Methods for the Mackay-Whitsunday
2017 Report Card

Environmental Indicators

Final Report

Regional Report Cards Technical Working Group
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HEALTHY RIVERS TO REEF PARTNERSHIP
MACKAY-WHITSUNDAY

Authorship statement

The Mackay-Whitsunday Healthy Rivers to Reef Healthy Partnership (Partnership) Methods for the Mackay-Whitsunday 2017 Report Card technical report was compiled by the Partnership's Technical Officers, Emma Maxwell and Alysha Sozou.

Substantial input was received from the Regional Report Cards Technical Working Group (TWG) members. Some content was also drawn from technical reports from earlier Mackay-Whitsunday report cards.

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Executive Summary

The Mackay-Whitsunday Healthy Rivers to Reef Partnership (the Partnership) was launched in 2014 with the '2014 Pilot Report Card', which reported on the 2013-14 year and was released the following year in October 2015. Since then, the Partnership has released three more report cards, the 2015 (reporting on data July 2014 to June 2015 and released in October 2016), 2016 (reporting on data July 2015 to June 2016 and released in October 2017) and 2017 report cards (reporting on data July 2016 to June 2017 and released in December 2018).

The purpose of this document is to provide detailed information on the methods used for the 2017 report card that produced assessments of condition for the freshwater, estuarine, inshore marine and offshore marine environments. Specifically, this document describes the following:

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

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 (photosystem II inhibiting herbicides) as indicator categories. Data reported for the water quality index was collected from the Department of Environment and Science (DES) Great Barrier Reef Catchment Loads Monitoring Program (GBR CLMP) sites and reported at the basin level for the Don, Proserpine, O'Connell, Pioneer and Plane basins. The habitat and hydrology index include indicators relating to habitat modification (impoundment length and fish barriers), riparian extent, wetland extent and flow. Data for the habitat and hydrology index (impoundment length, riparian extent, wetland extent and invasive weeds) was collected for all basins. The fish indicator in freshwater basins was assessed by comparing observed data to modelled data to report on two out of three indicators: native richness, pest fish and fish assemblage. Results for fish in freshwater are updated every three years, therefore results in the 2017 report card were repeated from the 2016 and 2015 report cards.

The indicators for estuaries are grouped within the water quality, habitat and hydrology and fish indices. The water quality index includes physical and chemical indicators (dissolved oxygen and turbidity), nutrient indicators (dissolved inorganic nitrogen and filterable reactive phosphorus) and pesticide indicators (photosystem II inhibiting herbicides). Data for the water quality index was collected at DES monitoring sites in all eight of the reported estuaries (Gregory, O'Connell, St Helens/Murray, Vines, Sandy, Plane, Rocky Dam and Carmila Creeks). The habitat and hydrology index include fish barriers, riparian extent, mangrove/saltmarsh extent, and flow indicators. Data for the habitat and hydrology index (riparian extent, mangrove and saltmarsh extent and fish barriers) was collected for all estuaries.

The indicators for the inshore marine environment are grouped within the water quality, coral, seagrass and fish indices. The water quality index includes water clarity (total suspended solids and turbidity), nutrient (oxidised nitrogen, particulate nitrogen and particulate phosphorus) and pesticide (photosystem II inhibiting herbicide equivalent concentrations) indicators. Inshore marine reporting

is separated into four zones: Northern, Whitsunday, Central and Southern inshore marine zones. Data was available only for the Northern, Whitsunday and Central inshore marine zones. Data for the water quality index was collected by a combination of the Marine Monitoring Program (MMP) and North Queensland Bulk Ports commissioned marine ambient monitoring programs at Abbot Point, Mackay and Hay Point. Data for coral was collected from the MMP, NQBP commissioned programs and Long-Term Monitoring Program (LTMP) coral monitoring sites. Data for seagrass was collected from the MMP seagrass monitoring sites and the Queensland Ports Seagrass Monitoring Program (QPSMP) sites.

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 are measured using remote sensing data and was collected from the Bureau of Meteorology (BoM) dashboard. The coral index includes coral cover, rate of coral cover increase and density of juvenile corals indicators. Data for coral was collected from the LTMP. The offshore marine reporting was conducted for the single offshore reporting zone.

Assessments of fish community health were deemed important across all aquatic environments of the Mackay-Whitsunday report card. The development of estuarine and marine fish indicators and methods is still progressing and was not included in the 2017 report card.

An overall condition grade was provided for each indicator for each of the five freshwater basins, eight estuaries, four inshore marine zones and the offshore marine zone. Ordinal categories are used to describe 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). All indicators have specific scoring ranges and bandwidths which correspond to the five-point system.

Indicator scores were aggregated from the indicator level to generate indicator category scores. In some cases, for example estuary fish barriers, multiple measures make up the indicator score. Where an indicator category is represented by a single indicator, the indicator category score is equal to the indicator score. Indicator categories were aggregated to generate an index score, and index scores were subsequently aggregated to produce an overall score for an individual reporting zone in an environment.

The assessment results in the report card were rated in terms of the confidence and uncertainty surrounding the data used in the analysis. To score this, five criteria relating to data confidence are assessed for each indicator in each reporting area: maturity of methodology, validation, representativeness, directness, and measured error. This information is used to provide a qualitative confidence assessment for all grades generated in the 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 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
NQBP	North Queensland Bulk Ports
Offshore (reporting zone)	Offshore is a reporting zone in the Mackay-Whitsunday 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 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 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)	The PSII herbicides (ametryn, atrazine, diuron, hexazinone, tebuthiuron, bromacil, fluometuron, metribuzin, prometryn, propazine,

	simazine, terbuthylazine, terbutryn) are included in pesticides reporting. Up to 28 pesticides with different modes of action will progressively be included in subsequent Mackay-Whitsunday report cards.
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

1. Introduction

1.1. Purpose of this document

The purpose of this document is to provide detailed information on the methods used to produce the Mackay-Whitsunday 2017 report card. This includes condition assessments of the environmental indicators in freshwater basins, estuaries, inshore and offshore marine environments. Specifically, this document describes:

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

Human dimensions (including stewardship, social, economic and cultural heritage) were not assessed in the 2017 report card. Methods used to assess human dimensions in previous report cards (2014, 2015 and 2016) can be found in the 'Development of methods for the Mackay-Whitsunday report card 2015: Stewardship and cultural heritage' technical document[1], the 'Development of methods and results for the pilot report card social and economics' technical document[2], and the 'Development of methods and results for the pilot report card stewardship' technical document[3].

1.2. Background

The Mackay-Whitsunday Healthy Rivers to Reef Partnership (the Partnership) was established in October 2014. The primary focus of the Partnership was 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 report card which helped 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 Health Rivers to Reef report card and its future scope

[1] https://healthyriverstoreef.org.au/wp-content/uploads/2018/12/development-of-methods-for-the-mackay_stewardship-and-cultural-2015.pdf
[2] https://healthyriverstoreef.org.au/wp-content/uploads/2018/08/final_s_e_methods-and-results_pilot-report_website_links.pdf
[3] https://healthyriverstoreef.org.au/wp-content/uploads/2018/08/final_stewardship_methods-and-results_pilot-reportapp_website-links.pdf

and will be reviewed again after the release of the 2022 report card. The 2017 report card is the fourth report card released by the Partnership. For more detail on the Mackay-Whitsunday report card and Partnership, refer to the 'Mackay-Whitsunday Report Card Program Design 2017 to 2022' document (MWHR2RP, 2018)[4].

1.3. 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, habitats and 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).

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).

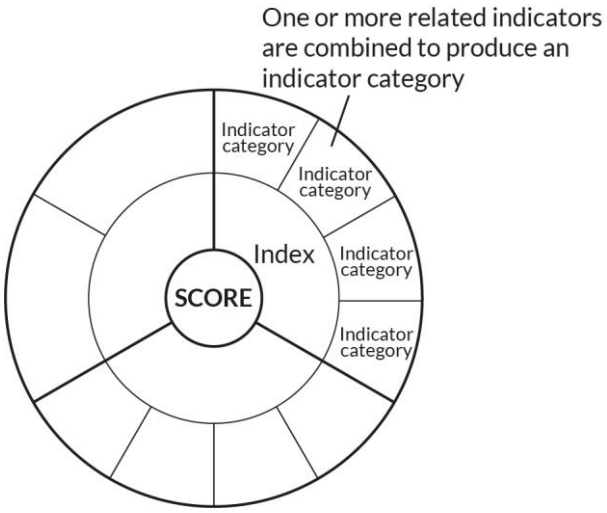

Figure 1. Terminology used for defining the level of aggregation of indicators and how they are displayed in coasters in the report card.

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

2. Data collection methods

The sections below provide an overview of the data collection methods for the environmental indicators reported in the Mackay-Whitsunday Report Card. The indicator selection process and descriptions of the environmental indicators are detailed in the Mackay-Whitsunday 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 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)	●	●		
		Pesticides PSII herbicide equivalent concentrations (PSII-HEq)			●	
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		●	●	●

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

2.1. Freshwater basins

The freshwater basin zones reported in the Mackay-Whitsunday 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 pictured in Figure 2. Refer to the Mackay-Whitsunday Report Card Program Design 2017 to 2022 (MWHR2RP, 2018) document for indicator descriptions.

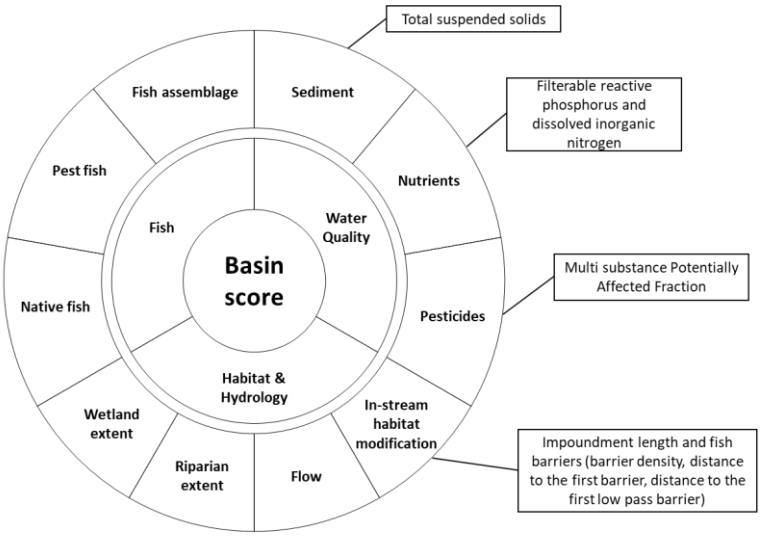

Figure 2. Indicator categories (outer ring) and indices (inner ring) that contribute to overall basin scores. Where multiple indicators are aggregated to determine the indicator category, these are listed in break-out boxes.

2.1.1. Water quality index

Indicators used to report on the water quality index in freshwater basins are: total suspended solids (TSS), dissolved inorganic nitrogen (DIN [5]), 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.

[5] 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.

2.1.1.1. Sediment, nutrients and pesticides

The water quality data used to report on the condition of basins in the Mackay-Whitsunday report card were collected through the Department of Environment and Science (DES) led Great Barrier Reef Catchment Loads Monitoring Program (GBRCLMP). Sampling was conducted in accordance with the Queensland Government's Monitoring and Sampling Manual (DEHP 2009). Data were obtained through analysis of water samples collected by manual grab sampling 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 2016 and June 30th 2017 were used to calculate water quality condition scores for the 2017 report card. For this time period, data was available from six end-of-system GBRCLMP sites within the Region (an improvement to the three available for the 2016 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

Intensive sampling (up to hourly) occurred during high flow events and monthly sampling was undertaken during ambient (low or base-flow) conditions. To derive DIN from freshwater basin data oxidised N is summed with ammonia N.

The pesticide samples used to estimate ms-PAF were limited to a six-month period of the year to capture the principle pesticide exposure period (generally November – April, depending on the timing of the wet season). Because time plays a critical role in the toxicity of a pesticide, in order to calculate the risk that pesticides pose to the ecosystem, a measure of the exposure period is needed. This period must be standardised to allow comparison between sites and over time. As exposure is low during the dry season[6], including dry season data would only dilute the estimation of risk. For the purpose of calculating an ms-PAF risk estimate, a period of 182 days, generally starting from the 1st of November to the 30th of April, was used as a standardised exposure period (unless the first run-off event containing pesticides occurred prior to 1st of November, from which the 182 day period commenced). If contaminant concentrations are high enough, this period exceeds the time required to cause adverse effects among populations of aquatic species (Warne *et al*. 2015). Alongside the ms-PAF score, the equivalent '%species protected' was listed. This allows for alignment with the approach that the GBR report card takes for scoring ms-PAF.

[6] Exposure to pesticides assessed as part of the ms-PAF estimation generally does not occur during the dry season because residual soil concentrations are low and pesticides are predominantly transported during rainfall run-off events (Devlin *et al*. 2015). During the dry season concentrations of pesticides in streams are generally below detection limits (Devlin *et al*. 2015) and therefore the risk of pesticide exposure to organisms is very low compared to the wet season.

This was the first year that water quality data was available to report on the Don and Proserpine Basins.

The Don River is ephemeral in nature which means water quality data was only collected when there was surface flow. This is different to the other rivers reported in the Region, which are typically perennial in nature. The episodic flow regime of the Don River means that data will usually only be available during or shortly after rainfall. It is therefore anticipated that the scores for the Don River will be based on data from conditions that typically result in poorer water quality.

For the Proserpine Basin, only pesticides were reported for the 2017 report card. This was due to the site being located in an estuary system where the concentration of nutrients (DIN and FRP) and sediments (TSS) were influenced by seawater and therefore not fully representative of the freshwater environment. Nutrients and sediments from this site were therefore not reported in the 2017 report card. Analysis of this data will be undertaken prior to the 2018 report card to better understand whether aspects of this data set can be used to represent the freshwater system or if additional sampling is needed upstream of the influence of seawater. Pesticides were still reported using data from this monitoring location as the site was considered to provide a reasonable estimate of the pesticide pressures in the freshwater catchment and the dilutive potential of the tidal inflow of seawater was not considered likely to dilute the magnitude of the ms-PAF score substantially. Further, an ms-PAF score calculated above the tidal zone would not necessarily provide a more accurate picture of the pesticide pressures in the catchment because it would miss some of the inputs. More detail is available in the Appendix.

The O'Connell River at Stafford's Crossing site was not included in the water quality score for the O'Connell Basin in the 2017 report card because an appropriate method for incorporating multiple sites into a score is yet to be developed for basins. Development of this method will be undertaken in time for the 2018 report card.

Future directions

Additional end-of-system water quality sites within the Mackay-Whitsunday report card Region occurred as an expansion of the GBRCLMP in November 2016 (Don and Proserpine Basins, and additional site at O'Connell Basin). In the 2018 report card, another GBRCLMP site in Plane Creek will provide additional data for the Plane Basin.

The Proserpine Basin data will be further explored to understand whether current data can be used as part of developing a score for nutrients and sediments, or if additional monitoring is needed to obtain freshwater basin water quality scores for these indicator categories.

With additional basin sites becoming available, a method for scoring basins where there are multiple monitoring sites will be developed. This method will be available for the release of the 2018 report card and will allow incorporation of additional basin sites established in the future.

2.1.2. Habitat and hydrology index

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

2.1.2.1. In-stream habitat modification

Impoundment length

All data for impoundment indicator was assessed in 2013-14. Impoundment is updated every four years, therefore data presented in the 2017 report card are repeated from 2016, 2015 and 2014 (pilot) report cards.

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. Only streams of order three or higher within the freshwater basin were included in the assessment.

Fish barriers

Fish barriers are 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'.

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.[7]

For the freshwater basins all measurements were made upstream of the Declared Downstream Limit (DDL). The DDL was selected because any potential barriers downstream of this point clearly allow tidal movements and thus not preventing connectivity with this interface.

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

[7] 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.

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' impact 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' impact 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 impacted by no/low passability barriers. A low passability barrier was defined as a barrier that never or rarely drowns out (<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.

All data for fish barrier indicators were assessed in 2014-15. Fish barriers are updated every four years, therefore data presented in the 2017 report card were repeated from the 2016 and 2015 report cards.

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 Region Freshwater Fish Barrier Prioritisation (Moore 2015b).

In the Don Basin, fish barriers were assessed using known barriers identified for the Burdekin Dry Tropics Natural Resource Management Group Region Fish Passage Study (Carter *et al*. 2007). There was less confidence in results generated from this data due to the improvements of satellite imaging since data collection. A desk-top assessment of current satellite imaging was used to cross-check identified barriers in the Don Basin, however no/low passability barriers could not be confidently confirmed with this process alone (due to a lack of ground truthing). Expert opinion was therefore used to assess the 'proportion of stream length to the first no/low passability barrier' indicator.

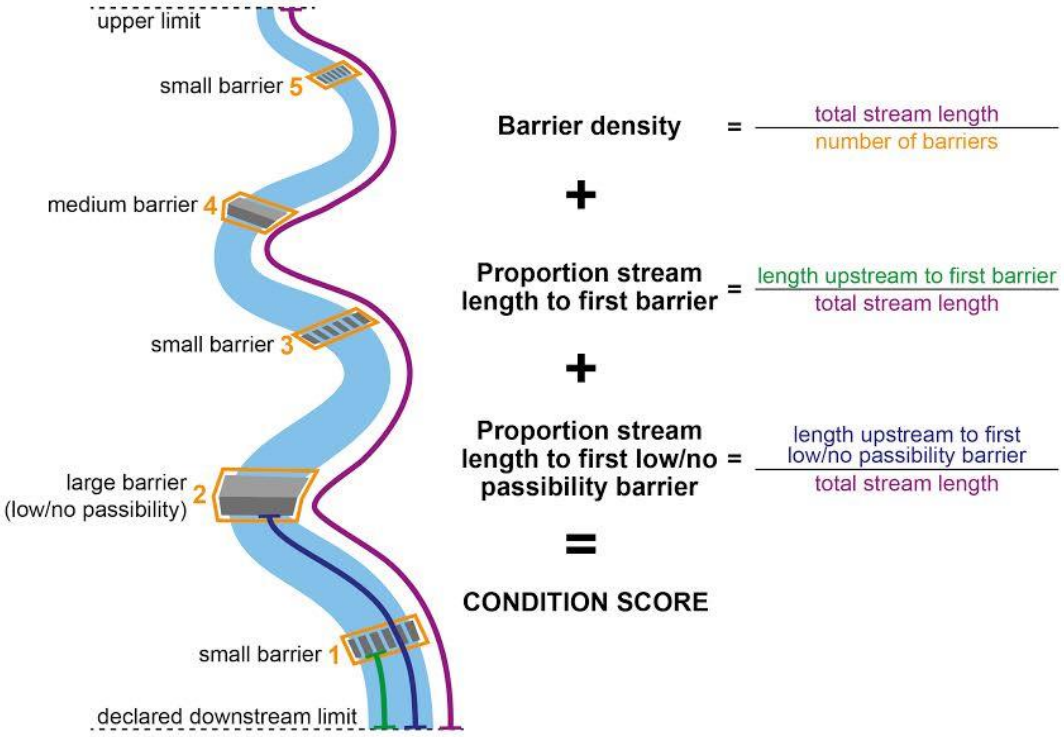

Figure 3. Diagram of the three fish barrier indicators and how they are calculated.

2.1.2.2. Flow

Methodologies for collecting data for flow indicators have been established and will be incorporated into the 2018 report card.

2.1.2.3. Riparian extent

Riparian extent is updated every four years, therefore data presented in the 2017 report card were repeated from the 2016, 2015 and 2014 (pilot) report cards. While data for this indicator is the same across these four report cards, final scores for 2016 and 2017 differ to 2014 and 2015 due to revised scoring ranges (see section 3.1.4.1. for explanation of scoring).

All data for riparian extent results was assessed in 2013-14. 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 was 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.

2.1.2.4. Wetland extent

Wetland extent is updated every four years, therefore data presented in the 2017 report card were repeated from the 2016, 2015 and 2014 (pilot) report cards. While data for this indicator is the same across these four report cards, as with riparian extent, the final scores for 2016 and 2017 differ to 2014 and 2015 due to revised scoring ranges (see section 3.1.4.1. for explanation of scoring).

All data for wetland extent results was assessed in 2013-14. The assessment of wetland extent uses similar methods to the GBR report card wetland extent assessment. The source data is the same for the GBR report card and the Mackay-Whitsunday report card, however only palustrine systems are reported in the five reported basins for the Mackay-Whitsunday report.

The condition of wetland extent was determined through a comparison of current extent against pre-development extent of vegetated freshwater swamp (palustrine) systems that had more than 30% emergent vegetation cover, using the Queensland Regional Ecosystem (RE) mapping version 9.

2.1.3 Fish index

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

- **Native richness**: Calculates a *native species* richness indicator by dividing the number of native fish species actually caught by the number expected to occur based on modelling (Proportion Observed Native Species compared to Expected, PONSE); and,
- **Pest fish**: Calculates the proportion of the total number (abundance) of fish caught that consists of *pest fish* by dividing the number caught to the number expected to occur based on modelling.
- **Fish assemblage**: This indicator is under development and was not reported in the 2017 report card.

The model developed for this calculation was reviewed by local experts to ensure validity. The model provides a means to compare fish species richness and pest fish abundance 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 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. +

Modelled data was compared with data from 2015-16. Results for fish in freshwater are updated every three years, therefore 2017 report card results were repeated from the 2016 and 2015 report cards.

2.2. Estuaries

The eight estuaries reported in the Mackay-Whitsunday 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 Report Card Program Design 2017 to 2022 (MWHR2RP, 2018) document for indicator descriptions.

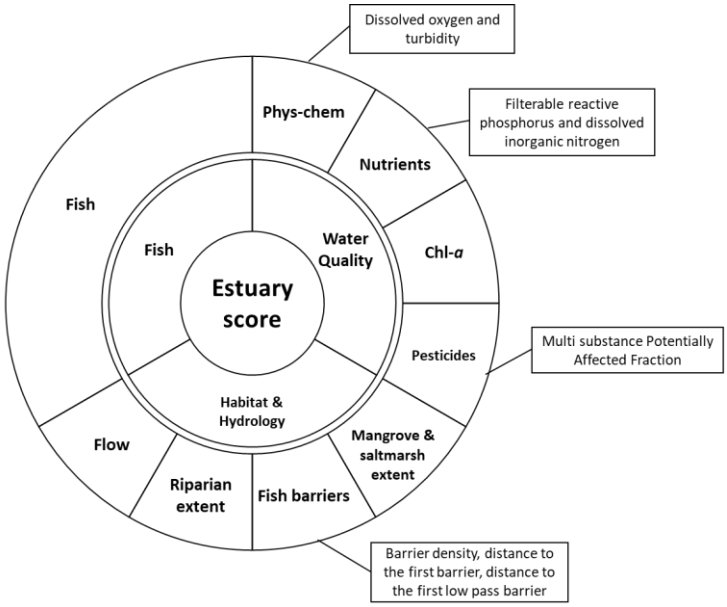

Figure 4. Indicator categories (outer ring) and indices (inner ring) that contribute to overall estuary scores. Where multiple indicators are aggregated to determine the indicator category, these are listed in break-out boxes.

2.2.1. 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.

2.2.1.1. Nutrients, phys-chem and pesticides

Water quality data used to report the condition of the eight estuaries was obtained through the estuary monitoring program established by DES. Monitoring commenced in October 2014 and is conducted in one, two or three sites in each of the eight estuaries (Table 2). Sampling sites are located upstream of the mouth of the estuary (Table 2; Figure 7). Distance of sampling sites upstream of the estuary mouth are based on adopted middle thread distance.

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, and not from the site listed in Table 2. Only phys-chem and chl-*a* were monitored at the site listed in the table.

For the first time in the 2017 report card, additional monitoring sites were available for water quality (highlighted in blue in Table 2). Additional sites at St Helens and Murray Creeks were incorporated into the overall water quality score. With the combined reporting of the St Helens/Murray estuary, the reporting area covers a large expanse. It is therefore important to have more sample sites when reporting on a larger area.

Table 2. Estuaries monitored for water quality, the location of sampling sites upstream of the estuary mouth and number of monthly samples (n) for each indicator. Blue shaded cells show sites with data that has not been included in past report cards. NB: water quality monitoring for Murray Creek and St Helens Creek are combined so that a condition score is provided for the 'St Helens/Murray Creek estuary'.

Monitoring sites	Sites (km upstream)	Nutrients temporal sampling (n)	Phys-chem temporal sampling (n)	Chlorophyll-*a* temporal sampling (n)	ms-PAF temporal sampling (n)
Gregory River	5.1	12	12	12	
	9.9	12	12	12	4
O'Connell River	7.5	*	12	12	*
St Helens Creek	7.5	0	12	0	
	8.9	12	12	12	3
Murray Creek	10	0	12	0	
	12.5	12	12	12	
	16.5	12	12	12	4
Vines Creek	2	12	12	12	3
Sandy Creek	4.5	11	5	11	
	13.5	12	7	12	4
Plane Creek	6	12	12	12	
	9	12	12	12	3
Rocky Dam Creek	8.9	12	12	12	
	12.9	12	12	12	3
Carmila Creek	3.4	12	12	12	3

*nutrients and ms-PAF reporting in the O'Connell estuary is based on GBRCLMP data.

Data samples collected between July 11th 2016 and June 15th June 2017 were used to calculate water quality condition scores for estuaries in the 2017 report card. Estuaries are monitored once a month with effort to ensure the conditions at each monitoring event are comparable. To this end, 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 (DEHP 2009).

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

The analyses of pesticides were undertaken by Queensland Health Forensic and Scientific Services (Coopers Plains, Queensland). As was the case for the freshwater basins, the ms-PAF risk estimations were limited to the principle exposure period of the year (generally November – April, depending on

the timing of the wet season) and are based on only one sample site per estuary (Table 2). Similar to freshwater basins, alongside the ms-PAF score the equivalent '% of species protected' was listed.

2.2.2. Habitat and hydrology index

Indicators used to report on the habitat and hydrology index in estuaries are: riparian extent, mangrove/saltmarsh extent, fish barriers and flow.

2.2.2.1. Riparian extent

The assessment of riparian vegetation extent in the estuarine environment was achieved by reviewing the proportion of riparian area that has 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 9) 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.

All data for riparian extent was assessed in 2013-14. Riparian extent is updated every four years, therefore results presented in the 2017 report card were repeated from the 2016, 2015 and 2014 (pilot) report cards. While data for this indicator is the same across these four report cards, as with riparian and wetland extent in freshwater basins, the final scores for 2016 and 2017 differ to 2014 and 2015 due to revised scoring ranges (see section 3.1.4.1. for explanation of scoring).

2.2.2.2. Mangrove/saltmarsh extent

All data for mangrove/saltmarsh extent results were assessed in 2013-14. Mangrove/saltmarsh extent is updated every four years, therefore results presented in the 2017 report card are repeated from the 2016, 2015 and 2014 (pilot) report cards. While data for this indicator is the same across these

four report cards, as with riparian wetland extent, the final scores for 2016 and 2017 differ to 2014 and 2015 due to revised scoring ranges (see section 3.1.4.1. for explanation of scoring).

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.

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.

2.2.2.3. Flow

As with flow methodologies for freshwater basins, methods for the flow indicator have been established and will be available for the 2018 report card (released in 2019).

2.2.2.4. Fish barriers

All data for fish barrier results was assessed in 2014-15. Fish barriers are updated every four years, therefore data presented in the 2017 report card are repeated from the 2016, 2015 and 2014 (pilot) report cards.

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). Knowledge was 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.

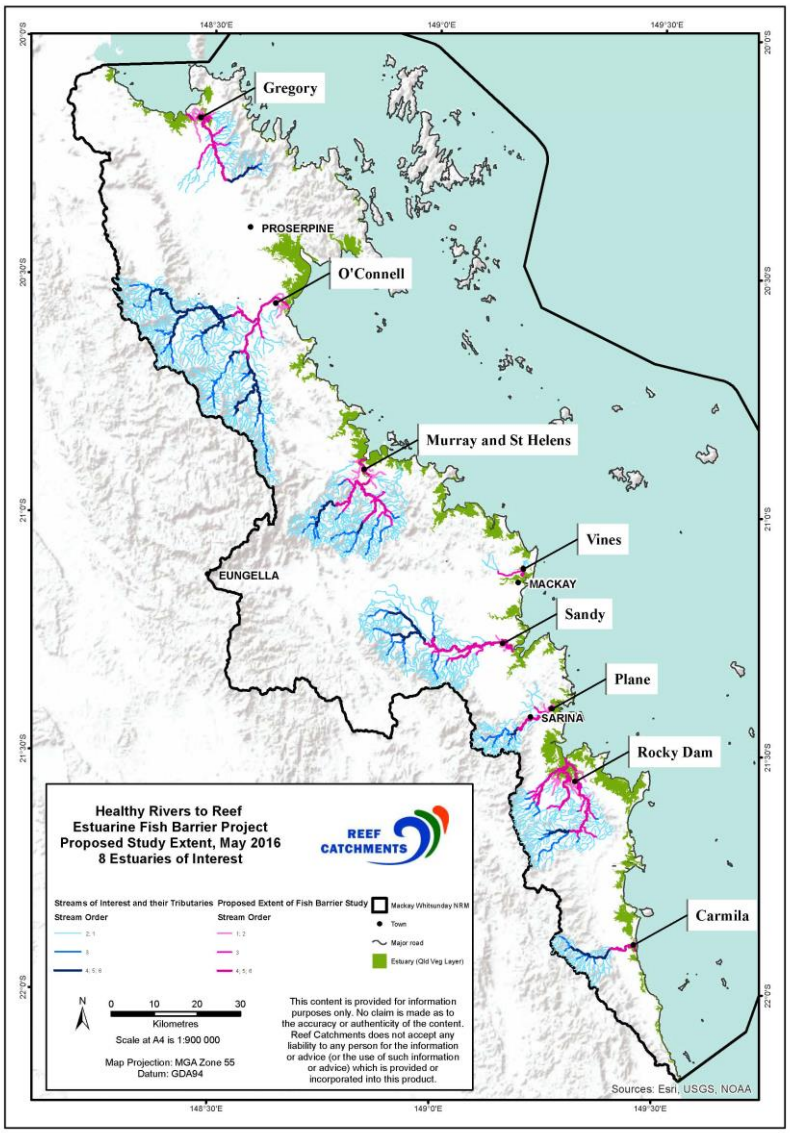

Figure 5. Extent of estuary assessment of fish barriers. Only pink/magenta waterways are included in the estuary barrier assessment; blue waterways are excluded as they do not intersect the estuary layer, are not 'Major' or 'High' impact tributaries and/or are higher than 18.5 m above DDL. NB the major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

2.2.3. Fish index

Assessments of fish community health were deemed important across all aquatic environments of the Mackay-Whitsunday report card. The development of estuarine fish indicators and methods is still progressing and was not included in the 2017 report card.

2.3. Inshore and Offshore marine environments

The inshore and offshore marine environment are reported separately in the Mackay-Whitsunday 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 Report Card Program Design 2017 to 2022 (MWHR2RP, 2018) document for indicator descriptions.

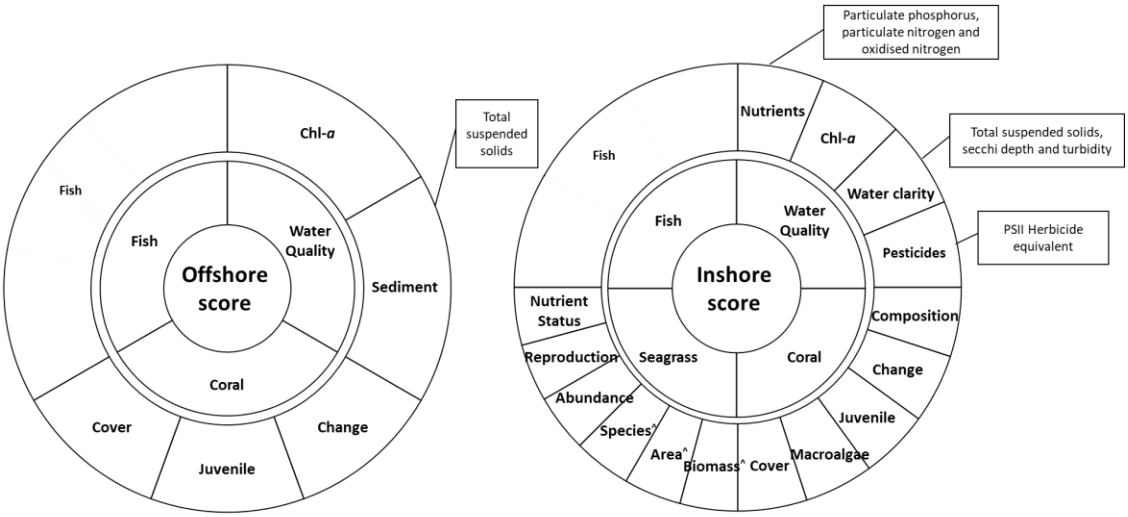

Figure 6. Indicator categories (outer ring) and indices (inner ring) that contribute to overall inshore (right) and offshore (left) marine scores. Where multiple indicators are aggregated to determine the indicator category, these are listed in break-out boxes.

2.3.1. Water quality index

Indicators used to report on the water quality index in inshore and offshore marine zones are: TSS, secchi depth, turbidity, particulate phosphorus (PP), particulate nitrogen (PN), nitrogen oxides (NOx), chl-*a* and pesticides reported as a PSII herbicide equivalent (PSII HEq). Where, 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.

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

Three existing marine water quality monitoring programs in the Mackay-Whitsunday Region provide data for the 2017 report card. These programs include 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 AIMS 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 (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).

Data from the 2016-17 reporting period from the Abbot Point, MMP and Mackay and Hay Point monitoring programs was used for reporting inshore water quality. Data from grab samples, in situ water quality loggers and passive samplers were used where available. The relevant program, number of temporal samples, water type and indicators sampled are summarised for each site in each inshore reporting zone in Table 3.

Grab sample data were reported from surface grab 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. Since the 2016 report card, one site (AMB6) in the Abbot Point ambient marine water quality monitoring program, had been discontinued. No data from this site was included in calculations of water quality scores for the northern marine inshore zone. Results for previous report cards were not back-calculated to exclude data from AMB6.

Where available, data from passive samplers were used for pesticide scores in preference to grab sample data. All data from passive samplers were obtained from the MMP. Passive samplers allow for a longer term 'average' concentration to be identified, which suits annual condition reporting. 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. In the report card, grab sample data from NQBP commissioned programs is used for reporting only in the absence of passive samplers, otherwise grab sample data is used to validate passive sampler data.

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

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

Table 3. Summary of relevant program, number of temporal samples (July 2016 – June 2017), 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. 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	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	4	OC	■	■				●	●	●		●	●
Amb 2	AP	4	OC	■	■				●	●	●		●	●
Amb 3	AP	4	OC	■	■				●	●	●		●	
Amb 4a	AP	4	OC	■	■				●	●	●		●	●
Amb 5	AP	4	OC	■	■				●	●	●		●	
Amb 6	AP	Site discontinued in February 2017; no data used in 2017 report card from this site.												
Whitsunday inshore zone														
Double Cone Island	MMP	5	OC	■	■		●	●	●	●	●	●	●	
Pine Island	MMP	5	OC	■	■		●	●	●	●	●	●	●	
Seaforth Island	MMP	4	OC	■	■		●	●	●	●	●	●	●	
Central inshore zone														
AMB1	MHP	8*	OC	■	■		●	●	o	●			●	●
AMB2	MHP	7*	OC	■	■		●	●	o	●			●	●
AMB3B	MHP	8*	OC	■	■		●	●	o	●			●	●
AMB5	MHP	8*	OC	■	■		●	●	o	●			●	●
AMB6	MHP	8*	OC	■			●	●	o	●			●	●
AMB8	MHP	8*	OC	■	■		●	●	o	●			●	●
AMB10	MHP	8*	OC	■	■		●	●	o	●			●	●
AMB11	MHP	8*	EC	■			o	o	o	●				●
AMB12	MHP	8*	OC	■	■		●	●	o	●			●	●
Repulse Islands dive mooring	MMP	4	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)														

* 1 sample for NOx

2.3.1.2. Offshore sediment and chlorophyll-*a*

The data for the offshore assessment of water quality was extracted from the Bureau of Meteorology (BoM) dashboard for the 2016-17 year (May 2016 to April 2017). The data is in the form of the percentage of the Mackay-Whitsunday offshore area that exceeds the GBRMPA guidelines (GBRMPA, 2010) for chl-*a* and TSS.

2.3.2. Coral index

The coral indicators used in the Mackay-Whitsunday 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 in the Central inshore zone (coral cover, change, macroalgae and juvenile density) and three indicators in the Northern inshore zone (coral 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 these 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.

2.3.2.1. Sampling programs and survey methods

The data included in the 2017 report card was collected up to August 2017. Data from August 2017 was included for inshore coral scores in the Central inshore zone despite this being outside of the standard financial year reporting period. This was to ensure data collected in surveys that occurred after Severe Tropical Cyclone Debbie (TC Debbie) were included in this zone. TC Debbie crossed the coast at Airlie Beach on the 28th of March 2017 and the poor visibility that followed the cyclone led to a delay in coral surveys in the Central inshore zone. Coral surveys in the Northern and Whitsunday inshore zones occurred after the cyclone, so including the August 2017 data from the Central inshore zone allowed for better comparability of coral scores across the three inshore zones.

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 survey reef 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. For the MMP reefs, when acute disturbances such as cyclones are suspected to have impacted reefs during the preceding summer, all reefs are surveyed. For full details refer to Thompson *et al.* (2016). Data included in the 2017 report card for the Whitsunday inshore zone was collected from reefs surveyed by the MMP in June 2017 and the LTMP in March 2017. This means that reefs surveyed by the LTMP do not capture impacts of TC Debbie.

MMP stratifies sampling by depth including transects at both 2 m and 5 m below lowest astronomical tide (LAT). The LTMP samples sites at 6-9 m depth only (Table 4). This is because coral community structure and exposure to disturbances differ markedly with depth, but the influence of depth is most apparent in inshore areas where the turbidity of waters causes a rapid attenuation of light. All coral

reefs monitored for the MMP or LTMP were selected with expert advice for the purposes of the specific coral monitoring programs.

Table 4. Survey methods for relevant coral monitoring programs reporting in the Mackay-Whitsunday 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 one or two depths*	5 x 20m
Belt transect	Abundance of juvenile corals < 5cm	4	2 at one or two depths*	5 x 20m
MMP (Whitsunday inshore zone)				
Photo point Intercept transect	Percentage cover of corals and other benthic categories.	7	2 at each of two depths	5 x 20m
Belt transect	Abundance of juvenile corals < 5cm	7	2 at each of two depths	5 x 20m
LTMP (Whitsunday inshore zone)				
Photo point Intercept transect	Percentage cover of corals and other benthic categories.	3	3	5 x 50m
Belt Transect	Size structure and density of juvenile (<5cm) coral communities.	3	3	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	4 x 20m
Belt transect	Abundance of juvenile corals < 5cm	4	6	4 x 20m
LTMP (Offshore zone)				
Photo point Intercept transect	Percentage cover of corals and other benthic categories.	10	3	5 x 50m
Belt transect	Abundance of juvenile corals < 5cm	10	3	5 x 55m

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

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 (Neale, 2016). At each site, cover of benthic reef organisms was assessed using four 20 m line intercept transects. Each transect was haphazardly positioned and run within a narrow depth band along approximately 50 m of reef (Neale, 2016). The depth range of the reef was 0.5-7 m below LAT, depending on the reef and the stratum where corals were abundant. For full details refer to Neale (2016). Data included in the 2017 report card was collected from these reefs in January and August 2017.

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 2017 report card was collected from these reefs in May 2017.

Offshore coral data was collected from permanent sites on nineteen 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 data for each reporting year is the rolling

mean of data collected over a four year period. The most recent data included in the 2017 report card was collected in March 2017, before TC Debbie. 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 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 and Abbot Point coral monitoring programs 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 4). Despite some differences in survey methodology and transect dimensions, similar data was collected across the different monitoring programs (Table 4).

Benthic photo point intercept method

The photo point intercept method was used to gain estimates of the composition of the benthic communities. The method follows closely 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 follows closely 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[8] and SOPs respectively.

2.3.3. Seagrass index

The seagrass indicators are based on indicators used in two existing monitoring programs: (1) the MMP used in the GBR report card, and (2) the Queensland Ports Seagrass Monitoring Program (QPSMP). To report 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

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

were used for the Central inshore zone. No seagrass data was available for the Southern inshore zone for the 2017 report card.

The seagrass indicators used for reporting based on the MMP are described in detail by McKenzie *et al*. (2015) and include seagrass percentage 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 *et al*. (2016) and include mean above-ground biomass, meadow area and species composition.

2.3.3.1. Marine Monitoring Program

The MMP seagrass sampling design was developed to detect change in inshore seagrass meadows in response to improvements in water quality parameters associated with specific catchments or regions and in 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 were selected at each location to account for spatial heterogeneity. Additionally, the minimum detectable difference had to be 20% (McKenzie *et al*. 2015).

Monitoring timing was determined by GBRMPA for the MMP, with advice from experts. 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, composition, and distribution – as per standardised protocols in McKenzie *et al*. (2003) and McKenzie (2009);
- Reproductive health – samples processed in accordance with McKenzie *et al*. (2010);
- Macroalgae cover – measured according to 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 2017 report card, MMP seagrass monitoring data was reported in the Whitsunday inshore zone at Hydeaway Bay, Hamilton Island, Pioneer Bay and Tongue Bay. In the Central inshore zone seagrass monitoring data was reported at Midge Point, Sarina Inlet and Newry Bay (Figure 7). Hydeaway Bay and Midge Point are long-term monitoring sites of the Seagrass-Watch program.

2.3.3.2. 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*. 2016a). The QPSMP monitors and reports on seagrass condition for entire individual 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 Region refer to previous QPSMP reports for Abbot Point (McKenna *et al*. 2016a) and Mackay and Hay Point (McKenna *et al*. 2016b).

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 2017 report card, QPSMP seagrass monitoring data was reported in the Northern inshore zone at nine sites near Abbot Point and at one site in the Central zone near Mackay and Hay Point. No seagrass data was available for the Southern inshore zone.

2.3.4. Fish index

Assessments of fish community health were deemed important across all aquatic environments of the Mackay-Whitsunday report card. The development of marine fish indicators and methods is still progressing and was not included in the 2017 report card.

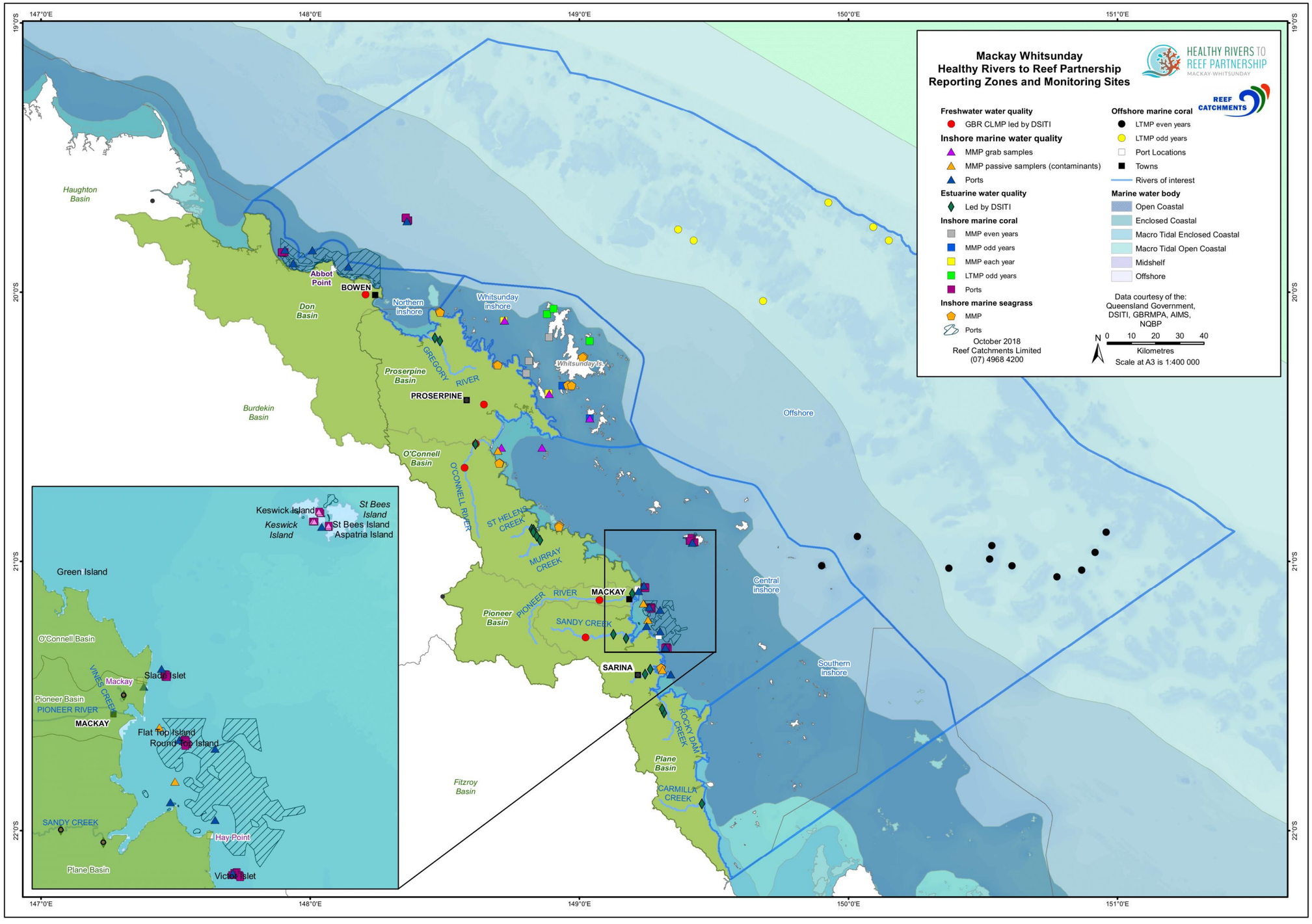

Figure 7. Sampling locations for water quality monitoring and coral and seagrass monitoring in the Mackay-Whitsunday Region.

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 seen in Table 5. 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 report card. Importantly, all significant figures are retained when averaging scores to roll up to category, index and overall scores.

Table 5. 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

2.3.4.1. 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[9].

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.

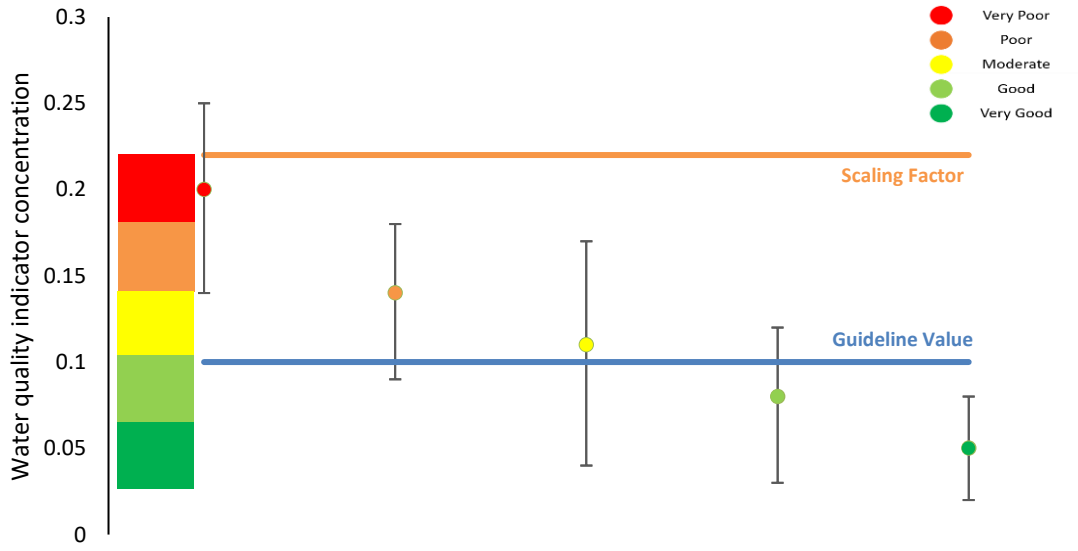

Figure 8. An example of how water quality grades are assigned. Where the middle point represents the annual median, the top whisker the 80th percentile and the bottom whisker the 20th percentile of the data. Only when the median meets or is better than the guideline (in this case meeting the guideline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

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

The approach to calculating a condition score (from 1 to 100) and translating this to the report card 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 6 and Table 7; and
- Aggregate indicator scores into indicator category scores (where relevant) and the water quality index (following decision rules for minimum information).

Table 6. 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[10]	81 to 100	Very good
Median meets GV, but 80% of data does not meet GV	80.9-(19.9*(((80th-GV)/(80th-median))))	61 to <81	Good
Median does not meet GV	60.9-(60.9*(ABS((median -GV)/(SF-GV))))	41 to <61	Moderate
		21 to <41	Poor
		0 to <21	Very poor

Where: 80th means 80th percentile of the data; GV means guideline value; median is the annual median of the data; ABS means the absolute value/positive value; SF means scaling factor based on 90th percentile[11] of available data.

Table 7. 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: 20th means 20th percentile of the data; GV means guideline value; median is the annual median of the data; ABS means the absolute value/positive value; SF means scaling factor based on 90th percentile[11] of available data.

[10] 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 80th percentile meets the GV was assigned. The middle (i.e. 90) of the very good range (Table 6) is used to assign a score for very good.

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

** 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 Heritage Protection 2009) and are listed in Table 8, with guidelines 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).

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'[12] 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 8. Water quality indicator categories, associated indicators and guideline values for freshwater basins in the Mackay-Whitsunday 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)
Nutrients	DIN	mg/L	0.03	0.03	0.008	0.03
	FRP	mg/L	0.045	0.006	0.005	0.015
Sediment	TSS	mg/L	5	2	5	5

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

Table 9. Water quality indicator categories, associated indicators and guideline values for estuaries in the Mackay-Whitsunday 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*	ug/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 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 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 Region is a newly commenced program, therefore only one year of data was available for calculation of the SF for the report card. 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.

2.3.4.2. Pesticides

Pesticide condition for the 2017 report card was based on 13 PSII herbicides (ametryn, atrazine, diuron, hexazinone, tebuthiuron, bromacil, fluometuron, metribuzin, prometryn, propazine, simazine, terbuthylazine, terbutryn). The concentration of these herbicides per sample was converted to an ms-PAF risk category. The risk categories attributed to the ms-PAF estimation were developed by the Water Quality and Investigations group within DES as part of the risk assessment for pesticides (Waterhouse *et al*. 2017a) and are consistent with ecological condition categories defined within the Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters (ANZECC and ARMCANZ 2000).

The concentration of each PSII herbicide in each water sample was converted to a relative toxicity scale (hazard unit, HU) by dividing the concentration detected in the sample by the estimated concentration that effects 50% of species (e.g. HU = 1 will affect 50% of species, and HU = 0.5 will affect 25% of species). By first converting the pesticide concentrations to hazard units, the concentrations of each pesticide detected in the sample is weighted based on the toxicity of that pesticide to the ecosystem, such that a concentration of a highly toxic pesticide will have a higher hazard unit compared to an equal concentration of another pesticide with low toxicity. This allows the hazard units of each pesticide detected in the sample to be summed and, therefore, a hazard unit of the mixture is produced (e.g. adding together a pesticide with a HU of 0.75 and a pesticide with a HU of 0.25, the mixture HU = 1, which means that the mixture of the two pesticides will affect 50% of species). The corresponding percentage of species (ms-PAF) that would be affected by the mixture can then be calculated. Where more than one sample per day was collected, a mean ms-PAF value for each day was calculated. These values are plotted as a cumulative frequency distribution against the number of days in the wet season (taken to be a fixed value of 182 days) and the area under the curve (i.e. the area under the cumulative frequency distribution) is then calculated to account for both the percentage of species affected and the exposure period together. The area under the curve was

divided by the duration of the wet season (182 days) to calculate the mean daily potentially affected fraction (% species affected). The corresponding % species protected was also reported for the first time in the results technical report. These values (calculated for each monitoring site) were then compared to the risk categories presented in Table 10.

For the 2017 report card onwards, rounded ms-PAF values were used to determine pesticide grades, such that no decimal places will be used in presentation of the scores nor in determining the scores.

Table 10. 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 to <99%	Low risk	Good	G= 61+ ABS((19.9 - ((score -1.01) *(19.9/3.99))))
>5-10%	90 to <95%	Moderate risk	Moderate	M=41+ ABS((19.9 - ((score -5.01) *(19.9/4.99))))
>10-20%	80 to <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))))

3.1.4 Habitat and hydrology

2.3.4.3. 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 11) 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 11. 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 12, Table 13 and Table 14). 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 15).

Table 12. Scoring range and subsequent score assigned for the barrier density indicator. Assessed on Stream Order (SO) as indicated[13].

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 13. 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[13].

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 14. 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[13].

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 15. 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))))

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

2.3.4.4. Fish barriers (estuaries)

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

3.1.4.1 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 2013 for each basin or estuary and assigning the result a grade as per Table 16.

Table 16. 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 Table 17 and Table 18. A qualitative rating scheme for native species richness (PONSE) was developed (Table 17), 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 18.

Table 17. 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 18. 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

3.2.3 Inshore water quality

2.3.4.5. 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[14]. For sites in the Northern inshore zone, the relevant guidelines from GBRMPA (2010) and DEHP (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[15]). The draft guidelines are expected to be scheduled in mid-2019. Once these guidelines are scheduled, more local guidelines will be used for scoring.

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*. 2017b), rather than GBR wide GBRMPA (2010) guidelines. The Mackay-Whitsunday 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 report card. Relevant inshore water quality guideline values used in the 2017 report card are presented in Table 19.

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.

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

Table 19. Water quality guideline values for relevant water quality indicators at inshore marine monitoring sites in Mackay-Whitsunday report card. Also listed are the programs associated with each site, source documents for the guideline values listed, associated basin/Region/water area, water type (OC: open coastal, EC: enclosed coastal) and management intent (SMD: slightly to moderately disturbed, HEV: high ecological value, MD: moderately disturbed) outlined in the source documents.
Underlined values are compared to means, other single value guidelines are compared to medians. Where a range of three values are listed, the middle value is compared to medians.

Sites in MW 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

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 Heritage Protection, 2009. Queensland Water Quality Guidelines 2009, Version 3.
3. Department of Environment and Heritage Protection, 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 Heritage Protection, 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 20.

Table 20. 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 *(19.9/0.50)))
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)))

2.3.4.6. Pesticides

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

In the 2017 report card, the PSII herbicide equivalent concentrations (PSII-HEq) method (Gallen *et al*. 2016) was used to assess pesticides PSII-HEq values. These are derived using relative potency factors (RPF) for each individual PSII herbicide with respect to the reference PSII herbicide, diuron (Gallen *et al*. 2016). A given PSII herbicide with an RPF of 1 is equally as potent as diuron, while a more potent herbicide will have an RPF of >1, and a less potent herbicide will be <1. To calculate the PSII-HEq

concentration of a given sample (the sum of the individual RPF-corrected concentrations of each individual PSII herbicide) it is assumed that these herbicides act additively (Gallen *et al*. 2016)[16].

Where passive samplers existed (i.e. Central inshore zone), the average maximum PSII-HEq concentration recorded within that zone was used as the pesticides result. Where grab sample pesticide data was the only available data (i.e. in the Northern inshore zone), the median PSII-HEq from samples taken in the wet season (Nov-Apr) was investigated for appropriateness of providing an overall PSII-HEq concentration result for the zone. However, it is recognised there is lower confidence in results calculated using grab samples when the sample size is low. If grab sample data was available in the same zone as passive samplers (i.e. Central inshore zone), grab sample data were used only to validate the passive sampler result.

The reported PSII-HEq concentrations for each zone were then assigned categories based on corresponding grades and standardised within the categories (Table 21) to allow for aggregation with other water quality indicators. The categories and grades for PSII-HEq concentrations are currently under review and may change in the future.

Before PSII-HEq concentrations were calculated from grab samples, a calculation of LOR x 0.5 was applied to data where a pesticide concentration was reported as <LOR. The exception was when the LOR was unusually high. Commonly, for PSII pesticides the LOR is <0.01 µg/L (for example Gallen *et al*. 2014; Lewis *et al*. 2009; Smith *et al*. 2012). If the LOR is unusually high, assuming a value of LOR x 0.5 can have a variable impact on the final reported concentration because of the additive nature of the PSII-HEq calculation. Thus, if the LOR is higher than 0.01 µg/L, the impact on the final PSII-HEq concentration of assuming a value of LOR x 0.5 for all pesticides in samples reported as <LOR is compared to assuming the value of the LOR or a value of zero. If this process causes the final PSII-HEq concentration to shift between grades, the LOR is considered too high to confidently interpret the data and all <LOR samples are excluded in the final calculation.

[16]Currently, the PSII Equivalent method estimates an equivalent concentration of diuron that would cause the same toxic effect as a mixture of photosystem II (PSII) herbicides detected in a water sample. The diuron Equivalent concentration is calculated using the relative potency method (Kennedy *et al*. 2010). The relative potency method relies on the chemicals within the mixture and the reference chemical (e.g. diuron) to have the same mode of action, as is the case with all photosystem II (PSII) herbicides (Safe 1998; Smith *et al*, 2017). This means that pesticides with different modes of action cannot be included in the PSII Equivalent calculation, e.g. metolachlor, cannot be included in the PSII Equivalent calculation. As a consequence, if other non-PSII herbicides are present, the toxicity of the whole pesticide mixture is underestimated using the toxicity equivalency approach. In contrast, the ms-PAF method (Traas *et al*. 2002) can estimate an effect of all pesticides in a mixture, with multiple modes of action, if the toxicity data are available to do so. Reporting of pesticides in marine ecosystems may transition to ms-PAF in the future, but this will depend on finalisation of data and methodology relevant to the marine zone.

Table 21. Categories applied to pesticides results in the PSII-HEq assessments and corresponding grade used in the Mackay-Whitsunday report card; Source Gallen *et al.* (2014).

Concentration (ng L^{-1})	Description	PSII-HEq Score	Grade	Scaling of scores for aggregation
PSII-HEq ≤ 10 or <LOR	No published scientific papers that demonstrate any effects on plants or animals based on toxicity or a reduction of photosynthesis. The upper limit of this category is also the detection limit for pesticide concentrations determined in field collected water samples.	5	Very good	81+ (19 - ((score-0) * (19/10)))
10 < PSII-HEq ≤ 50	Published scientific observations of reduced photosynthesis for two diatoms.	4	Good	61+ (19.99 - ((score - 10) *(19.99/40)))
50 < PSII-HEq ≤ 250	Published scientific observations of reduced photosynthesis for two seagrass species and three diatoms.	3	Moderate	41+ (19.99 - ((score - 50) *(19.99/200)))
250 ≤ PSII-HEq ≤ 900	Published scientific observations of reduced photosynthesis for three coral species	2	Poor	21+ (19.99 - ((score - 250) * (19.99/650)))
PSII-HEq > 900	Published scientific papers that demonstrate effects and death of aquatic plants and animals exposed to the pesticide. This concentration represents a level at which 1% of tropical marine plants and animals are not protected, using diuron as the reference chemical.	1	Very poor	0 (assigned)

NB For categories 2 – 4

- The published scientific papers indicate that this reduction in photosynthesis is reversible when the organism is no longer exposed to the pesticide;
- Detecting a pesticide at these concentrations does not necessarily mean that there will be an ecological effect on the plants and animals present;
- These categories have been included as they indicate an additional level of stress that plants and animals may be exposed to in the Marine Park. In combination with a range of other stressors (e.g. sediment, temperature, salinity, pH, storm damage, and elevated nutrient concentrations) the ability of these plant and animal species to recover from impacts may be reduced.

3.2.4 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 (Table 22) (mid-shelf waters that are included in the offshore zone are not assessed). This data was specifically extracted by the Bureau of Meteorology from the marine water quality dashboard[17]. 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 5). The TSS and chlorophyll-*a* results are weighted equally (Table 22), therefore are averaged to provide the water quality indicator category result for the offshore zone.

Table 22. 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).

[17] http://www.bom.gov.au/marinewaterquality/

3.2.5 Coral

Condition assessment of the coral indicators for the inshore zones followed the method of the MMP:

- **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 2017 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 23. 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 23. 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 24. 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

3.2.6 Inshore seagrass

2.3.4.7. 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 5). 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 25, reproductive effort in Table 26, and nutrient status in Table 27. 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 25. 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 26. 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 27. 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

2.3.4.8. 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 impacts against the baseline. 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*. (2016a).

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 have been determined based on the annual percentage 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*. 2016a).

Each meadow/site score is defined as the lowest grade/score of the three indicators within that meadow. For further details on the scoring methods see Carter *et al*. (2016a).

2.3.4.9. 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 (Table 5) 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 (Table 5). For a full description and worked example of the combined display approach refer to Carter *et al*. (2016b).

Overall indicator scores are also provided by averaging all indicator scores within a zone. Due to the differences in deriving site/meadow scores between programs (averaging indicators vs using the indicator grade that is lowest), 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, 2015). This is based on a multi-criteria analysis approach to qualitatively score the confidence for each key indicator used in the report card. The approach enables the use of expert opinion and measured data.

The multi criteria analysis identifies the key components 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 Region have been given a higher weighting when determining the overall confidence.

5.1.3 Methods

Determining confidence for the report card used five criteria:

- 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 in to 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 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 28. Scoring matrix for each criteria 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

5.1.4 Scoring

For all indicators where a condition score was reported, each criterion is scored 1 (lowest) to 3 (highest) as defined in Table 28. 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 29). The final scores and the associated confidence rankings have been adjusted from the previous report cards to reflect the Mackay-Whitsunday specific weightings applied to the criteria. The confidence ranking (out of five) is then presented in the report cards.

5.1.4.1 Scoring confidence criteria in the Mackay-Whitsundays report card

When scoring confidence for indicators in the Mackay-Whitsunday 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.

5.1.4.2 Final confidence scores for presentation in the Mackay-Whitsundays 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 29). 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 29. 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

The 2017 report card has seen the inclusion of additional sites, after previous report cards identified limitations to 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, major limitations still exist when reporting water quality at the basin scale:

- 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 influenced by the estuary system, therefore no score for water quality was produced for the 2017 report card. Analysis of this data is needed to determine if it can be used to report on the freshwater environment of the Proserpine basin or if another monitoring site upstream is needed;
- With additional sites being established and recommended (for example, the O'Connell River at Stafford's and the Plane Creek in the Plane basin), a method to incorporate additional sites into basin scores is required.

The Partnership will be developing a method for incorporating additional sites for the release of the 2018 report card and exploring options for using data from the Proserpine freshwater site.

Low confidence in reporting on pesticides in the estuaries has been highlighted since the report card was first released (2014 pilot report card). In the 2018-19 wet season, additional pesticide sampling has been undertaken in the estuaries to increase temporal representativeness of sampling from <6 samples to 18 samples over the wet season, which will increase confidence in scores. The outcomes of this additional sampling will help to determine whether ms-PAF risk estimations for estuaries change greatly with the availability of more information.

A knowledge gap was identified in previous report cards for the southern inshore region. 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 will see the release of a water quality score for the southern inshore region for the first time. A coral score is expected to be released for the 2019 report card (released in 2020) and a seagrass score for the 2022 report card (released in 2023), 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, gaps in reporting of freshwater flows 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);
- Indicator selection and flow methodology will be available for the release of the 2018 report card where flow will be reported on for the first time. This was directed by the Mackay-Whitsunday Healthy Rivers to Reef Partnership and the Wet Tropics Healthy Waterways Partnership;

Further improvements to the report card that have been identified for the future are outlined in the Mackay-Whitsunday Report Card Program Design 2017 to 2022 (MWHR2RP, 2018) 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);
- Improve confidence in fish barriers reporting for the Don basin;
- 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.

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Appendix

For the Proserpine basin, it was recognised by the TWG that the Proserpine site was located in the middle of the Proserpine River estuary, and as such, data was more likely to represent estuary concentrations, at least in ambient conditions.

For sediment and nutrients indicators, estuary influences could not be confidently separated from the data set without analysis of the hydrograph, rainfall, salinity data and historical data. Due to time limitations, this has not been undertaken in time for the 2017 report card, however will be explored for the 2018 report card. It is anticipated that exploration of the aforementioned data will identify that freshwater conditions could be separated from estuary conditions during high flow/rainfall events only. Given the report card reports on ambient conditions, this may mean additional sampling above the estuary will be needed to inform non-event conditions for freshwaters in the Proserpine River.

Despite being located in the estuary, pesticides have still been reported for the Proserpine basin using data from this site. This was based on the below observations:

- The monitoring location, although in a tidal section of the Proserpine River, is suitably located to capture pesticide inputs from the majority of agriculture that flows to the Proserpine River (**Error! Reference source not found.**)

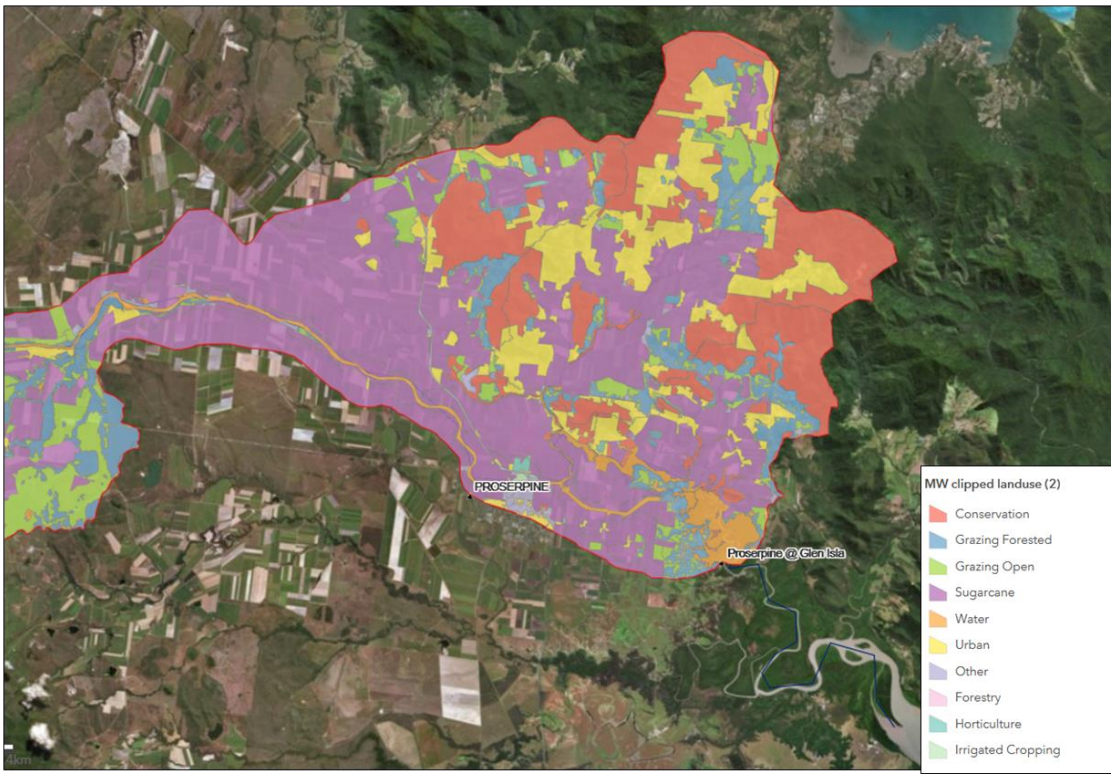

Figure A 1. Land use upstream of the Proserpine River GBRCLMP site.

- The monitoring period (beginning of November to end of April[18]) captures the majority of freshwater (event) flows. The conductivity trace (conductivity data is only available from January 2017) illustrates that the Proserpine River site was dominated by freshwater for a significant proportion of this six-month period (**Error! Reference source not found.**). In **Error! Reference source not found.** all the event samples (shown as red dots) and a large proportion of the weekly ambient samples (not shown) would have been relatively representative of fresh water.

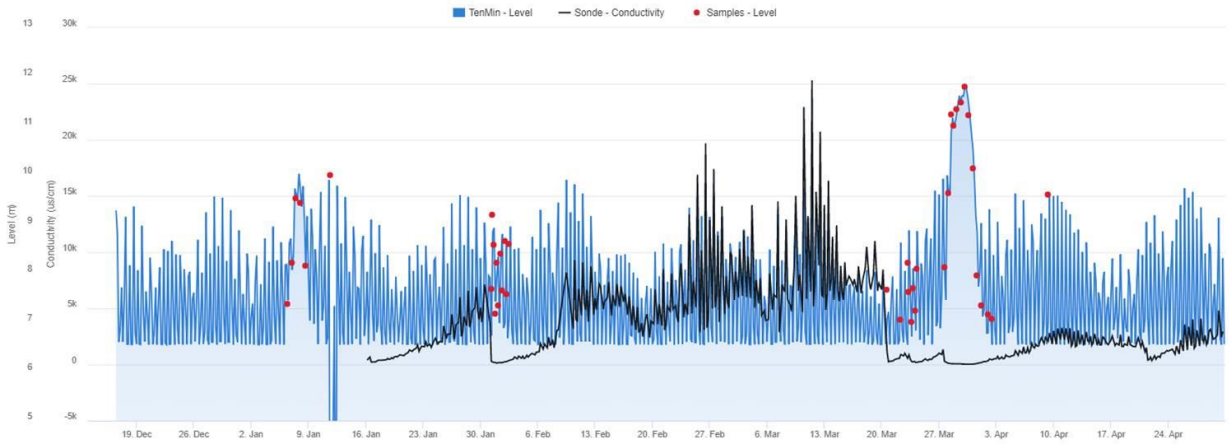

Figure A 2. Conductivity, stream height and pesticide sampling times in the Proserpine River GBRCLMP site.

It was therefore recommended that data from the Proserpine River GBRCLMP site provided a reasonable estimate of the pesticide pressures in the freshwater catchment and the dilutive potential of the tidal inflow of seawater was not likely to dilute the magnitude of the ms-PAF score substantially. Further, an ms-PAF score calculated above the tidal zone would not necessarily provide a more accurate picture of the pesticide pressures in the catchment because it would miss some of the inputs.

In summary, for the Proserpine basin in the 2017 report card:

- Sediment and nutrients indicators are not reported;
- The pesticide indicator is reported; and,
- Due to minimum information rules, no water quality index score is calculated.

[18] The wet season monitoring period is not fixed. It depends on the first rainfall even that causes the first flush of nutrients into waterways. Therefore the wet season can start earlier than stated.