to report on the condition of seagrass in the highest risk areas of Queensland and use this information to assist in the planning and management of anthropogenic activities. The QPSMP assesses seagrass condition at seven port locations across the GBR at 50 individual meadows (Carter et al. 2019). The QPSMP monitors and reports on seagrass condition for entire meadows (Figure 7) 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 (dominant species, intertidal/subtidal, meadow size and mean biomass). The program and approach has been independently reviewed on several occasions and results regularly published in peer reviewed journals (Carter et al. 2016a). For further information on site selection and methods in the Mackay-Whitsunday-Isaac Region refer to previous QPSMP reports for Abbot Point (McKenna et al. 2019) and Mackay and Hay Point (York & Rasheed 2019).

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

For the 2019 report card, QPSMP seagrass monitoring data was reported in the Northern inshore zone for five inshore meadows and four deep-water monitoring blocks near Abbot Point, and in the Central zone for meadows at Dudgeon Point, St Bees Island, Keswick Island, and the deep-water meadow near Hay Point. No seagrass data was available for the Southern inshore zone, however as mentioned above Seagrass-Watch data from Clairview will be combined with Southern Inshore Monitoring Program data in the 2021 report card.

3.3.4. Fish index

Assessments of fish community health were deemed important across all aquatic environments of the Mackay-Whitsunday-Isaac report card. Potential marine fish indicators and assessment methods are still being explored and therefore are not included in the 2019 report card.

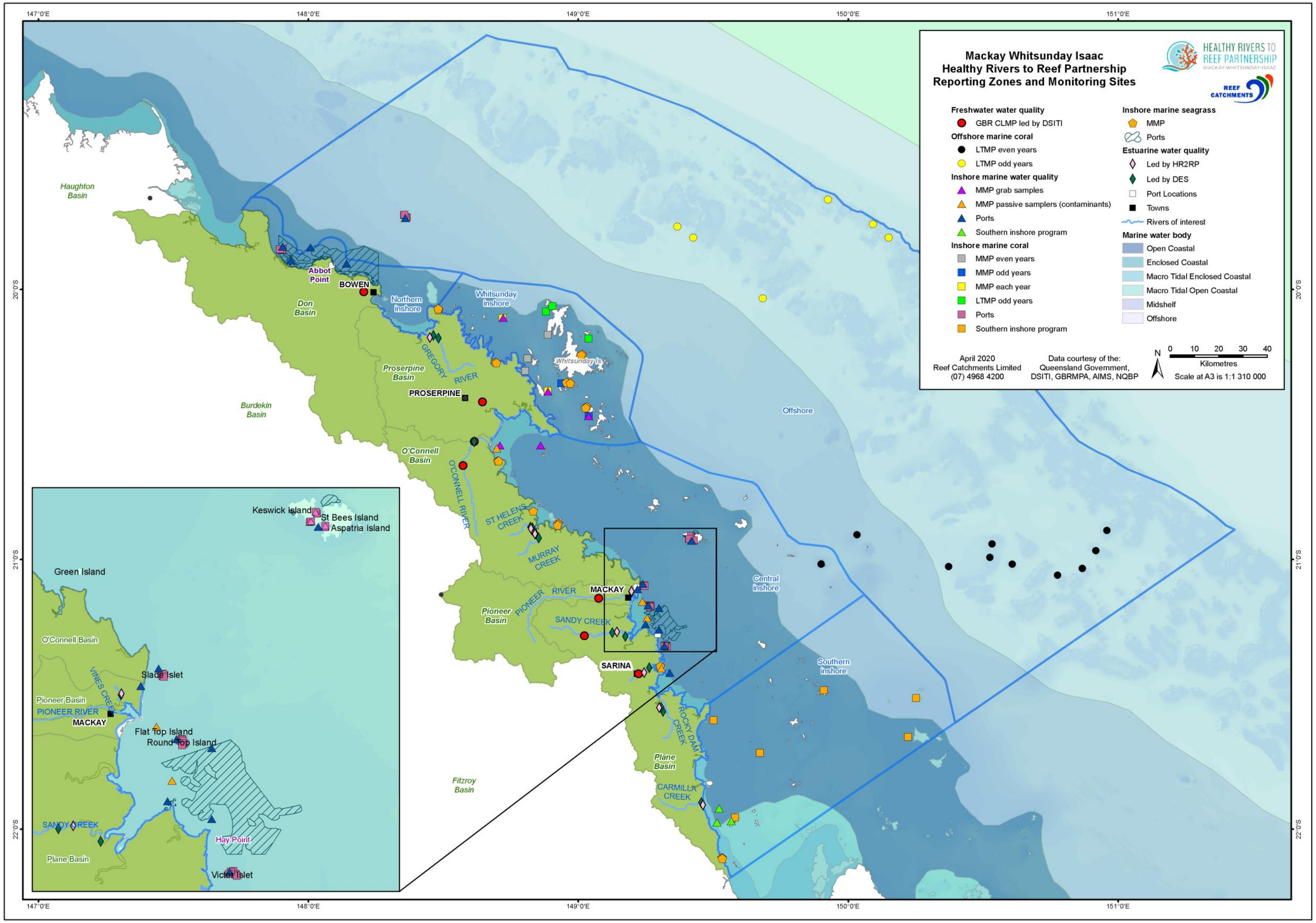

Figure 7. Sampling locations for water quality monitoring and coral and seagrass monitoring in the Mackay-Whitsunday-Isaac Region for the 2019 report card.

3.4. Stewardship

Stewardship is 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'. Stewardship is represented as the level of effective environmental management practice implemented across the region in relation to waterways and the marine environment. Stewardship is an important aspect to include in the report card, as it provides information on the voluntary action's landholders and organisations in the region are implementing (such as improved land management practices) to provide benefits to ecosystems. Stewardship activities have a direct link to water quality in the region and can be used to demonstrate how on-ground activities (*responses* undertaken by landholders/organisations in the region) impact water quality (the *state* of the natural environment). For the 2019 report card, agricultural stewardship was reported. Non-agricultural stewardship will be reported in future report cards, with agricultural and non-agricultural management activities highlighted in the Partnership's stewardship reporting, which was released for the first time with the 2018 report card. An urban stewardship framework is under development, which can be utilised in regional report card. A pilot workshop for the framework was conducted in 2019, and it is expected that future report cards will incorporate the urban stewardship framework into non-agricultural stewardship reporting.

3.4.1. Management frameworks

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 and are based on Paddock to Reef (P2R) reporting that uses "Water Quality Risk frameworks" (previously "ABCD Frameworks") (Australian and Queensland Governments 2019b).

3.4.2. Agricultural stewardship

The Mackay-Whitsunday-Isaac report card aligns its agricultural stewardship reporting with the GBR report card, which are reported through the Paddock to Reef (P2R) program[1]. Each year, significant investment from Government is directed towards adoption of best practice farm management systems with the aim to achieve the Reef 2050 Water Quality Improvement Plan's outcomes and targets and improve the quality of water flowing into the Great Barrier Reef (Australian and Queensland governments 2019c).

Farm management practice adoption benchmarks are reviewed and revised every 5 years and annual change is based on data reported each year. The 2016-17 year is currently set as the benchmark from which to show improvements and aligns to the GBR water quality report card. P2R program management practice and management system benchmarks were developed for each agricultural industry sector, and in each of the five major river basins within each region. Best management

[1] https://www.reefplan.qld.gov.au/tracking-progress/reef-report-card/2017-2018

practices for water quality outcomes are defined in the Paddock to Reef program water quality risk frameworks[1] for each major agricultural industry.

Grazing, sugarcane and horticulture are the major agricultural industries in the Mackay-Whitsunday-Isaac Region. For grazing systems, the water quality risk frameworks describe practices impacting upon land condition, soil erosion (pasture-hillslope, streambank and gully) and water quality. For sugarcane and horticulture, nutrients, pesticides and soil are reported against the framework.

Best management practice is defined as the summed area managed under Low and Moderate-Low risk (or 'A and B' practice) levels in each catchment (Australian and Queensland Governments 2019d). The breakdown of practice standards, across all agricultural industries, are outlined further in Table 17 below.

Table 17. Water Quality Risk Frameworks for the Reef 2050 Water Quality Improvement Plan and alignment with the 'ABCD' terminology and industry best management practice (BMP) programs (generalised).

Terminology	Practice Standard			
Water Quality Risk Framework	Lowest risk, commercial feasibility may be unproven	Moderate-low risk	Moderate risk	Moderate-High risk
	Innovative	Best practice	Minimum Standard	Superseded
ABCD	A	B	C	D
Industry BMP (generalised)	Above industry standard (typically aligns with Moderate-Low risk but in some instances aligns with Lowest risk state)		Industry Standard	Below Industry Standard

A summary of the data sources and levels of uncertainty around management system baselines for agricultural stewardship related to the Mackay-Whitsunday-Isaac (aligning with the GBR report card) Region is included in Table 18 below.

Table 18. Summary of the data sources and uncertainty around management system baselines developed for the Reef 2050 WQIP agricultural management practice adoption benchmarks.

Industry	Primary data sources	Confidence in benchmarks	Sources of uncertainty
Grazing	• Grazier 1:1 surveys 2013-16 • Previous reporting to P2R • Grazing BMP (aggregated, anonymous)	Moderate – low	Relatively small proportion of the overall large population is represented in the datasets. Inability to describe land condition (as a consequence of management) across the landscape.

[1] https://www.reefplan.qld.gov.au/tracking-progress/paddock-to-reef/management-practices

Horticulture	• Hort360 BMP • Industry experts	Moderate	Very good industry representation, however lack of alternative lines of evidence for cross checking.
Sugarcane	• Previous reporting to P2R • Compliance reporting (reef protection legislation) • Smartcane BMP (anonymous, aggregated) • Industry surveys • Soil analyses trends • Industry experts • Confidential commercial data	Moderate – High	Several different large and representative datasets providing evidence for most practices in most catchments. However, benchmarks for some practices are based on expert opinion (as no data sources exist).

A detailed outline of the methods for assessing agricultural stewardship can be found within the GBR Report Card, on the Reef 2050 Water Quality Improvement Plan website[1].

At the regional reporting level, assessed best practice management progress for each basin do not align fully with those outlined in the GBR Report Card. The Mackay-Whitsunday-Isaac report card incorporates assessment of the Don Basin, which extends from South of Ayr to the north east of Airlie Beach, spanning the Burdekin and Mackay-Whitsunday-Isaac Natural Resource Management (NRM) regions. Although the Don Basin is principally managed by the North Queensland Dry Tropics (NQDT) NRM body, its condition is hydrologically relevant to the Mackay-Whitsunday-Isaac region due to upgradient inputs being captured within local catchments. As a result, stewardship results for the Don Basin are included within the calculations for stewardship within the Mackay-Whitsunday-Isaac report card. This results in a slight disparity between scores presented in the Mackay-Whitsunday-Isaac region and the GBR water quality report card.

[1] https://www.reefplan.qld.gov.au/tracking-progress/reef-report-card/methods-to-create-report-card

3 Development of condition assessments scoring methods

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

Scores are aggregated (rolled up by calculating an average across indicator scores) from the indicator level to generate indicator category scores. In some cases, an indicator category is represented by a single indicator. Indicator categories are aggregated (by averaging across indicator category scores) to generate an index score, which are subsequently aggregated (by averaging across index scores) to produce an overall score for an individual reporting zone in an environment.

Decision rules were developed for the minimum information required to generate the rolled-up scores:

≥ 50% of measured indicators to generate the indicator category score (where relevant)
≥ 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 visually shows what components contribute to the overall grade.

All indicators have specific scoring ranges and bandwidths which correspond to the five-point system. Specific scoring ranges for each indicator are described in detail in subsequent sections.

Results for indicators that have divergent scoring ranges and bandwidths must be translated into a common scoring range before aggregating (rolling up). The common scoring range used for reporting is based on that used by the GBR report card and is shown in Table 19. 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 formula for scaling are presented. Once standardised, relevant scores were averaged to aggregate into the higher category.

For presentation purposes in the technical documents and online, scores are shown as integers; no rounding is applied. The exception to this rule is for coral and seagrass scores, which are presented as rounded scores to ensure scores presented for the MMP and QPSMP align directly with scores presented in the Mackay-Whitsunday-Isaac report card. Importantly, all significant figures are retained when averaging scores to roll up to category, index and overall scores.

Table 19. Overall scoring range, associated grades and colour codes.

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

3.1 Freshwater basins and estuaries

Indicators in freshwater basins and estuaries have closely aligned approaches to determining their condition. The following section therefore describes individual indicator scoring approaches and associated formula for indicators in both freshwater basins and estuaries.

3.1.3 Water quality index

3.1.3.1. Nutrients, sediments and phys-chem

To calculate a condition score for individual 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[1].

Only annual medians that meet or are better than the guideline value achieve a good or a very good score (Figure 8). 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.

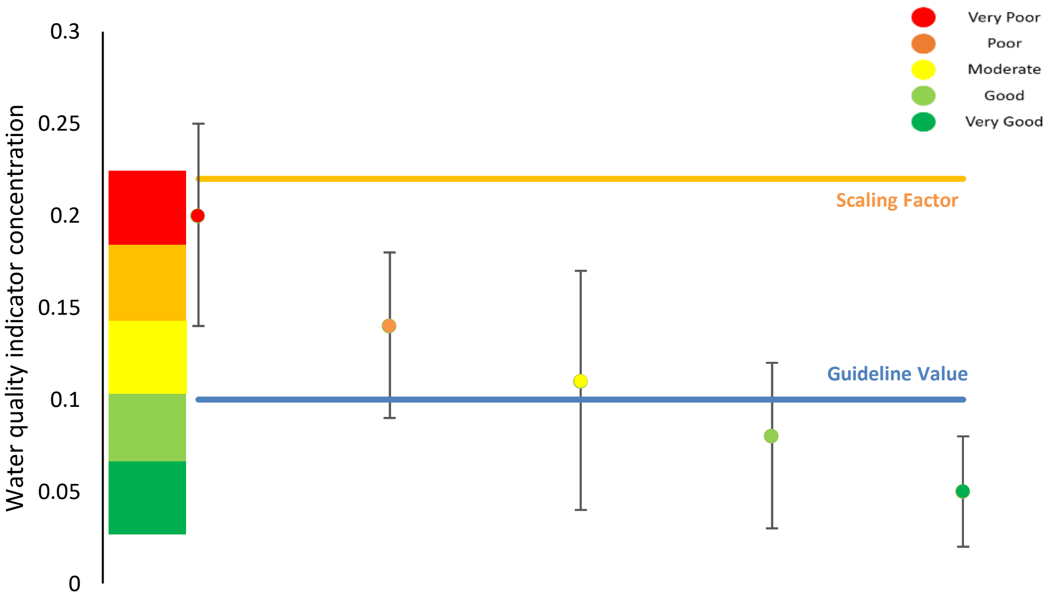

Figure 8. An example of how water quality grades are assigned. Where the middle point represents the annual median, the top whisker the 80th percentile and the bottom whisker the 20th percentile of the data. Only when the median meets or is better than the guideline (in this case meeting the guideline 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.

The approach to calculating a condition score (from 1 to 100) and translating this to the report card

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

five-point grading is outlined below.

Steps used in calculating condition scores for each water quality indicator:

- If the measured concentration of an indicator is less than the limit of reporting (LOR), then use a value of 0.5 x LOR;
- Calculate monthly median concentrations (where relevant);
- Calculate annual median from monthly medians;
- Compare annual median to the relevant local guideline value;
- Calculate condition score (0 – 100) following rules and formula in Table 20 and Table 21; and
- Aggregate indicator scores into indicator category scores (where relevant) and the water quality index (following decision rules for minimum information).

Table 20. Rules, formula 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 Mackay-Whitsunday report card.

Rule	Formula	Scoring range	Grade
Median meets GV and ≥80% of data meets GV	Assigned 90[1]	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: 80^{th} means 80^{th} percentile of the data; GV means guideline value; median is the annual median of the data; ABS means the absolute value/positive value; SF means scaling factor based on 90^{th} percentile[2] of available data.

Table 21. Rules, formula and scoring ranges for associated grades for DO (when comparing to the lower guideline value*) in estuaries of the Mackay-Whitsunday report card.

Rule	Formula	Scoring range	Grade
Median meets GV and ≥80% of data meets GV	Assigned 90[10]	81 to 100	Very good
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: 20^{th} means 20^{th} percentile of the data; GV means guideline value; median is the annual median of the data; ABS means the absolute value/positive value; SF means scaling factor based on 90th percentile[11] of available data.

** To meet the lower DO guideline value, % saturation must be higher than the guideline value; this is inverse to how other indicators meet guideline values, thus formula to calculate grade must also be inverse.*

Guideline values

Guideline values used for freshwater basins are based on the Queensland Water Quality Guidelines (2009) (Department of Environment and Science 2009) and are listed in Table 2222, with guidelines

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[1] QLD Water quality guidelines 2009 recommend protocols for testing against 20th, 50th (median) and 80th percentiles. There is no *a priori* knowledge or guidelines regarding the entire distribution of water quality parameters in our systems, so assumptions/decisions regarding the other 20% of the data (between 80-100%) and how it should be distributed around the GV cannot be made. Thus, a discrete value within the very good range to systems if the 80^{th} percentile meets the GV was assigned. The middle (i.e. 90) of the very good range (**Error! Reference source not found.**) is used to assign a score for very good.

[2] Scaling Factor for DO is based on the 99th percentile of all values.

relating to the individual river or creek that was sampled. For the Don River, guideline values used are based on the 'Draft environmental values and water quality guidelines: Don and Haughton River basins, Mackay-Whitsunday 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.

Guideline values for estuaries are based on the 'Draft environmental values and water quality guidelines: Don and Haughton River basins, Mackay-Whitsunday estuaries, and coastal/marine waters' (Newham et al. 2017) (**Error! Reference source not found.**23).

A draft guideline for DIN for the Don Basin and monitored estuaries were not available, therefore a guideline value was created by summing Ammonium nitrogen and Oxidised nitrogen draft guideline values. There is precedent for this approach in the EPP 2009 'Proserpine River, Whitsunday Island and O'Connell River basins environmental values and water quality objectives'[1] which, in reference to DIN guideline values, states: "DIN = ammonia-N + NOx-N" (page 49). This is reflected by the additive nature of the scheduled water quality objectives for the mid and lower-estuaries in this document.

Table 22. Water quality indicator categories, associated indicators and guideline values for freshwater basins in the Mackay-Whitsunday-Isaac report card, with guidelines relating to the individual river or creek that was sampled.

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

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

Table 23. Water quality indicator categories, associated indicators and guideline values for estuaries in the Mackay-Whitsunday-Isaac 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
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 a 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 SF's 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 indicator's 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 Mackay-Whitsunday-Isaac Region, except for DO. The SF for DO is based on the 99th percentile of all values for DO collected from estuarine monitoring in the Mackay-Whitsunday-Isaac Region. This is because the adoption of the 90th percentile would have resulted in adoption of a 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.

It should be noted that three of the monitored estuaries (Sandy, Rocky Dam, and Carmila Creeks) are strongly tidal influenced, and this may be apparent in the results. This could affect turbidity values through increased suspension of sediments by tidal currents. It should also be noted that the estuarine monitoring in the Mackay-Whitsunday-Isaac Region is a newly commenced program, therefore only one year of data was available for calculation of the SF at the time of. SF values will be re-visited in the future as more data is collected.

Limits of reporting (LOR)

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

- Where a monitoring program reports a LOR that is greater than 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 Queensland); and
- Where a monitoring program reports a LOR that is less than the guideline value, a value of 0.5 x LOR is applied to data where <LOR is reported in a sample.

It should be noted that 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 x LOR may have the impact of biasing results towards better scores than is true in the field. This, and the quantity of samples where data is 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.

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:

- The total catchment area upstream of the site was requested from DES;
- 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;
- The proportion of total catchment area for each monitoring site was determined and multiplied by the standardised score for each monitoring site;
- All scores were summed to provide the final basin score.

3.1.3.2. Pesticides

In regional report cards prior to the 2017-2018 reporting period, the Pesticide Risk Metric scores (previously referred to as the ms-PAF (multisubstance-Potentially Affected Fraction)) method had been used to calculate the mixture toxicity for PSII herbicides only. PSII herbicides share a common mode of action (MoA), and therefore, the Pesticide Risk Metric (PRM) could be calculated using the concentration addition model of joint action (Bliss 1939; Plackett and Hewlett 1952; Könemann 1981). From the 2017-2018 report card, the ms-PAF approach was applied to pesticides with multiple MoAs. The ms-PAF for pesticides with different modes of action was calculated using the independent action model of joint action (Plackett and Hewlett 1952). Further details on how the Pesticide Risk Metric calculations were made are provided in Warne et al. (2019). The pesticide mixture toxicity was calculated for all samples collected over the standardised 182-day wet season. 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 PRM single value. In order to do this, it was necessary to estimate the daily average ms-PAF for days that weren't monitored during the wet season using a multiple imputation technique (Rubin 1996; Donders et al. 2006; Patrician 2002). This involved fitting a statistical distribution to the observed data for the wet season for the site. This distribution was then used to impute values to fill in the missing days in the 182-day period. The resultant 182 days of data were then divided by 182 to obtain the Pesticide Risk Metric and ranked into five risk categories (Table 24). These categories are consistent with the ecological condition categories used in the Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters.

For the 2018 report card onwards, pesticide risk metric values were used to determine pesticide grades. All values were rounded to the nearest whole number.

Table 24. 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	VG = 81+ ABS((19 - ((score-0) *(19/1))))
>1 – <5%	>95 – <99%	Low risk	Good	G= 61+ ABS((19.9 - ((score -1.01) *(19.9/3.99))))
5 – <10%	>90 – 95%	Moderate risk	Moderate	M=41+ ABS((19.9 - ((score -5.00) *(19.9/4.99))))
10 – <20%	>80 – 90%	High risk	Poor	P= 21+ ABS((19.9 - ((score -10.00) * (19.9/9.99))))
≥20.0%	≤80%	Very high risk	Very poor	VP=0+ABS((20.9 - ((score-20.00) *(20.9/79.99))))

3.1.4 Habitat and hydrology

3.1.4.1. Habitat Modification/instream habitat modification (freshwater basins)

The two in-stream habitat modification indicators, impoundment length and fish barriers, were equally weighted to generate the habitat modification/in-stream habitat modification score. 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

The scoring range (Table 25) 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 (see DNR 2000 and Sheldon et al. 2000). An assumption of status quo is implied in the scoring for impoundment length (rather than cause-and-effect with ecological function), with additional impoundments lowering subsequent report card scores.

Table 25. 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	VG= 81+ ABS((19 - ((score-0) *(19/0.99))))
1.0-3.99%	Good	G= 61+ ABS((19.9 - ((score -1) *(19.9/2.99))))
4.0-6.99%	Moderate	M=41+ ABS((19.9 - ((score -4) *(19.9/2.99))))

7.0-9.99%	Poor	P=21+ ABS((19.9 - ((score -7) * (19.9/2.99))))
≥ 10.0%	Very poor	VP=0+ABS((20.9 - ((score-10) *(20.9/90))))

Fish barriers

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 26, Table 27 and Table 28). Each basin and estuary was allocated a score for each indicator based on these scoring ranges. For the Don basin, the indicator 'stream length to the first low/no passability barrier as a proportion (%) of total stream length' could not be measured with confidence, and expert opinion was used to apply a score. The final aggregated fish barriers indicator score for each basin and estuary was derived by adding these three scores together (Table 29).

Table 26. Scoring range and subsequent score assigned for the barrier density indicator. Assessed on Stream Order (SO) as indicated[1].

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 27. 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 28. 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 29. Overall fish barrier condition scoring range and fish barrier condition rating.

Scoring Range	Overall Fish Barrier Condition Rating	Scaling of scores for aggregation
14-15	Very good	VG = 81+ ABS((19 + ((score-15) *(19/1)))
11-13	Good	G= 61+ ABS((19.9 + ((score -13) *(19.9/2))))
8-10	Moderate	M=41+ ABS((19.9 + ((score -10) *(19.9/2))))
5-7	Poor	P= 21+ ABS((19.9+ ((score -7) * (19.9/2))))
3-4	Very poor	VP=ABS((20.9 + ((score-4) *(20.9/1)))

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

3.1.4.2. Fish barriers (estuaries)

The final score for the fish barrier indicator in each estuary was generated using the fish barrier scoring regime described above.

3.1.4.3. Flow (Freshwater basins and estuaries)

The flow indicator scores the daily flow record for the reporting year at a given flow assessment site. There are 10 measures that contribute to the flow indicator score (Table 30). Each measure assesses observed flow data against the reference distribution from the predevelopment modelled flow for the given flow assessment site. The reference distributions are selected for one of the four rainfall types (drought, dry, average or wet) to match the rainfall type of the reporting year. The 10 flow measures 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 ecological assets are: cease to flow- amphibians, riffles and waterholes; low flows- low flow spawning fish species, reptiles, amphibians, riffles and waterholes; medium flows- riffles; and high flows- fisheries production in estuaries. Details of the flow requirements of the assets (including seasonal flow requirements), their links to the flow measures and a description of the flow measures are presented in the Report Card Flow Indicator Project report (Stewart-Koster et al. 2018), which can be requested from info@healthyriverstoreef.org.au.

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 predevelopment levels the actual hydrological characteristics of the flood and inundation events, and hence their ecological functioning, may be altered.

Table 30. The 10 flow measures used for the flow indicator, the season to which they apply and the hydrologic definition of the measure.

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

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

The scoring for each flow measure is based upon the percentile range representative of standard deviations from the mean as presented in **Error! Reference source not found.**31.

Table 31. 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 flow measures score the flow for the reporting year on a scale of 1 to 5. For each flow assessment site the 30th percentile value of all 10 flow measures is used to provide a summary score. Several summary statistics were evaluated during the development of the flow indicator (Stewart-Koster et al. 2018) and the 30th percentile value was selected as the most appropriate summary statistic for representing the range of the 10 flow measures. The other summary statistics 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 10 flow measures (each scores 1-5) for each flow assessment site.

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

Step 2 was to provide a value of 0 to 20.9 for scores of less than two graded very poor.

Step 3 was to provide a value between 21 and 80 for scores between two and less than five and are graded poor, moderate or good.

Step 4 is to provide a value of between 80 to 100 for scores of five using the lowest contributing flow measure score as a scale and also prevents a flow assessment site for which a flow measure is score 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 32.

Table 32. Standardisation formula 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) x5)
4- <5	Good	(score x 20) - 19
3- <4	Moderate	(score x 20) - 19
2- <3	Poor	(score x 20) - 19
1-<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 are summed to provide the final basin score.

Worked example of the flow indicator

The 2018 to 2019 rainfall for the Pioneer Basin and the annual flow records for Finch Hatton Creek and Dumbleton Weir Tailwater are presented in Figure 8. Finch Hatton is located upstream in the upper catchment whilst Dumbleton Weir Tailwater (TW) downstream, in the lower catchment of the Pioneer River. Difference 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 assessment of flow records using the indicator differ between a site that has minimal alteration from predevelopment flows (Finch Hatton) and one that has substantial alteration from predevelopment flows (Dumbleton Weir TW) for the 2018-19 reporting period.

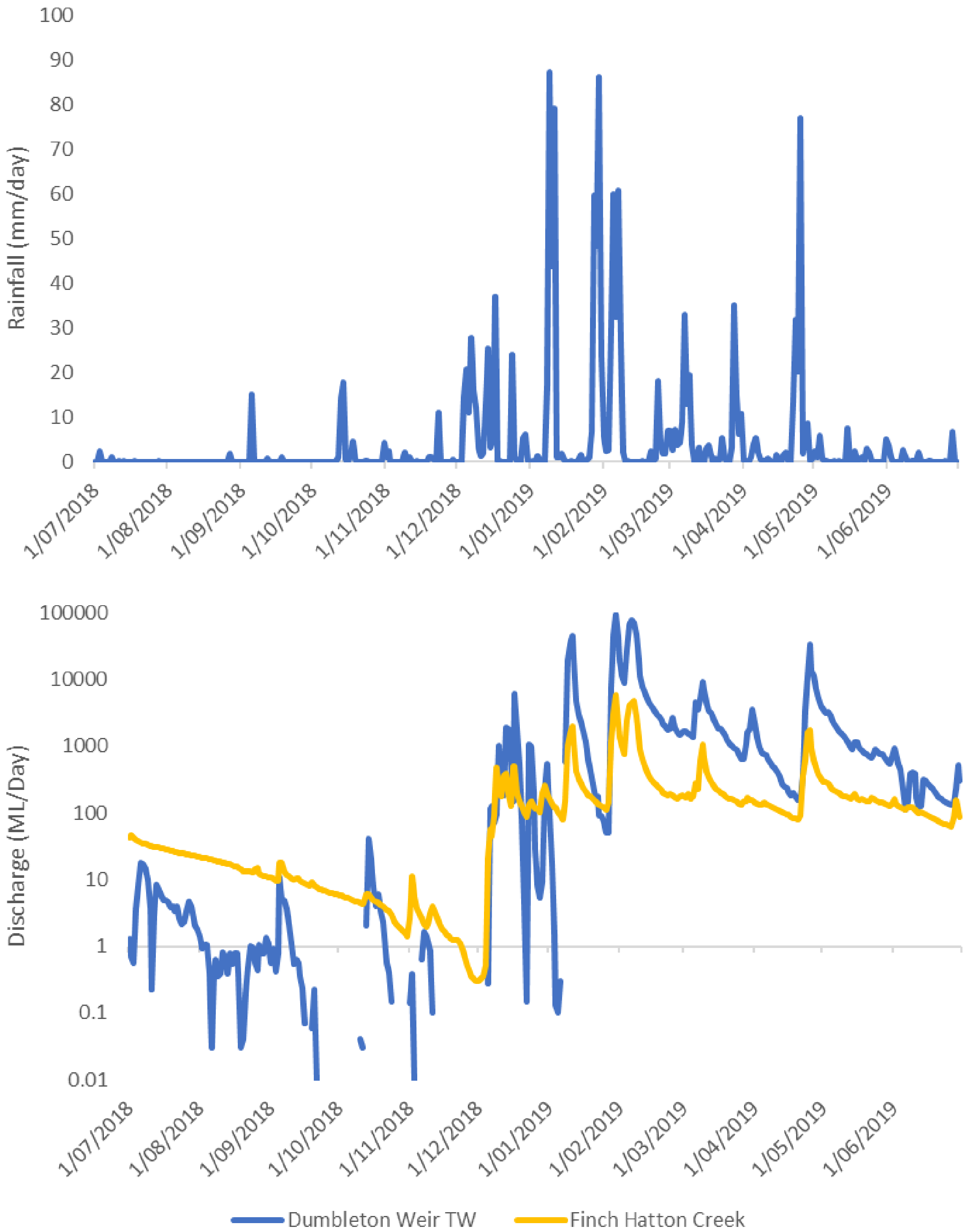

Figure 8. Rainfall for the Pioneer Basin and flow records for Dumbleton Weir Tailwater (TW) and Finch Hatton Creek for 2018-19. Flow (ML/day) is represented in log scale.

The flows at Finch Hatton for 2018-19 scored a maximum of five for eight of the ten flow measures, determining that much of the flow for the 2018-19 reporting period were not substantially altered from pre-development flows. The flow measure of medium flow frequency and high flow frequency for Finch Hatton scored two and four respectively, and likely resulted from the very dry conditions that occurred in the region between August 2018 and November 2018. The overall freshwater flow score at Finch Hatton was 5, calculated from the 30th percentile of the ten flow measures. The standardised report card value of this score was 85 (very good). The flows at Dumbleton Weir TW were substantially altered from predevelopment flows for the following three of ten flow measures: cease to flow duration (score=1/5), cease to flow frequency (score= 1/5), low flow duration (score 1/5). The flow record at Dumbleton Weir TW show 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 3.1, with the standardised report card value of this score of 43 (moderate). 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 10 flow measures are able to assess and score aspects of the flow regime that may not be as clearly visualised from the flow record but may still be important to waterway health. The potential impacts upon waterway health attributes linked to low flows include low flow spawning fish, critical hydraulic habitat, longitudinal connectivity and water quality, those linked to medium flows include riffle habitats and macrophyte beds, and those linked to high flows include fishery production (Stewart-Koster et al. 2018). The results of the flow indicator for Dumbleton Weir TW identify that alteration of flows may be impacting on waterway health for the attributes linked to low flows and medium flows.

3.1.4.4. Riparian, wetland and mangrove/saltmarsh extent (freshwater basins and estuaries)

The condition score for the extent of riparian, wetland and mangrove/saltmarsh extent vegetation was determined by calculating the per cent loss of vegetation since pre-development to 2017 for each basin or estuary and assigning the result a grade as per **Error! Reference source not found.**33.

Table 33. 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	VG = 81+ ABS((19 - ((score-0) *(19/4.99))))
>5.0-15.0%	Good	G= 61+ ABS((19.9 - ((score -5.01) *(19.9/9.99))))
>15-30.0%	Moderate	M=41+ ABS((19.9 -((score -15.01) *(19.9/14.99))))
>30-50%	Poor	P= 21+ ABS((19.9- ((score -30.01) * (19.9/19.99))))
>50%	Very poor	VP=ABS((20.9 - ((score-50.01) *(20.9/49.99))))

3.1.5. Fish

The scoring methods for the freshwater fish community condition is outlined in **Error! Reference source not found.**34 and **Error! Reference source not found.**35. A qualitative rating scheme for native species richness (PONSE) was developed (Table 34), 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 pest fish model output is presented in Table 35**Error! Reference source not found.**.

Table 34. Rating scheme for condition of native species richness using PONSE model for freshwater fish communities.

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

Table 35. Rating scheme for the modelled pest fish condition indicator for freshwater fish community.

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

3.2. Inshore and Offshore condition assessment

3.2.4. Inshore water quality

3.2.4.1. Nutrients, chlorophyll-*a*, water clarity and pesticides

For indicators in nutrients, chlorophyll-*a* and water clarity categories, annual medians or means were calculated (with the appropriate statistic to be calculated as dictated by the guidelines of the relevant water area that each site is located) at each site and condition scores were calculated using the relevant guideline value and the procedure below.

Guideline values used to calculate indicator scores for the Whitsunday and Central inshore zones were the relevant guidelines in the 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[1]. For sites in the Northern inshore zone, the relevant guidelines from GBRMPA (2010) and DES (2009b) for Central Queensland were used because more local guidelines are currently only in draft form (Draft environmental values and water quality guidelines: Don and Haughton River basins, Mackay-Whitsunday estuaries, and coastal/marine waters[2]). Southern inshore zone scores were calculated from relevant guidelines for Central Queensland and Environmental Protection (Water) Policy Pioneer River and Plane Creek Basins Environmental Values and Water Quality Objectives. Once guidelines are scheduled, more local guidelines will be used for scoring.

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

In past report cards (2014 – 2015), only the relevant guidelines from GBRMPA (2010) were used. The shift towards using locally relevant QLD guidelines (where available) reflects a move from the MMP toward reporting on the 'interim site-specific water quality index' for the 2015-16 year based on guideline values refined using site-specific long-term water quality data collected at MMP sites (Waterhouse et al. 2017), rather than GBR wide GBRMPA (2010) guidelines. The Mackay-Whitsunday-Isaac report card has not employed the same guideline values as the MMP, preferring to use scheduled guidelines. The guideline values refined by and used by MMP are similar to the scheduled guideline values used in the Mackay-Whitsunday-Isaac report card. Relevant inshore water quality guideline values used in the 2019 report card are presented in Table 36.

Prior to calculating annual medians or means and comparing them to the guidelines, the LOR was explored, and the same rules applied as described for freshwater basins and estuaries.

Table 36. Water quality guideline values for relevant water quality indicators at inshore marine monitoring sites in Mackay-Whitsunday-Isaac 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

Sites in MWI report card	Documents	Basin/Region/water area	Water type	Management intent	NOx (µg/L)	PN (µg/L)	PP (µg/L)	Chl-*a* (µg/L)	TSS (mg/L)	Secchi (m)	Turb (NTU)
Northern zone											
All sites (Abbot Point)	1 & 2	Don 121	OC	SMD	3	20	2.8	0.45	2	10	1
Whitsunday zone											
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
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
Central zone											
WHI6 O'Connell River mouth (MMP)	3	SD2381 (EC)	EC	HEV	2-4-10			0.8-1.3-2			
WHI7 Repulse Islands 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	D1-2-8; W5-12-33
AMB3B (Mackay & Hay Point)	3 & 4	OC landward of plume line	OC	SMD		<20	<2.8	<0.45	<2.0	>10	<1
AMB5 (Mackay & Hay Point)	4	MD2341 (port open waters)	OC	MD		<20	<2.8	<0.45	<2.0	>10	D1-2-8; W5-12-33
AMB6 (Mackay & Hay Point)	4	MD2343	OC	MD		<20	<2.8	<0.45	<2.0	>10	D1-2-8; W5-12-33
AMB8 (Mackay & Hay Point)	3 & 4	OC landward of plume line	OC	SMD		<20	<2.8	<0.45	<2.0	>10	D1-2-8; W5-12-33
AMB10 (Mackay & Hay Point)	3 & 4	OC landward of plume line	OC	SMD		<20	<2.8	<0.45	<2.0	>10	<1
AMB11 (Mackay & Hay Point)	4	MD2341 (marina)	EC	MD	<10			<2.0		>1	D1-2-8; W5-12-33
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
Southern zone											
Cam 1 (Aquilla Island)	2&4	SD2383	OC	HEV	3	<20	<2.8	<0.45	<2.0	>10	<1
Cam 2	2& 4	SD2383	OC	HEV	3	<20	<2.8	<0.45	<2.0	>10	<1
Cam 3	2&4	SD2383	OC	HEV	3	<20	<2.8	<0.45	<2.0	>10	<1

Document:

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.*

The following steps were used to calculate a score for each indicator (this formula and method are described in full in Lønborg et al. 2016 and 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:

   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 (for example Secchi depth):

   Condition score = $\log_2$ (AM/GV)

   Where:

   AM is annual median or mean of the measured indicator
   GV is guideline value
2. Ratios exceeding -1 or 1 were capped to bind the water quality index to the range from -1 to 1, such that all indicators were on the same scale.
3. For turbidity, where a wet and dry score is calculated, these scores were averaged to give one annual score for turbidity.
4. The nutrients indicator score was calculated as the average of NOx, PP and PN scores (where available and following rules for minimum information); the water clarity indicator was calculated as the average of Secchi, TSS and turbidity scores (where available and following rules for minimum information);
5. The indicator scores for nutrients, water clarity and chl-*a* are translated to the report card five-point grading scale using the ranges and grades shown in Table 37.

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

Condition grade and colour code	Score Range	Scaling of scores for aggregation
Very good	>0.5 to 1	100- (19 - ((score-0.51) * (19/0.49)))
Good	0 to 0.5	80.9 - (19.9 – ((score-0.01) *(19.9/0.49)))
Moderate	<0 to -0.33	60.9- (19.9 - ((score -(-0.33)) *(19.9/0.32)))
Poor	<-0.33 to -0.66	40.9- (19.9 - ((score -(-0.66)) * (19.9/0.32)))
Very poor	<-0.66 to -1	20.9- (20.9 - ((score -(-1)) *(20.9/0.34)))

3.2.4.2. Pesticides

Pesticide data are collected by both Ports, MMP and Southern inshore programs, either by grab samples or passive samplers respectively.

In order to express the concentration data for all selected pesticides as a single number that represented the overall risk to aquatic ecosystems, it was necessary to convert all the concentration data into a numerical term that represented the toxicity of the mixture of pesticides in each passive sampler or water sample. In the 2014-2017 report cards, the hazard equivalence (HEq) method was used to express the toxicity of PSII herbicides based on their toxicities relative to diuron (Grant et al. 2018). From the 2018 report card, the multi-substance potentially affected fraction (ms-PAF) approach (Traas et al. 2002) was adopted to determine pesticide risk metric grades and bring this metric in line with freshwater catchments. The ms-PAF approach was applied to pesticides with multiple modes of actions (MoAs) (Table 12). The ms-PAF for pesticides with different modes of action was calculated using the independent action model of joint action (Plackett and Hewlett 1952). Further details on how the pesticide risk metric calculations were made are provided in Warne et al. (2019).

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

The corresponding percent species protected (calculated for each passive sampler at 4 monitoring sites) were then allocated to the risk categories presented in Table 38Table 38. These categories are consistent with the ecological condition categories used in the Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters (ANZG (2018))[1].

The average maximum ms-PAF concentration recorded within the zone was used as the pesticide result. If grab sample data was available in the same zone as the passives, grab sample data were used only to provide reference for the passive sampler result.

All values were rounded to the nearest whole number.

Table 38. Grading description for the pesticides indicator in the freshwater basin assessments.

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

3.2.5. Offshore Water Quality

The offshore water quality condition assessment uses the per cent of area of offshore waters in the zone that exceeds the relevant water quality guideline value (mid-shelf waters that are included in the offshore zone are not assessed) (Table 39). This data was specifically extracted by the Bureau of Meteorology from the marine water quality dashboard[2]. Each indicator score (chlorophyll-*a* and sediment [TSS]) was calculated by subtracting the percentage of the area which exceeded the guideline value from 100%, with the resulting value being that percentage of area that did *not* exceed the water quality guideline value within the reporting period. The score (from 0 – 100) was then directly translated to a report card grade using the GBR report card grading (Table 19). The TSS and chlorophyll-*a* results are weighted equally (Table 39), therefore are averaged to provide the water quality indicator category result for the offshore zone.

Table 39. Offshore water quality indicators, guideline values and weightings.

Indicator	Measured indicators	Guideline value*	Weighting
Water clarity	TSS	0.7 mg/L	50%
Chlorophyll-*a*	Chlorophyll-*a*	0.4 μg/L	50%

*Guideline values are based on water quality guidelines for the Great Barrier Reef Marine Park 2010 (Great Barrier Reef Marine Park Authority 2010).

[1] https://www.waterquality.gov.au/anz-guidelines/resources/key-concepts/level-of-protection
[2] http://www.bom.gov.au/marinewaterquality/

3.2.6. Coral

Condition assessment of the coral indicators for the inshore zones followed the method of the MMP (Table 40):

- **Coral cover:** This indicator simply scores reefs based on the level of coral cover. For each reef, the proportional cover of all genera of hard (order Scleractinia) and soft (subclass Octocorallia) corals are combined;
- **Macroalgae cover:** This indicator is the percentage cover of macroalgae as a proportion of the total cover of all algal forms (inshore regions only);
- **Density of juvenile hard corals:** Counts of juvenile hard corals were converted to density per m2 of space available for settlement;
- **Change in coral cover**: The change in coral cover indicator is derived from the comparison of the observed change in coral cover between two visits and the predicted change in cover derived from multi-species, in the form of a Gompertz growth equation. 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 combined grouping of all other slower growing hard coral taxa; and
- **Community composition:** The basis of the indicator is the scaling of cover for constituent genera (subset to life forms for the abundant genera Acropora and Porites) by genus weightings that correspond to the distribution of each genus along a gradient of turbidity and chlorophyll concentration. This is a new indicator for inshore coral condition reporting applied to inshore regions only.

For the Central inshore zone, 'coral cover' and 'density of juvenile hard coral' indicators were analysed using the MMP approach. This involved aggregating juvenile hard coral abundance that was collected at the site level, up to the reef level mean, for the size classes 0-2cm and 2-5cm. Consistent with MMP and the GBR report card, these data excluded the genus Fungia (mushroom/disc corals). Mean hard coral and soft coral cover for each reef was provided and these estimates summed to produce 'coral cover'. Mean total algae cover was also supplied and this was used, along with the transect dimensions, to convert juvenile abundance to the indicator juvenile density. The central inshore zone scores are the mean of the reef level scores for each indicator.

For the 2019 report card, indicators for both inshore and offshore regions were scored in a similar way. Observations for each indicator were scored on a continuous scale following Thompson et al. (2016) and can be seen in Table 41. The approach involves selecting bounding values for each indicator based on biology. These bounds become zero (very poor) and 1.0 (very good) on an approximately linear scale (see Section 6 of Thompson et al. 2016). This linear scale is then used to convert the value of each indicator from each reef a value between zero and 1.0, and the values for the reefs in each reporting zone are averaged.

Note that different sets of reefs are surveyed in alternate years. For this reason, the indices for coral cover and the density of juveniles are based on the most recent surveys of each reef in the reporting zone. The most recent surveys for some of the reefs will have been made in the preceding year. The coral change index is based on the most recent estimate of the rate of *change over the interval* *between surveys*, which for some of the reefs will include the change in cover over the two years up until the preceding year.

Table 40. Threshold values for the condition assessment of coral where indicators that are reported in inshore zones only are identified.

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

Table 41. 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' x 100
Good	> 0.6 – 0.8	'score' x 100
Moderate	> 0.4 – 0.6	'score' x 100
Poor	> 0.2 – 0.4	'score' x 100
Very poor	0 – 0.2	'score' x 100

3.2.7. Inshore seagrass

3.2.7.1. Marine Monitoring Program

Through the MMP seagrass monitoring, a method has been developed and documented (refer to McKenzie et al. 2015) to roll up seagrass data results into the GBR report card scoring range (Table 19). Each set of seagrass indicator results are analysed to provide a relevant score and grade. These scores are translated to fit the GBR report card scoring range. The scoring thresholds and their relation to the GBR report card scoring ranges are provided for seagrass abundance in Table 42, reproductive effort in Table 43, and nutrient status in Table 44. An overall score for a site is then calculated by averaging the three seagrass indicator scores (scores of 0 - 100) where all indicators are equally weighted. For further detail on the seagrass scoring methods, refer to McKenzie et al. (2015).

Table 42. Seagrass 'abundance' scoring thresholds in relation to condition grades (low = 10th or 20th percentile guideline); Source McKenzie et al. (2015).

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

Table 43. Seagrass 'reproductive effort' scoring in relation to condition grades; Source McKenzie et al. (2015).

Reproductive effort Monitoring period / long-term	Ratio	Score	0-100 Score	Score Range	Condition grade
≥ 4	4.0	4	100	80 – 100	Very good
2 to < 4	2.0	3	75	60 – < 80	Good
1 to < 2	1.0	2	50	40 – < 60	Moderate
0.5 to < 1	0.5	1	25	20 – < 40	Poor
< 0.5	0.0	0	0	0 – <20	Very poor

Table 44. Seagrass 'nutrient status' scoring in relation to condition grades; Source McKenzie et al. (2015).

C:N Ratio Range	Value	Score	Score Range	Condition grade
C:N ratio > 30	30	100	80 – 100	Very good
C:N ratio 25 – 30	25	75	60 – < 80	Good
C:N ratio 20 – 25	20	50	40 – < 60	Moderate
C:N ratio 15 – 20	15	25	20 – < 40	Poor
C:N ratio <15		0	0 – <20	Very poor

3.2.7.2. 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. The baseline is ideally calculated using a 10-year average. Seagrass 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 will be 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 0 to 1 and is assigned one of five grades: A (very good), B (good), C (moderate), D (poor) and E (very poor). For details on how a condition score is derived, see Carter et al. (2019). Scores are multiplied by 100 to align to the 0-100 MMP scale.

To derive a condition score, a meadow classification system defines threshold ranges for the three indicators: 'biomass', 'area' and 'species composition', 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 (all species comprise <80% of baseline species composition). Where species composition was determined to be anything less than in 'perfect' condition (i.e. a score <1), a decision tree was used to determine whether equivalent and/or more persistent species were driving this grade/score (Carter et al. 2019).

Each meadow/site score is defined as the lowest grade/score of the three indicators within that meadow. A review of the QPSMP methods in 2017 produced a slight modification from previous score aggregation. The new method still defined overall meadow condition as the lowest indicator score where this is driven by biomass or area, however, where species composition was the lowest score, it contributed to 50% of the overall meadow score, and the next lowest indicator (area or biomass) contributed the remaining 50%. For further details on the scoring methods see Carter et al. (2019).

3.2.7.3. 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 Northern or Whitsunday inshore zones, but both programs have seagrass monitoring in the Central inshore zone.

The GBR report card scoring range (**Error! Reference source not found.**) has been adopted for all seagrass indicators, regardless of the program. Scores for each monitoring site/meadow (derived by averaging across indicators at MMP sites or using the lowest indicator grade at QPSMP sites) are averaged to generate an overall score for a defined reporting zone. These final zone scores are graded based on the GBR report card scoring ranges (**Error! Reference source not found.**). For a full description and worked example of the combined display approach refer to Carter et al. (2016).

Overall indicator scores are also provided by averaging all indicator scores within a zone. Due to the differences in deriving overall location/meadow scores between programs, overall indicator scores are not averaged to provide final zone scores.

4. Development of progress to targets scoring methods

To provide information on how the 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:

Progress to target = ((X-Z)/(X-Y))*100

Where:

X = baseline
Z = current condition
Y = 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 Government and Queensland Government 2015a). This is based on a multi-criteria analysis approach to qualitatively score the confidence for each key indicator used in the report card. The approach enables the use of expert opinion and measured data.

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

The 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 Mackay-Whitsunday-Isaac Region have been given a higher weighting when determining the overall confidence.

5.1.4. Methods

Determining confidence for the report card used five criteria (Table 45):

- Maturity of methodology;
- Validation;
- Representativeness;
- Directness; and
- Measured error.

Maturity of methodology

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

Validation

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

Representativeness

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

Directness

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

Measured error

The purpose of this criterion is to incorporate uncertainty into the indicator and use any quantitative data where it exists. This score is weighted 0.71 for this criterion so as not to outweigh the importance of the representativeness criterion.

Table 45. 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

5.1.5. Scoring

For all indicators where a condition score was reported, each criterion is scored 1 (lowest) to 3 (highest) as defined in Table 43. 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 44). The final scores and the associated confidence rankings have been adjusted from the previous report cards to reflect the Mackay-Whitsunday-Isaac specific weightings applied to the criteria. The confidence ranking (out of five) is then presented in the report cards.

5.1.5.1. Scoring confidence criteria in the Mackay-Whitsunday-Isaac report card

When scoring confidence for indicators in the Mackay-Whitsunday-Isaac Region, confidence of an indicator was considered separately for the different reporting zones (i.e. for each of the five freshwater basins, eight estuaries, four inshore marine zones and the one offshore marine zone). 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 reporting 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 inshore 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/data sets contribute to an overall indicator score in the same reporting zone, the following decision rule was applied:

- When data is partitioned equally between the two methods/programs/data sets, confidence is scored conservatively (i.e. the lower of two scores is applied where relevant);
- When data is not partitioned equally between the methods/programs/data sets, confidence is scored by using the score for the dominant method/program/data set.

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

5.1.5.2. Final confidence scores for presentation in the Mackay-Whitsunday-Isaac 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 46). However, for presentation in a printed report card, confidence scores must be aggregated into a single score for freshwater basin, estuarine, inshore marine 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. The freshwater fish barriers indicator score used therefore 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 46. 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 ●○○○○
		NO DATA ○○○○○

5.2. Limitations and recommendations

Since the pilot report card was released in 2014, considerable advances have been made in improving the quality and accuracy of report card results. However, to adequately interpret the 2019 report card, methods and results reports[1], it is important to highlight and acknowledge the limitations of our existing approach. A summary of the known limitations and proposed recommendations are provided below.

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 after previous report cards highlighted the low spatial representativeness of water quality monitoring data in freshwater basins. In 2016 and 2017, sites were established as part of the GBRCLMP in each of the Don and Proserpine basins, and additional sites in the O'Connell and Plane basins (now two monitoring sites in each basin).

However, limitations still exist when using data obtained from one or two discrete monitoring sites, to report water quality at the basin scale:

[1] https://healthyriverstoreef.org.au/report-card-results/

- 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 freshwater basin water quality site was identified as being situated in the estuary and subject to tidal influence which may influence the concentrations of sediment and nutrients through physical re-suspension and tidal mixing. As the representativeness of results obtained from this site was deemed obscured, no score has been reported for sediment and nutrients in the Proserpine basin. The Partnership and report card's TWG are currently exploring alternate monitoring sites to better represent the Proserpine River and, ultimately, the Proserpine Basin.
- A water quality score was not derived for the Proserpine Basin in the 2019 report card; this remains a significant data gap in the MWI report card framework and impedes our understanding of regional waterway health. A review of the available water quality data suggested that the site was located within the estuary where the concentration of sediments (TSS) is influenced by tidal action and therefore not fully representative of the freshwater environment. It is anticipated 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 2019 report card
- The method produced for assessing multiple freshwater sites for the 2019 report card is currently being reviewed and refinements may be incorporated in the development of future report cards.

Flow was incorporated into the report card for the second consecutive year. Considerable work has been undertaken between the 2018 and 2019 report card releases to explore opportunities to fill data flow data gaps in basins and estuaries that were identified in the 2018 report card. This work is currently progressing with the Bureau of Meteorology (BoM), with technical advice from the report card's TWG. It was recommended at the 2020 Independent Science Panel (ISP) and TWG meetings that a review of the flow indicator tool to be undertaken, as the flow indicator tool has been utilised in the Mackay-Whitsunday-Isaac and Wet Tropics and report cards for two and three years respectively. This is anticipated to occur between the release of the 2019 and 2020 report cards.

Low confidence in pesticide data in the estuaries has been highlighted since the report card was first released (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 <6 to approximately 18 in the current assessment. The results obtained through this monitoring program are reported for the first time in the 2019 report card. Consequently, this represents the most reliable estimate of pesticide condition in the Mackay-Whitsunday-Isaac estuaries, reported to date.

A knowledge gap was identified in previous report cards for the Southern inshore 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 inshore region for the first time. The 2019 report card reported water quality in this zone for the second consecutive year, including pesticides for the first time, and a score for coral for the first time. A seagrass scores will be released in the 2021 report card, due to timing of data collection and recommendations.

Other limitations to the report card include seagrass reporting, which currently does not allow for direct comparison across marine reporting zones, and limitations around the understanding of riparian, wetland and mangrove/saltmarsh habitats.

The Partnership and Partners have been working towards addressing some of these limitations:

- 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);
- Working with the report card's TWG and riparian and wetland data providers/experts to improve report card indicators for wetland and riparian extent and ensure comparability over time.

Further improvements to the report card that have been identified for the future are outlined in the Mackay-Whitsunday-Isaac Report Card Program Design 2017 to 2022[1] document. Some of the key improvements include:

- Exploration of passive samplers across the four inshore zones;
- Exploration of estuary and marine fish indicators (using RIMReP as a guide);
- Review of inshore marine water quality condition scoring and exploring the option to use eReefs modelling as part of condition assessments;
- Expansion of water quality monitoring in freshwater basins to include the upper and middle of catchments; and
- Moving towards inclusion of reporting progress-to-targets.

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

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