Methods for the Mackay-Whitsunday 2016 Report Card

Environmental Indicators

Final Report

Regional Report Cards Technical Working Group

September 2017

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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
Climate	In the context of the pilot report card, climate refers to both climate variability and climate change
DDL	Declared Downstream Limit
DIN	Dissolved Inorganic Nitrogen
DNRM	Department of Natural Resources and Mines
DO	Dissolved Oxygen
DPSIR	Driver, Pressure, State, Impact, Response
Driver	An overarching cause of change in the environment
DSITI	Department of Science Information Technology and Innovation Queensland
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 a fauna indicator)	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
ISP	Independent Science Panel established under the Reef Plan, who have independently reviewed the methodologies involved in the report card assessments

JCU	James Cook University
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
RIMMReP	Reef 2050 Integrated Monitoring, Modelling 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
SMART	Specific, measurable, achievable, relevant, time-bound
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 2016 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.

Methods used to assess stewardship, social and economic context and cultural heritage associated with the Region's waterways for the previous (2015) report card can be found in the Development of Methods for the Mackay-Whitsunday report card 2015: Stewardship and Cultural Heritage reporting document[1].

1.2. General

The Mackay-Whitsunday Healthy Rivers to Reef Partnership (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 has occurred since the release of the 2015 report card and this has been incorporated in the 2016 report card, which now includes analyses and scoring methods that are more aligned with other report cards in the Great Barrier Reef region.

For more detail on the Mackay-Whitsunday report card and Partnership, refer to the 'Program Design for the Mackay-Whitsunday 2016 report card' document[2].

[1] http://healthyriverstoreef.org.au/report-card/technical-reports/
[2] http://healthyriverstoreef.org.au/report-card/program-design/

1.3. Terminology

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

- 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).

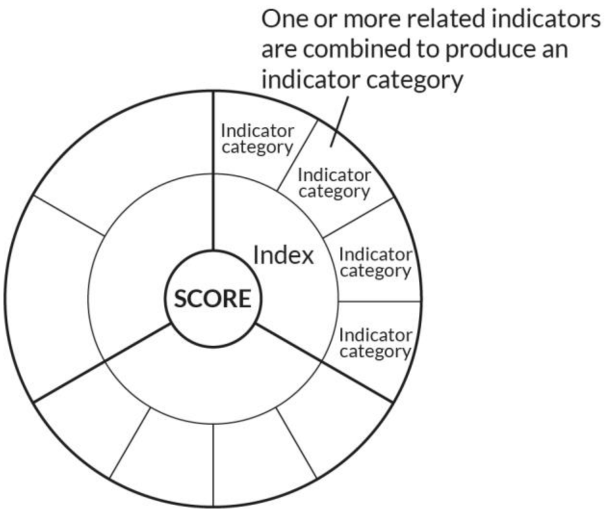

Figure 1. Terminology used for defining the level of aggregation of indicators and how they are displayed in coasters in the report card.

2. Selection of Indicators

The sections below include an outline of the process and final outcomes of determining the most appropriate indicators used for environmental assessments for the report card. The indicators needed to be relevant to the Region and be directly linked to pressures occurring within the Region (refer to the 'Program Design for the Mackay-Whitsunday 2016 report card' document[3] and the conceptual model specifically developed for the report card).

All potential indicators were shortlisted based on the following questions:

- Is the indicator clearly linked to an objective of the report card?
- Can the indicator easily be used to provide a report card score?
- Do other programs and report cards use this indicator?

[3] http://healthyriverstoreef.org.au/report-card/program-design/

Additionally, it was identified that indicators needed to be:

- Indicative of what the Partnership is trying to protect (or a good 'proxy');
- Sensitive to change;
- SMART (specific, measurable, achievable, relevant, time-bound);
- Of strong scientific and conceptual basis - i.e. indicators based on well-defined or validated cause-and-effect chains linking human-related pressures to ecosystem response if possible;
- Signals that can be measured in simple, cost-effective ways with available resources, and analysed in a fashion that allows unambiguous interpretation;
- Well-established, with links to specific management objectives and responsive to related management actions; and
- Easily communicated and understood by stakeholders and/or the target audience.

3. Freshwater Basins

3.1. Water Quality

3.1.1. Indicator selection

Freshwater basin water quality indicators used in the report card are: Total suspended solids (TSS), dissolved inorganic nitrogen (DIN), filterable reactive phosphorus (FRP) and pesticides reported as multisubstance-Potentially Affected Fraction (ms-PAF).

The water quality indicators included in the report card for the freshwater basins were selected through an analysis of the range of monitoring programs (historical, current, and planned) that collect water quality data in the freshwater environment and consider the general requirements for indicators that are outlined in Section 2 above and the 'Program Design for the Mackay-Whitsunday 2016 report card' document[4].

The parameters for water quality were also chosen because of their linkages to land management practices and their potential to impact on waterway and ecosystem health.

In addition to the selected indicators, other indicators were investigated, but these were not considered the most relevant to specific regional freshwater issues, or the most representative (examples listed below). Consideration was also given to the relevance of the sampling frequency to the indicator (i.e. if the indicator was measured once a month in a grab sample, does that actually provide useful information?). Some indicators were determined to be less useful for incorporating into a report card, but instead would be useful to explain any anomalies or provide further detail on results obtained. Finally, selected water quality indicators needed to have scheduled guideline values available that are used in the assessment scoring.

The other considered indicators included:

- Biochemical oxygen demand;
- pH;
- Dissolved oxygen (DO);
- Salinity;
- Temperature;
- Metals; and
- Chlorophyll-*a* (chl-*a*).

Rationale and explanation on the selected indicators for the freshwater basin water quality indicator category are described below.

3.1.1.1. Sediment

Elevated sediments in waterways can impact ecosystem health by changing light availability and can cause silting of benthic environments (DEHP 2009b). The indicator selected to represent sediment

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

was TSS, which measures small particles (soil, plankton, organic debris) suspended in water. This indicator is a common representative of sediment levels in freshwater systems (DEHP 2009b), and is very strongly linked to land management practices. Turbidity was also investigated (it is used in the estuary assessments), but in the freshwater system the availability of data for turbidity was more limited than for TSS. The preferred indicator was therefore TSS, as a guideline value exists for TSS in freshwater systems and there is a volume of data on TSS as it is currently included in the monitoring program suite (without additional cost).

3.1.1.2. Nutrients

The relationship between land use and nutrient export is widely acknowledged. Nutrients such as nitrogen and phosphorus are critical in shaping biodiversity in waterways, however agricultural, industrial and urban development has led to increased nutrient inputs, which can lead to eutrophication and algal blooms (Brodie & Mitchell, 2005). Nutrient indicators were shortlisted from a large suite of parameters that are associated with the major land uses within the Mackay-Whitsunday freshwater basins. The nutrient indicators for the freshwater basins in the report card included:

- DIN (ammonia + nitrite + nitrate); and
- FRP.

DIN and FRP are both highly bioavailable and typically are found in low concentrations in natural waters but in high concentrations where pollution through fertilisers or sewage is present (Rohde et al. 2006). Furthermore, DIN is considered the highest risk to Great Barrier Reef (GBR) ecosystems (Schaffelke et al. 2017) and as such is an important component to monitor in freshwater systems that feed into the GBR.

In order to avoid doubling up on speciation of nutrients, the number of report card indicators was restricted to the minimum that were representative of the issues and pressures in the Region for freshwater waterways. In addition to the general requirements for indicators that are outlined in Section 2 above, and the 'Program Design for the Mackay-Whitsunday 2016 report card' document[5], nutrient indicators were selected based on:

- Availability of freshwater guideline values for nutrients;
- Maintaining consistency where appropriate across environmental zones;
- Relevance to the freshwater environment;
- Availability of data (current and likely in future);
- One measure of each nutrient species selected to avoid double counting; and
- Inorganic forms, as they are often more biologically available.

3.1.1.3. Pesticides

Up to 56 pesticides with different modes of action are detected in the GBR. The 2016 report card will move from reporting on just five PSII herbicides (ametryn, atrazine, diuron, hexazinone and tebuthiuron) previously identified as the pesticides of greatest concern to the health and the

[5] http://healthyriverstoreef.org.au/report-card/program-design/

resilience of the Great Barrier Reef (DPC, 2013), to thirteen PSII herbicides detected in the GBR (ametryn, atrazine, diuron, hexazinone, tebuthiuron, bromacil, fluometuron, metribuzin, prometryn, propazine, simazine, terbuthylazine, terbutryn).

The report card uses the ms-PAF metric to report on pesticide risk. The ms-PAF method (Traas *et al*. 2002) estimates the impact (i.e. the percentage of species in an ecosystem likely to be affected) of mixtures of pesticides with multiple modes of action. To date, only PSII herbicides have been incorporated into the ms-PAF metric, however there are many other types of pesticides that are also frequently detected in the Region's catchments that need to be accounted for. Looking ahead, the toxicity data required for the ms-PAF metric is expanding to include pesticides with other modes of action, meaning that the range of pesticides included in the ms-PAF estimations will progressively increase in future reporting. However, the ms-PAF estimate is limited to pesticides with guideline values. Currently guideline values are available for 28 of the pesticides detected in the GBR.

Changes from 2015 report card

In the 2015 report card: The ms-PAF value for the pesticides score in freshwater basins and estuaries was calculated using the five PSII herbicides (ametryn, atrazine, diuron, hexazinone and tebuthiuron) identified as being of greatest concern to the health and the resilience of the Great Barrier Reef (DPC, 2013).

2016 report card: This has moved to reporting on thirteen PSII herbicides detected in the GBR (ametryn, atrazine, diuron, hexazinone, tebuthiuron, bromacil, fluometuron, metribuzin, prometryn, propazine, simazine, terbuthylazine, terbutryn).

The impacts that incorporating 13 PSII herbicides into ms-PAF scores in the 2015 report card can be seen in the Appendix.

3.1.2. Data collection

The water quality data used in the Mackay-Whitsunday report card were collected through the DSITI Great Barrier Reef Catchment Loads Monitoring Program (GBRCLMP). Sampling was conducted in accordance with the Queensland Government's Monitoring and Sampling Manual (DEHP 2009a). Data were obtained through analysis of water samples collected by manual grab sampling and the use of automatic samplers. Samples for sediments, nutrients and pesticides 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 2015 and June 30th 2016 were used to calculate water quality condition scores for the 2016 report card. For this time period, data were available from only three end-of-system GBRCLMP sites within the Region (Figure 4). These sites have been used to provide water quality scores for three basins (i.e. one site is currently used to represent water quality across the relevant basin):

- O'Connell Basin: O'Connell River at the Caravan Park;
- Pioneer Basin: Pioneer River at Dumbleton Pump Station; and
- 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.

The ms-PAF risk estimations were limited to a six-month period of the year to include the principle exposure period (generally November – April, depending on the timing of the wet season). Exposure to pesticides assessed as part of these estimations 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. 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, including dry season data would only dilute the estimation of risk. For the purpose of calculating an ms-PAF risk metric, a period of 182 days, generally starting from the 1st of November to the 30th of April (unless the first run-off event containing pesticides occurred prior to 1st of November, from which the 182 day period commenced), was used as a standardised exposure period; a period which, if contaminant concentrations are high enough, exceeds the time required to cause adverse effects among populations of aquatic species (Warne *et al*. 2015).

Future directions

Additional end-of-system water quality monitoring sites within the Mackay-Whitsunday report card Region have been established since December 2016. This has occurred as part of the expansion of the GBRCLMP. These additional sites are now monitoring water quality in the Don River, Proserpine River, and Plane Creek. This will provide water quality data that will allow reporting in the Don and Proserpine basins for the first time in the 2017 report card and will improve our understanding of water quality in the Plane Basin, thus improving confidence in water quality results in these basins.

3.2. Habitat and Hydrology Indicators

3.2.1. Indicator selection

3.2.1.1. In-stream Habitat Modification

The in-stream habitat modification indicator category is made up of two indicators – impoundment length and fish barriers. Whilst both indicators relate to artificial in-stream structures, the impoundment length indicator is a measure of the proportion of artificially ponded habitat within a basin and results from larger barriers, whilst the fish barrier indicator is a measure of the potential impact on fish movement and includes smaller barriers that do not result in substantial ponding of habitat.

Impoundment Length

The basis for using this indicator is that impoundment of rivers and streams by the construction of artificial in-stream structures, including dams and weirs, has a profound impact upon stream ecology and connectivity (Agostinho et al. 2008). The purpose of constructing in-stream barriers is commonly to store water for later use, and impounded areas generally have increased water depth and decreased water velocities. Cycles of wetting and drying are disrupted, decreasing the occurrence of natural disturbance and altering the nutrient processing cycle. Increased sedimentation may occur and benthic habitats may become stratified and anoxic. This can also lead to eutrophication and algae blooms, including potentially toxic blue green algae. The spawning habitat of some aquatic organisms may be lost.

The indicator was selected with the intention to describe how much “natural” channel habitat remained, compared with artificially ponded channel habitat which has relatively little diversity in terms of depth (benthic light availability, oxygen availability), flow rate, and wetting and drying cycles due to the river channel being filled by impounded waters. The length of impounded channel will vary according to attributes such as the height of the constructed in-stream barrier and landscape features such as gradient of the channel.

In-stream barriers constructed to store water also disrupt the movement of aquatic organisms. Consequently the impoundment length indicator is likely to have some correlation with the indicator of fish barriers. However, the intended focus of the impoundment length indicator is on the ecological impact of the proportion of affected in-stream habitat and not the movement of organisms.

Fish Barriers

Fish barriers are an important indicator for inclusion in the Mackay-Whitsunday report card due to their links to ecosystem health and the value the local community places on the presence of freshwater fish species. The majority of freshwater fish species of the Mackay-Whitsunday Region migrate at some stage during their life cycle. Of the 47 freshwater fish species found to occur in the Mackay-Whitsunday Region, 27 (57%) require unimpeded access between freshwater and estuarine habitats to complete their life cycle and maintain sustainable fish populations (Moore 2016). Therefore, barriers that prevent or delay connectivity between key habitats have the potential to impact migratory fish populations, decrease the diversity of freshwater fish communities and reduce the condition of aquatic ecosystems (Moore 2015a).

The amount of longitudinal in-stream habitat available to estuarine fish species in un-disturbed, connected habitats is determined by a number of naturally occurring factors, such as: habitat availability and condition, gradient, refuge areas, water temperature and food resources. However, anthropogenic factors such as man-made barriers to fish passage and habitat destruction often have a far greater impact in determining the amount of connected upstream habitat available to fish. One large low transparency barrier (barrier that is most difficult for fish to pass) close to the freshwater/estuarine interface has the potential to alter upstream fish communities (and particularly the number of diadromous fish species) more than any other naturally occurring factor. Thus, selected indicators were:

- **Barrier density** (average length of stream per barrier). A measure of the average length of stream available that is unimpeded by barriers, acting as an indication of connected habitat availability.
- **Proportion of stream to first barrier** (amount of stream to the first upstream barrier as a proportion of total stream length). A measure of the average proportion of stream available upstream of the interface between fresh and saline water that is unimpeded by any barriers.
- **Proportion of stream to first no/low 'passability' barrier** (amount of stream to the first upstream low passability barrier as a proportion of total stream length). A measure of the average proportion of stream available upstream of the interface between fresh and saline water that is unimpeded by barriers that do not allow fish to pass at any time (no passability) or rarely allow fish to pass (low passability), thus having the greatest impact on fish passage.

Not all barriers on all streams have the same impact on fish community assemblage within aquatic ecosystems. Streams that fall within 'Major' and 'High' impact categories are generally lower in the catchment and are higher order streams with low gradients. These streams are categorised by having a high diversity of species, often with weak swimming abilities. Barriers located on high gradient, top of catchment 'Moderate' (Amber) and 'Low' (Green) impact streams (stream order 1 & 2) are still important, but are not as influential in determining fish community assemblage within aquatic ecosystems as barriers on 'Major' (Grey and Purple) and 'High' (Red) impact streams (Table 1).

Because passage between the freshwater and estuarine environment is critical for the migration of both freshwater and estuarine species, the same three barrier indicators will be used for the freshwater basins and estuaries, however barrier assessments will be made at different scales (different stream classifications) depending on which ecosystem is being assessed.

Table 1. Queensland Government classification of streams according to the risk of impact from barrier works on fish movement and fish communities, including spatial data layer colour code and stream characteristics. Source: 'Queensland waterways for waterway barrier works' (DAFF 2013).

Risk of impact	Stream classification (represented by colour code)	Stream characteristics
Major	Grey	Estuarine habitats
Major	Purple	Strahler stream orders 4-7
High	Red	Strahler stream orders 2-3 with low gradient
		Strahler stream order 3 with medium gradient
Moderate	Amber	Strahler stream order 3 with high gradient
		Strahler stream order 2 low/medium gradient
Low	Green	Strahler stream order 2 with high gradient
		Strahler stream order 1 within tidal waters
N/A	*N/A*	Strahler stream order 1 outside tidal waters

3.2.1.2. Flow

Flow is an important indicator to include in the report card due to its relevance to ecosystem and waterway health. This indicator is intended to report on delivery of environmental flows compared to expected natural flows on an annual basis and should provide transferability between basins and regions. It is proposed that the indicator category will assess attributes of flow that are linked to the key ecological values of the waterways identified using a Driver, Pressure, State, Impact, Response (DPSIR) model which will be adapted from the Pressure Stressor Response model as applied in the Environmental Flow Assessment Program in Queensland.

Flow has not been included in the 2016 report card but work is currently underway to identify appropriate flow indicators and develop methodology for assessing these indicators annually.

3.2.1.3. Riparian Extent

The extent of riparian vegetation was determined to be an important indicator to include in the report card due to the importance of riparian vegetation for ecological function, habitat provision and benefits to water quality including bank stabilisation and filtering of coarse sediment inputs into waterways as well as moderating stream water temperature from shading.

3.2.1.4. Wetland Extent

Wetland extent was determined to be a relevant indicator to include within the freshwater basin assessments in the report card due to its importance in ecological function, provision of habitat for a range of species and benefits to water quality including sediment retention and nutrient cycling. Indicators for wetland values including function and condition of wetlands have been identified for inclusion in future reporting.

3.2.2. Data collection

3.2.2.1. Habitat Modification/Instream Habitat

Impoundment

All data for impoundment results was assessed in 2013-14. Impoundment is reported four yearly, thus results presented in the 2016 report card are repeated from the 2015 and 2014 pilot report card.

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 (DNRM) 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 DNRM 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

All data for fish barrier results were assessed in 2014-15. Fish barriers are reported four yearly, thus results presented in the 2016 report card are repeated from the 2015 report card.

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 2015c).

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 assigned to the results generated from this data due to the improvements of satellite imaging since the collection of the data. 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 (lack of ground truthing). Expert opinion was used to score this indicator for the Don basin.

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 (Table 1). Queensland waterways that fall within these two risk categories were determined by Fisheries QLD 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.

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 were clearly allowing 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 2).

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 2). 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 2). 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.

For the Don basin, expert opinion was used to assess the 'proportion of stream length to the first low/no passability barrier' indicator, due to the lack of confirmation of no/low passability barriers via current satellite imaging in this area.

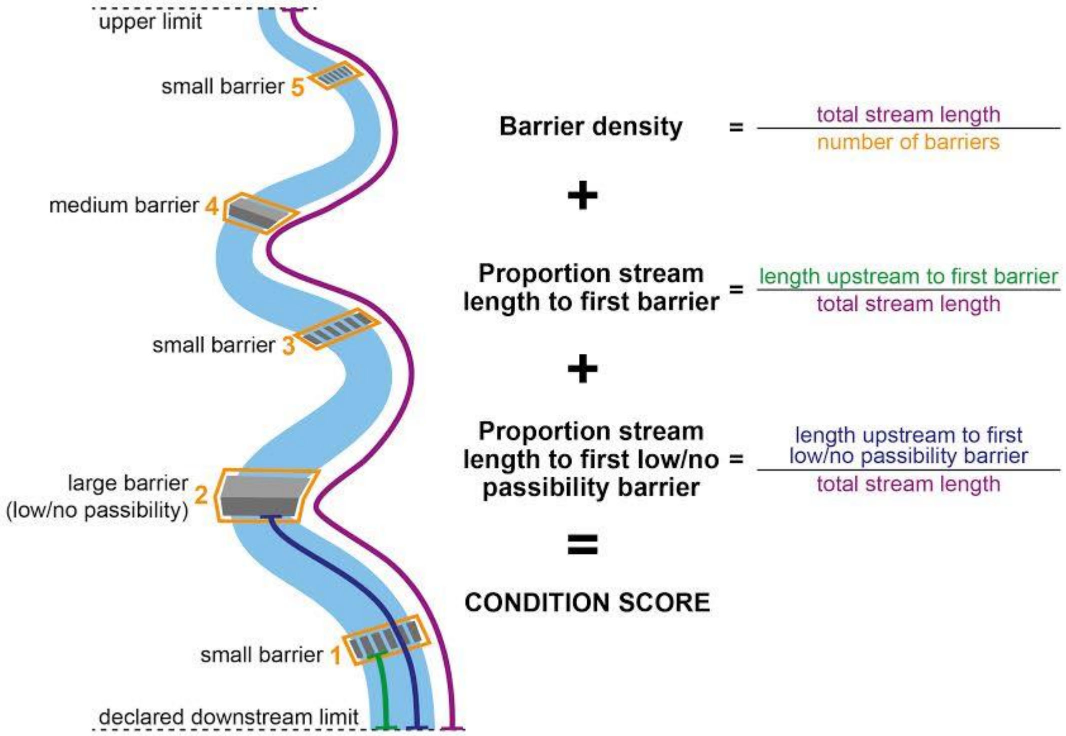

Figure 2. Diagram of the three fish barrier indicators and how they are calculated.

3.2.2.2. Flow

Methodologies for collecting data for flow indicators are currently under development.

3.2.2.3. Riparian Extent

The assessment of riparian extent follows the same methodology used for GBR report card assessed in 2013-14. Riparian extent is reported four yearly, thus results presented in the 2016 report card are repeated from the 2015 and 2014 pilot report cards.

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.

3.2.2.4. Wetland Extent

The assessment of wetland extent uses similar methods to the GBR report card wetland extent assessment. The source data is the same for both report cards, however with a focus on only palustrine systems in the five reported basins for the Mackay-Whitsunday report card (the Don, Proserpine, O'Connell, Pioneer, and Plane basins).

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

All data for wetland extent results was assessed in 2013-14. Wetland extent is reported four yearly, thus results presented in the 2016 report card are repeated from the 2015 and 2014 pilot report card, though scores are based on revised scoring ranges.

3.3. Fish

3.3.1. Indicator selection

Assessments of fish community health were deemed important for the Mackay-Whitsunday report card in terms of ecosystem health assessment and outcomes of water quality impacts. In addition, the value the local community places on the presence of freshwater fish species was also considered.

The aquatic ecosystems of the Mackay-Whitsunday Region have been significantly impacted by the surrounding land use practices (Folkers *et al*. 2014). Impacts include (but are not limited to) poor water quality runoff, degraded riparian and in-stream habitats, flow modification, and barriers to fish migration (Folkers *et al*. 2014). The cumulative impacts of these modifications have led to changes in the condition of the Region's fish communities, adversely impacting fish abundance, species richness, fish community composition and exacerbating the prevalence of pest fish species

(Moore 2015b). Significantly, where in-stream and terrestrial habitats persist undisturbed, healthy fish populations remain (Moore 2015b).

The freshwater fish community condition indicator is based on two ecological indicators:

- **Native species richness**; and
- **Pest fish abundance**.

Assessment in the report card of the two identified fish indicators is an important step towards understanding the health of the local freshwater fish communities. Inclusion of fish community composition and abundance indicators is an aspiration of the report card but will depend on funding research for developing appropriate methods to assess these indicators.

<u>Changes from 2015 report card</u>

In the 2015 report card: Macroinvertebrates were listed as an indicator for fauna in the 2015 report card however were not reported in any of the basins in the 2015 report card.

2016 report card: Macroinvertebrates have been removed as an indicator for fauna in freshwater basins. This is due to a lack of on-going monitoring in the Region and the decision from the Partnership that monitoring for this indicator was unlikely to be established in the near future. Macroinvertebrate reporting will be considered a long-term ambition for the report card. Removing macroinvertebrates as an indicator means that the condition assessments for freshwater fish will contribute to the overall basin scores for the first time.

The impact of incorporating freshwater fish condition scores into final basins scores in the 2015 report card can be seen in the Appendix.

3.3.2. Data collection

The two ecological indicators for fish are assessed by comparing observed data to modelled data:

- **Native species richness**: Calculate 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 abundance**: Calculate the proportion of the total number of fish caught that consists of *pest fish* by dividing the number caught to the number expected to occur based on modelling.

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 recent species richness at the ‘least disturbed’ site with 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. The results from this data are repeated for the 2016 report card due to the three yearly reporting frequency of this indicator.

4. Estuaries

4.1. Water quality

4.1.1. Indicator selection

Freshwater basin water quality indicators used in the report card are: dissolved oxygen (DO), turbidity, DIN, FRP, chlorophyll-*a* and pesticides reported as multisubstance-Potentially Affected Fraction (ms-PAF).

Prior to the establishment of the Mackay-Whitsunday pilot report card, there had been limited water quality data collection from estuaries in the Region. In October 2014, DSITI commenced an estuarine monitoring program for the Mackay-Whitsunday Region. This included data collection on key indicators for assessing pressures and issues in the Region.

The parameters measured in the newly-established monitoring program were shortlisted in terms of relevance to, and representation of, the regional report card. They were chosen because of their linkages to land management practices, and their potential to show impact on waterway and ecosystem health. Consideration was also given to the relevance of the sampling frequency to the indicator. Finally, selected water quality indicator guideline values (either scheduled or constructed from scheduled guideline values [i.e. DIN guidelines were derived from guidelines for NOx and ammonia]) are used in the assessment scoring.

4.1.1.1. Physical-Chemical

The physical-chemical (phys-chem) indicator category includes two indicators: DO and turbidity. These parameters are commonly used to assess the quality of water in estuarine environments and have water quality guidelines scheduled through the Environmental Protection (Water) Policy 2009. These two indicators can also be linked to land management practices through sediment and organic carbon loads from runoff into waterways.

In South East Queensland, DO has had long standing use in estuarine report cards, assessed against guidelines for both minimum and maximum daytime water quality guideline values. It is considered a useful indicator to include in the report card as it is often linked to fish kills, something that tends to cause community concern. In South East Queensland it has been used to monitor waterways receiving large organic loads leading to long-term low DO concentrations (DO-sags).

Turbidity was also selected, as the intent of the report card was to use similar water quality indicators (i.e. sediment/nutrients/pesticides) across the three (freshwater, estuarine, marine) environmental zones. Turbidity was used as the sediment component in the estuarine environment because it does not have any additional monitoring cost (unlike suspended sediments which has an analysis/ lab cost) and because site-specific relationships between sediment and turbidity can often be derived if necessary when funds can be found for periodic analysis of TSS.

4.1.1.2. Nutrients

Only a portion of the full suite of nutrients measured monthly through the DSITI estuary monitoring program are used to produce the nutrient indicator. The decision to restrict the report card indicators to as few nutrient species as possible was intended to avoid doubling up on speciation of nutrients while ensuring that those used would still be representative of the issues and pressures in the Region for estuaries.

In addition, the nutrient indicators were selected based on:

- Maintaining consistency where appropriate across environmental zones;
- Relevance to the estuarine environment;
- Availability of data (current and likely in future);
- One measure of each nutrient species selected to avoid double counting; and
- Inorganic forms are often more biologically available.

Considering the above and the indicators selected in freshwater basins, DIN and FRP were used as indicators of nutrients for estuaries. No specific estuarine, regional DIN guideline currently exists for the Mackay Whitsunday Region but this was constructed using the Queensland Water Quality guidelines for Ammonia and Oxidized nitrogen.

4.1.1.3. Chlorophyll-*a*

Chlorophyll-*a* (chl-*a*) (a measure of the phytoplankton population) was included as an estimator of the degree of eutrophication occurring in estuaries. Any additional interpretation will require more information about species composition and turnover rates.

4.1.1.4. Pesticides

As in freshwater basins, 56 pesticides with different modes of action are detected in the GBR. The 2016 report card will move from reporting on just the five PSII herbicides (ametryn, atrazine, diuron, hexazinone and tebuthiuron) previously identified as the pesticides of greatest concern to the health and the resilience of the Great Barrier Reef (DPC, 2013) to thirteen PSII herbicides detected across the GBR (as listed in the freshwater basins pesticides section).

As in freshwater basins, the report card uses the ms-PAF method to report on pesticides. Looking ahead, the toxicity data required for the ms-PAF metric is expanding to include pesticides with other modes of action, meaning that the range of pesticides included in the ms-PAF estimations will progressively increase in future reporting. The ms-PAF estimate is however, limited to pesticides with guideline values. Currently guidelines values are available for 28 of the pesticides detected in the GBR.

4.1.2. Data collection

The estuarine water quality data (for phys-chem, nutrients, chl-*a* and pesticides indicators) used in the report card were obtained through the monitoring program established by DSITI. Monitoring commenced in October 2014 and is conducted in the eight estuaries (Table 2). Sampling sites are located upstream of the mouth of the estuary (Table 2; Figure 4). 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, pesticides data is reported using the freshwater basin end-of-system water quality monitoring site, and not from the site listed in Table 2 where only phys-chem, nutrients and chl-*a* were monitored.

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. 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, phys-chem, chl-*a*	ms-PAF
		temporal sampling (n)	temporal sampling (n)
Gregory River	5.1	9	
	9.9	9	5
O'Connell River	7.5	11	*
St Helens Creek	8.9	11	6
Murray Creek	12.5	11	
	16.5	11	6
Vines Creek[6]	2	11	6
Sandy Creek	4.5	11	
	8	0	
	13.5	11	6
Plane Creek	6	11	
	9	11	6
Rocky Dam Creek	8.9	11	
	12.9	11	6
Carmila Creek	3.4	11	6

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

Data samples collected between August 1st 2015 and June 30th 2016 were used to calculate water quality condition scores for estuaries in the 2016 report card. Estuaries are monitored once a month (excluding July 2015), 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 2009a).

[6] The estuary upstream of Vines Creek is formally called Goosepond Creek, but the main channel has been treated as Vines Creek.

Laboratory analyses for chl-*a* and nutrients were conducted in-house at the DSITI Science Division Chemistry Centre (Ecoscience Precinct, Dutton Park, Queensland) using standard methods and the analyses for the PSII herbicides 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).

4.2. Habitat and Hydrology

4.2.1. Indicator selection

4.2.1.1. Riparian Extent

The extent of riparian vegetation associated with the estuaries was determined to be an essential indicator to include in the report card due to the importance of riparian vegetation for ecological function, habitat provision and benefits to water quality including bank stabilisation, temperature regulation and filtering of coarse sediment inputs into waterways.

4.2.1.2. Mangrove/Saltmarsh Extent

The extent of mangrove and saltmarsh vegetation was determined to be a critical indicator to include in the report card due to the importance of these systems in both estuarine ecological function and habitat provision, and its benefits to estuarine water quality and filtering of inputs to waterways.

4.2.1.3. Flow

Freshwater flow is an important indicator to include in the estuarine component of the Mackay-Whitsunday report card due to its relevance to ecosystem and waterway health. The flow of freshwater is a crucial defining component of estuaries. The flow indicator will help provide information on the level of modified freshwater flow regimes (from pre-development or "near natural" levels) into the estuarine environment.

Flow has not been included in the 2016 report card, but work is underway to develop practical flow indicators that can be reported annually. This is expected to be ready in time for the next report card.

4.2.1.4. Fish Barriers

Fish barriers are an important indicator for inclusion in estuaries because 57% of freshwater fish species found to occur in the Mackay-Whitsunday Region require unimpeded access between freshwater and estuarine habitats to complete their life cycle and maintain sustainable fish populations (Moore 2016). Therefore, barriers that prevent or delay connectivity between the freshwater and saltwater interface have the potential to impact migratory fish populations, decrease the diversity of freshwater fish communities and reduce the condition of aquatic ecosystems (Moore 2015a).

Indicator selection for fish barriers in estuaries reflected those in freshwater basins.

4.2.2. Data collection

4.2.2.1. 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 DSITI, 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 reported four yearly, thus results presented in the 2016 report card are repeated from the 2015 and 2014 pilot report cards, though scores are based on revised bandwidths.

4.2.2.2. Mangrove/Saltmarsh Extent

To assess the condition of mangrove/ saltmarsh extent in the estuaries, the 2013 (data repeated due to four year reporting frequency) aerial extent of intertidal habitat categories (mangrove and saltmarsh) was compared to the same habitat areas in their pre-development condition.

The spatial data was prepared by DSITI and derived from the Queensland Herbarium's Regional Ecosystem (version 9) data. The current year 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 in the pre-development to 2013 of the four selected important riparian categories of mangrove, samphire, tussock and melaleuca (REs 8.1.1, 8.1.2, 8.1.3 and 8.1.5) in the dominant Regional Ecosystem data was:

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

All data for mangrove/saltmarsh extent results was assessed in 2013-14. Mangrove/saltmarsh extent is reported four yearly, thus results presented in the 2016 report card are repeated from the 2015 and 2014 pilot report cards, though scores are based on revised calculations and bandwidths.

4.2.2.3. Flow

Methodologies for collecting data for flow indicators are currently under development.

4.2.2.4. Fish Barriers

All data for fish barrier results was assessed in 2014-15. Fish barriers is reported four yearly, thus results presented in the 2016 report card are repeated from the 2015 and 2014 pilot report card.

Assessment of fish barriers in the estuarine environment was undertaken using the same metrics 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 (Table 1) 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 3).

The elevation threshold (18.8 m above the DDL) itself was selected based on Fisheries QLD fish community monitoring data and local expert knowledge (Fisheries Biologists Matt Moore and Trent Power). Knowledge was based on highest known upstream locations 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.

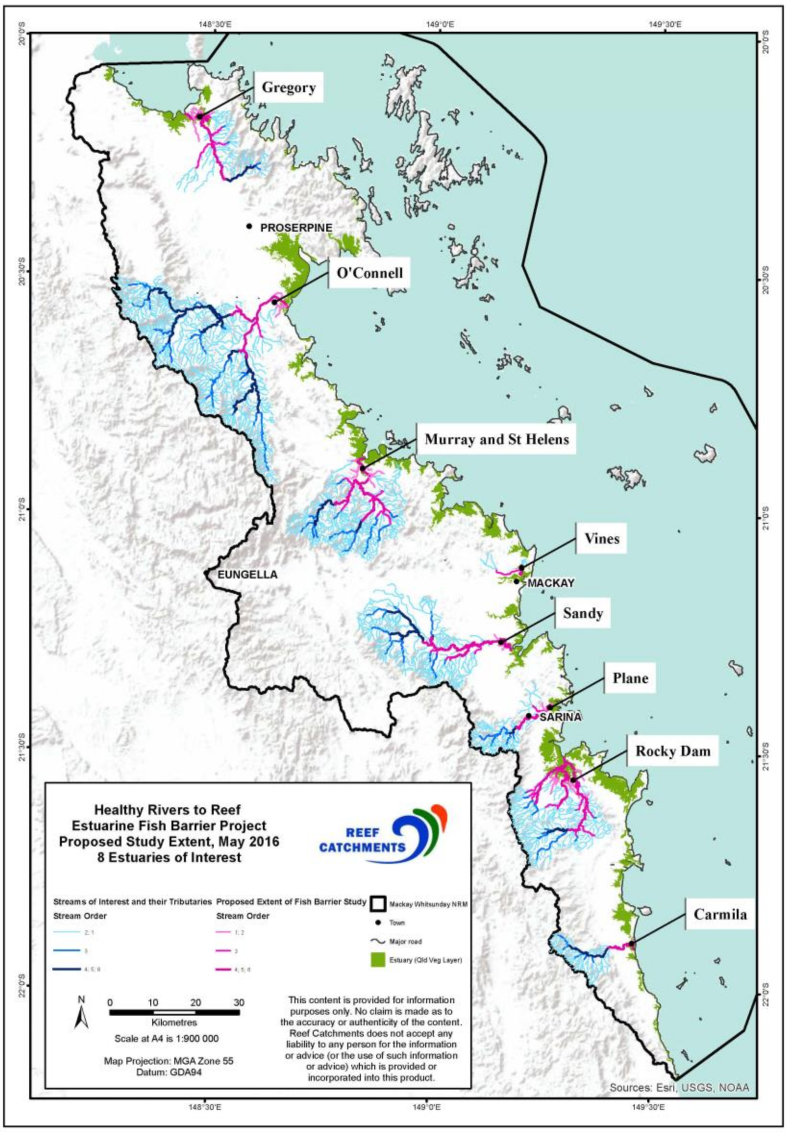

Figure 3. Extent of estuary assessment of fish barriers. Only pink/magenta waterways are included in the estuary barrier assessment; blue waterways are excluded as they do not intersect the estuary layer, are not 'Major' or 'High' impact tributaries and/or higher than 18.5 m above DDL. NB the major river near Mackay is the Pioneer, however it is not assessed for estuary condition, thus does not feature on this map.

4.3. Fish

4.3.1. Indicator selection

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 2016 report card.

Changes from 2015 report card

In the 2015 report card: Macroinvertebrates were listed as a fauna indicator for estuaries in the 2015 report card however were not reported in any of the estuaries in the 2015 report card.

2016 report card: Macroinvertebrates have been removed as an indicator for estuaries due to a lack of understanding of invertebrates as health indicators in estuaries, a lack of on-going monitoring in the Region and the decision from the Partnership that development of methodology and on-going monitoring to report on the indicator was unlikely to be established in the near future. Removing macroinvertebrates as an indicator has no impact on scores in the 2014 or 2015 report cards.

5. Inshore and Offshore Marine Environments

5.1. Water Quality

5.1.1. Indicator selection

5.1.1.1. Inshore Marine Environment

The inshore marine zone includes coastal waters extending from the land to the eastern State jurisdiction boundary. This includes enclosed coastal, open coastal and mid-shelf waters as defined by the GBRMPA (2010).

The water quality indicators included in the 2016 report card for the inshore marine zone are in Table 3. The full suite of potential indicators and programs that were considered for reporting can be found in earlier technical reports including the 'Development of Methods for the Mackay-Whitsunday Report card 2015'[7] document. A critical aspect to the report card was to align reporting with other relevant programs. The indicators selected for marine inshore water quality reporting match those used in the water quality index derived from in-situ monitoring in the inshore water quality monitoring program for the Marine Monitoring Program (MMP).

Table 3. Inshore marine water quality indicators.

Indicator category	Measured indicators	Abbreviation	Unit
Nutrients	Particulate Nitrogen	PN	µg/L
	Particulate Phosphorus	PP	µg/L
	Nitrogen oxide	NO_x	µg/L
Chlorophyll-*a*	Chlorophyll-*a*	Chl-*a*	µg/L
Water clarity	Total Suspended Solids	TSS	mg/L
	Secchi depth (m)	Secchi	m
	Turbidity	Turbidity	NTU
Pesticides	PSII herbicides (using PSII-HEq method)	N/A	N/A

5.1.1.2. Offshore Marine Environment

The offshore zone extends from the State jurisdiction boundary to the eastern boundary of the Great Barrier Reef Marine Park and includes offshore and mid-shelf waters.

The offshore marine water quality indicators used were selected based on whether the data was currently collected, and the likelihood that it would continue to be collected in the future. The rationale for the selected indicators:

- Chlorophyll-*a* is a measure of overall phytoplankton biomass and is widely considered as a useful proxy for nutrient availability and the productivity of a system; and
- TSS is a measure of particulate matter in the water column, which influences water clarity and sedimentation regimes. Suspended solids concentrations are in turn controlled by sediment and pollutant inputs from rivers and oceanographic factors such as wind, waves and tides.

[7] http://healthyriverstoreef.org.au/report-card/technical-reports/

5.1.2. Data collection

5.1.2.1. Inshore Water Quality

Three existing marine water quality monitoring programs in the Mackay-Whitsunday Region provide data for the 2016 report card. These programs include the Abbot Point ambient marine water quality monitoring program and the Mackay and Hay Point ambient marine water quality monitoring program and Inshore Marine Water Quality Monitoring, led by AIMS as part of the 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 2015-16 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 reporting zone in Table 4. 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.

Where available, data from passive samplers was used for pesticides scores in preference to grab sample data. 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 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 4. Summary of relevant program, number of temporal samples (July 2015 – June 2016), 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.

Site	Program	Temporal (grab samples)	Water type	Sample type			Indicators sampled							
				Grab	Logger	Passive	PN	PP	NOx	Chl-*a*	TSS	Secchi	Turbidity	Pesticides
Northern zone														
Amb1	AP	1	OC	■	■				●	●	●		●	●
Amb 2	AP	1	OC	■	■				●	●	●		●	●
Amb 3	AP	1	OC	■	■				●	●	●		●	
Amb 4a	AP	1	OC	■	■				●	●	●		●	●
Amb 5	AP	1	OC	■	■				●	●	●		●	
Amb 6	AP	1	OC	■	■				●	●	●		●	
Whitsunday zone														
Double Cone Island	MMP	6	OC	■	■		●	●	●	●	●	●	●	
Pine Island	MMP	6	OC	■	■		●	●	●	●	●	●	●	
Seaforth Island	MMP	6	OC	■	■		●	●	●	●	●	●	●	
Central zone														
AMB1	MHP	2|7*	OC	■	■		●	●	●	●	●		●	●
AMB2	MHP	2|7*	OC	■	■		●	●	●	●	●		●	●
AMB3B	MHP	2|7*	OC	■	■		●	●	●	●	●		●	●
AMB5	MHP	2|7*	OC	■	■		●	●	●	●	●		●	●
AMB6	MHP	2|7*	OC	■			●	●	●	●	●		●	●
AMB8	MHP	2|7*	OC	■			●	●	●	●	●		●	●
AMB10	MHP	2|7*	OC	■	■		●	●	●	●	●		●	●
AMB11	MHP	2|7*	EC	■			●	●	●	●	●		●	●
AMB12	MHP	2|7*	OC	■			●	●	●	●	●		●	●
Repulse Islands dive mooring	MMP	6	OC	■	■		●	●	●	●	●	●	●	
O'Connell River mouth	MMP	6	EC	■			●	●	●	●	●	●		
Round Flat	MMP		OC			■								●
Sarina	MMP		EC			■								●
Sandy Creek	MMP		OC			■								●
Repulse Bay	MMP		EC			■								●
Southern zone (monitoring program established September 2017)														

* 2 samples for TSS and NOx; 7 samples for PP, PN and Chl-*a*

Changes from 2015 report card

In the 2015 report card: Turbidity data from water quality loggers were not used in 2014 or 2015 report cards due to uncertainty around the comparability of logger installation between Abbot Point, MMP, Mackay and Hay Point water quality monitoring programs.

2016 report card: The 2016 report card is the first time that turbidity data from loggers has been included in the report card for the inshore water quality assessment. Data from loggers from the Abbot Point, MMP, Mackay and Hay Point water quality monitoring programs were confirmed as comparable when considering program objectives and logger installation (see Waltham et al. 2016, Lonborg et al. 2016 and Vision Environment 2016 for detail). The key differences in water quality loggers between programs were the depth that loggers were installed. MMP loggers were installed at either 2 or 5 m below lowest astronomical tide (LAT), however Abbot Point and Mackay and Hay Point water quality loggers were installed anywhere between 4 and 16 m below LAT. Despite this difference, data from all loggers was used in calculations because no correlation was found (r = 0.11) when depth was compared to annual median turbidity (NTU) across all available logger data from 2013 to 2016 from Abbot Point, MMP and Mackay and Hay Point water quality monitoring programs.

The impacts that incorporating turbidity data has on 2015 and 2014 water clarity scores for inshore marine zones can be seen in the Appendix.

5.1.2.2. Offshore Water Quality Data Collection

The data for the offshore assessment of water quality was extracted from the Bureau of Meteorology (BoM) dashboard. The offshore data for the Mackay-Whitsunday Region was extracted for the 2015-16 year (May 2015 to April 2016). The data is in the form of the percentage of the Mackay-Whitsunday offshore area that exceeds the GBRMPA guidelines (GBRMPA, 2010) for chlorophyll-a and TSS.

5.2. Coral Indicators

5.2.1. Indicator selection

The coral indicators used in the Mackay-Whitsunday 2016 report card closely follow the indicators used in the GBR report card. These are drawn from two coral monitoring programs led by the Australian Institute of Marine Science (AIMS), the MMP and the Long Term Monitoring Program (LTMP). The indicators are integrated into an overall coral reef condition index. The coral index is formulated around the concept of community resilience (Thompson et al. 2016). The underlying assumption is that a 'resilient' community should show clear signs of recovery after inevitable acute disturbances, such as cyclones and coral bleaching events, or, in the absence of disturbance, maintain a high cover of corals and successful recruitment processes (Thompson et al. 2016). The coral index was revised for the 2015 GBR report card and a detailed description, including the reasoning behind threshold selection and methods used for the calculation of the coral index, can be found in Thompson et al. (2016).

Most of the same coral indicators are collected for inshore and the offshore coral reporting in the 2016 report card, and the same method of calculation is used to determine the coral reef condition index for these zones. For further justification for the indicators used refer to Thompson et al. (2016).

The indicators used in the 2016 report card include:

- **Coral cover**: High coral cover is a desirable state for coral reefs, both in providing essential ecological goods and services related to habitat complexity which promotes diverse reef communities, but also from a purely aesthetic perspective with clear socio-economic value. In terms of reef resilience, although low cover may be expected following severe disturbance events, high cover implies a degree of resilience to any chronic pressures influencing the reef (Thompson et al. 2016);
- **Macroalgae cover**: In contrast to coral cover, high macroalgal cover on coral reefs is widely accepted as representing a degraded state. As opportunistic colonisers, macroalgae generally out-compete corals, recovering more quickly following physical disturbances. Macroalgae have been documented to suppress coral fecundity, reduce recruitment of hard corals and diminish the capacity of growth among local coral communities (Thompson et al. 2016). Macroalgae are much less evident on offshore reefs, so this indicator is not calculated for reefs in the offshore reporting zone or included in the offshore reef condition index.
- **Rate of coral cover increase (change in coral)**: A second avenue for recovery of coral communities is the growth of corals during periods free from acute disturbance. Chronic pressures associated with water quality or temperature stress may suppress the rate that coral cover increases and indicate a lack of resilience (Thompson et al. 2016);
- **Density of juvenile corals**: For coral communities to recover rapidly from disturbance events there must be adequate recruitment of new corals into the population. This indicator captures this important recruitment process by recording corals that have survived the early life stages (Thompson et al. 2016); and
- **Community composition:** This metric is used in the inshore zones only and compares the composition of hard coral communities with the expected community composition given each survey site's location along a gradient in water quality. Differences from expectation are interpreted in terms of water quality conditions.

Changes from 2015 report card

In the 2015 report card: Macroalgae was included in the offshore coral index in the 2015 and 2014 report cards.

2016 report card: Macroalgae are considered an important indicator for coral in inshore reefs, but due to different processes in offshore and open coastal waters it is not used for reporting in these areas for the 2016 report card.

The impacts that removal of the macroalgae indicator has on 2015 and 2014 coral index scores for offshore zones can be seen in the Appendix.

5.2.2. Data Collection

A combination of data from MMP or LTMP programs is used to report on coral in the inshore marine Whitsunday zone and match reporting for the GBR report card. Only LTMP coral data were used for reporting coral in the offshore zone (macroalgae was not used for reporting for offshore coral).

There are also coral monitoring programs associated with the Ports of Abbot Point, Mackay and Hay Point, commissioned by NQBP. In this report card, 2015-16 data from the coral monitoring program at the Ports of Mackay and Hay Point and Abbot Point is used to report on the coral condition in the Central inshore zone and for the first time in the Northern inshore zone. The same analysis used for the GBR report card was applied to this data to produce scores for four indicators in the Central zone (coral cover, change, macroalgae and juvenile density) and three indicators in the Northern 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 reporting as data becomes available.

5.2.2.1. Sampling programs and survey methods

Despite some differences in survey methodology, similar data was collected across the different monitoring programs (Table 5). All coral reefs monitored for the MMP or LTMP were selected with expert advice for the purposes of the specific coral monitoring programs.

Table 5. Survey methods for relevant coral monitoring programs reporting in the Mackay-Whitsunday Region.

Program (relevant zone) Survey Method	Information provided	No. 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 20 m transects
Belt transect	Abundance of juvenile corals < 5cm	4	2 at one or two depths*	5 x 20 m transects
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 20 m transects
Belt transect	Abundance of juvenile corals < 5cm	7	2 at each of two depths	5 x 20 m transects
LTMP (Whitsunday inshore zone)				
Photo point Intercept transect	Percentage cover of corals and other benthic categories.	3	3	5 x 50 m transects
Belt Transect	Size structure and density of juvenile (<5cm) coral communities.	3	3	5 x 5 m transects
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 20 m transects
Belt transect	Abundance of juvenile corals < 5cm	4	6	4 x 20 m transects
LTMP (Offshore zone)				
Photo point Intercept transect	Percentage cover of corals and other benthic categories.	10	3	5 x 50 m transects
Belt transect	Abundance of juvenile corals < 5cm	10	3	5 x 55 m transects

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

Inshore coral data within the Whitsunday inshore marine zone was collected from seven reefs by the MMP and an additional three reefs by the LTMP (see Figure 4 for locations). Both these programs have a biennial sampling design, so not every survey reef is sampled every year. Values of each index from the most recent surveys are used to calculate the value each year. Since some reefs will have been surveyed last in the preceding year, the values for each reporting year are effectively a 2-year rolling mean. The data included in the 2016 report card was collected over the period May 2014 to July 2016. Coral community structure and exposure to disturbances differ markedly with depth. This influence of depth is most apparent in inshore areas where the turbidity of waters causes a rapid attenuation of light; hence the MMP stratifies sampling by depth including transects at both 2 m and 5 m below LAT. The LTMP samples sites at 6-9 m depth only.

Inshore coral data for the Ports of Mackay and Hay Point coral monitoring program, relevant to the Central 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 detail refer to Neale (2016).

Inshore coral data for the Abbot Point coral monitoring program, relevant to the Northern 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 2016 report card was collected from these reefs in May 2016.

Offshore coral data was collected from permanent sites on nineteen reefs that were surveyed as part of the AIMS LTMP and the Monitoring program to assess the effects of rezoning the GBR Marine Park in 2004. As mentioned, reefs in these programs are sampled in alternating years, so data for each reporting year is the rolling mean of data collected over a two year period. Data included in the 2016 report card was collected over the period May 2015 to July 2016. 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 reporting zone (set by the boundary of Queensland waters) 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 and belt transects from which the density of juvenile corals can be estimated (Table 5). Despite some differences in survey methodology and transect dimensions, similar data was collected across the different monitoring programs (Table 5).

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, i.e. which result from the settlement and subsequent survival and growth of coral larvae, and 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

Intercept lengths for all colonies of a species or benthic group along each transect 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.

Analysis of offshore coral data have been revised for the 2016 report card so that offshore coral and inshore coral indicators are more comparable.

5.3. Seagrass Indicators

5.3.1. Indicator selection

The seagrass indicators were selected based on existing monitoring programs likely to continue in the future. The monitoring of seagrass is conducted by the MMP through James Cook University (JCU) for GBRMPA and is used in the GBR report card, and by the Queensland Ports Seagrass Monitoring Program (QPSMP) by JCU for Queensland ports authorities and use in the Gladstone Healthy Harbour Partnership annual report card.

The seagrass indicators selected for reporting from the MMP 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 include mean above-ground biomass, meadow area and species composition. Both programs produce condition scores for seagrass using the three indicators specific to the program and both programs also collect data on a variety of other aspects of seagrass ecology that are used in explanatory narratives of their reports. Relevant indicators from both of these programs are reported separately in the Mackay-Whitsunday report card.

Options for fully integrating the various methods for reporting seagrass are currently under investigation through the Reef 2050 Integrated Monitoring, Modelling and Reporting Program (RIMMReP) seagrass working group.

5.3.2. Data Collection

5.3.2.1. 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.

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

Mapping surveys were conducted to select representative meadows, which were those that had greater extent. 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) (McKenzie *et al*. 2015). Two sites were selected at each location to account for spatial heterogeneity (McKenzie *et al*. 2015). 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.

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 2016 report card, MMP seagrass monitoring data is reported in the Whitsunday zone at Hydeaway Bay, Hamilton Island, Pioneer Bay and Tongue Bay. In the Central zone seagrass monitoring data is reported at Midge Point, Sarina Inlet and Newry Bay (Figure 4). Tongue Bay and Newry Bay represent an expansion to the number of sites that contributed to the condition assessment in the 2015 report card and monitoring at these sites was undertaken by the Queensland Parks and Wildlife Service. Hydeaway Bay and Midge Point are long-term monitoring sites of the Seagrass-Watch program.

5.3.2.2. 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 7 port locations along the Great Barrier Reef at 50 individual meadows (Carter *et al*. 2016). The QPSMP monitors and reports on seagrass condition for entire individual meadows (Figure 4) and sampling occurs annually during the peak of the seagrass growing season in late spring/early summer at the end of the dry season (Carter *et al*. 2016). Meadow selection is based on their representation of the range of meadow types found in each location (dominant species, intertidal/subtidal, meadow size and mean biomass). Condition indicators reported for each meadow are mean above-ground biomass, meadow area and species composition (Carter *et al*. 2016). The program and approach has had independent review on several occasions and results are regularly published in peer reviewed journals (Carter *et al*. 2016). For further information on site selection and methods in the 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 2016 report card, QPSMP seagrass monitoring data is reported in the Northern zone at Abbot Point (nine sites) and in the Central zone at Mackay and Hay Point (one site).

5.4. Fish Indicators

The development of inshore and offshore marine fish indicators and methods is still progressing and will be determined in collaboration with RIMMReP and other regional report card partnerships.

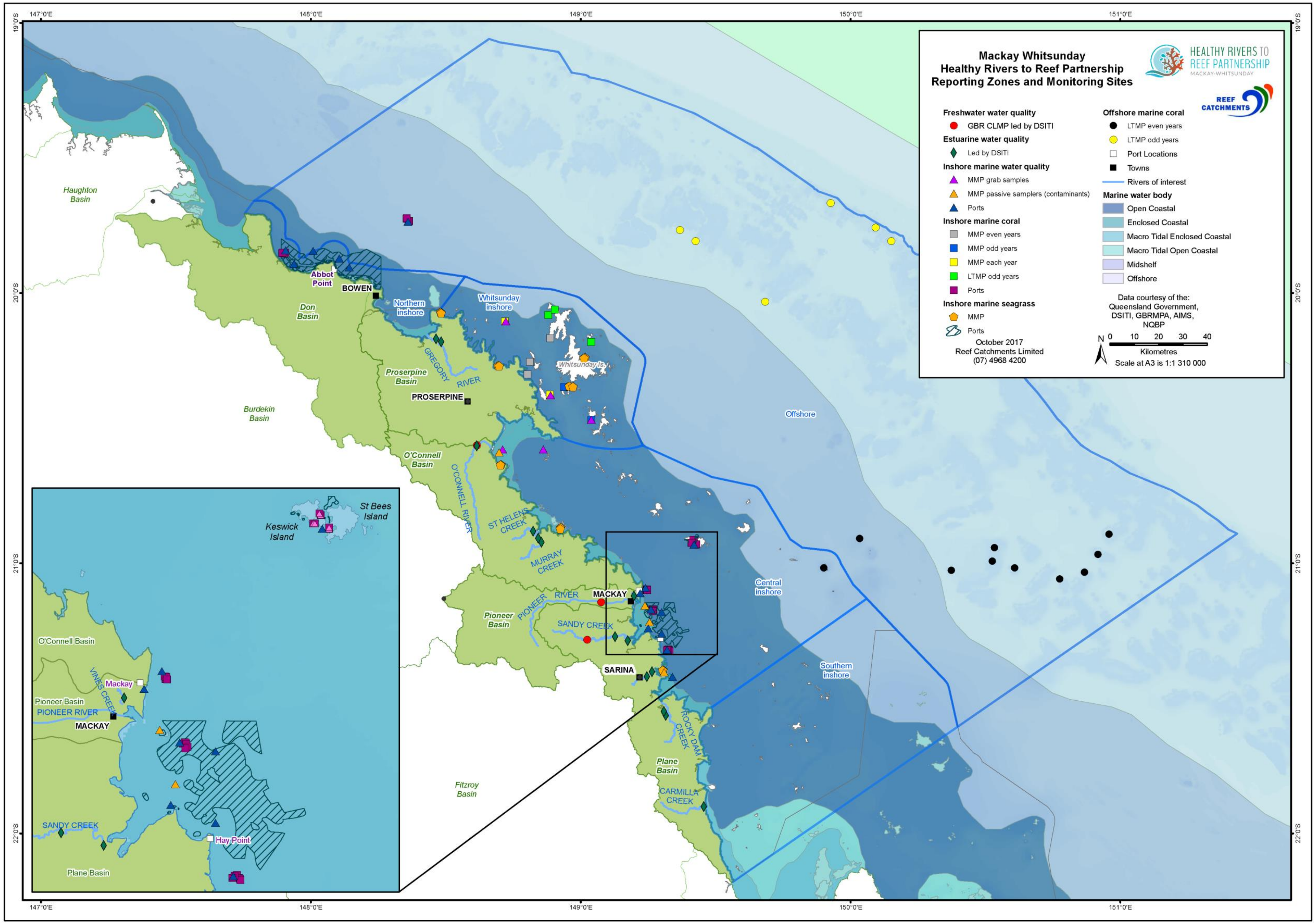

Figure 4. Sampling locations for water quality monitoring and coral and seagrass monitoring in the Mackay-Whitsunday Region.

6. Development of Condition Assessments Scoring Methods

Ordinal categories are used to describe the scores for 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 applicable scoring ranges and bandwidths which correspond to the five-point system. Specific scoring ranges for each indicator are described in detail in subsequent sections.

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.

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 6. 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.

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, e.g. which three out of four indicator categories.

Table 6. 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

<u>Changes from the 2015 report card</u>

In the 2015 report card: Scores across all environmental condition indicators in the freshwater basin and estuaries were standardised into a scoring range different to the GBR scoring range. This alternate scoring range meant that indicators that scored good or very good were assigned a value of 100. Derived rules around rolling up indicators with good and/or very good scores meant that these grades were not given equal weighting to very poor, poor and moderate grades. Thus aggregated scores were biased towards very poor to moderate grades.

The marine environmental condition indicators followed the GBR scoring range. This difference led to confusion around scoring between the different ecosystems.

2016 report card: All indicators are now standardised into the GBR scoring range. Grades are now equally weighted upon rolling up and there is no bias towards any grade.

A back-calculation of the 2014 and 2015 report card results using the improved scoring methods outlined in this document, along with how this compares to the original results can be seen in the Appendix.

6.1. Freshwater Basins and Estuaries

6.1.1. Water quality

6.1.1.1. Nutrients, sediments and phys-chem

To calculate a condition score (ranging from 0 – 100) for individual nutrients, sediments and phys-chem indicators, annual medians (calculated from monthly medians) are compared to guideline values. Only annual medians that meet or are better than the guideline value achieve a good or a very good score (Figure 5). This approach is very similar to the MMP system used in the marine zones, where the cut-off between “Good” and “Moderate” is where the indicator median (or mean) is equal to the guideline value.

Medians that do not meet the guidelines are scaled between the guideline and a scaling factor (SF). The approach to calculating a condition grade and translating this to the report card five-point grading is outlined in Table 7 and Table 8.

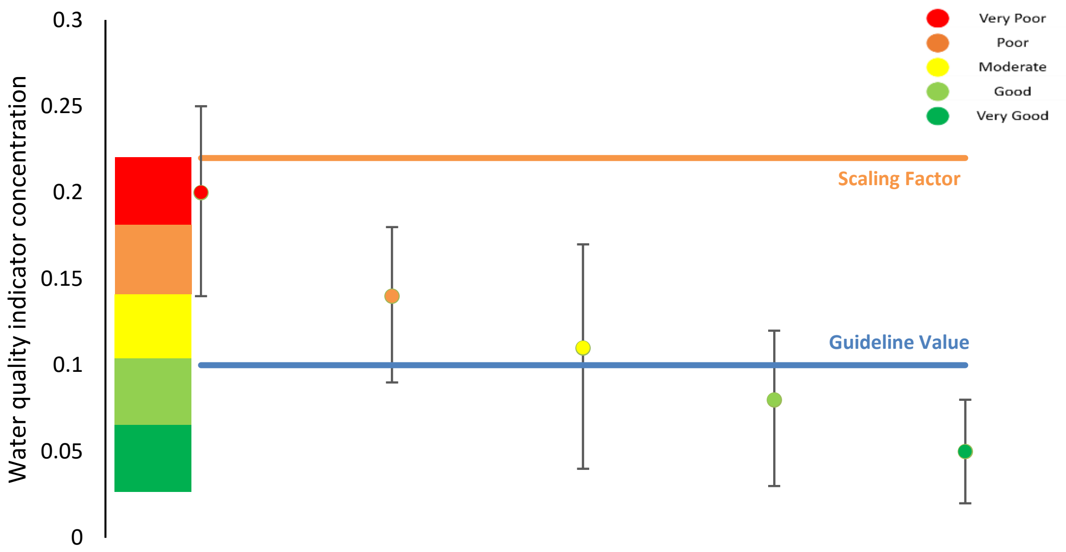

Figure 5. An example of how water quality grades are assigned. Where the middle point represents the annual median, the top whisker the 80th percentile and the bottom whisker the 20th percentile of the data. Only when the median meets or is better than the guideline (in this case meeting the guideline 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.

Steps used in calculating condition scores for water quality indicators:

- If the measured value is less than the level of reporting (LOR), then use a value of 0.5 x LOR;
- Derive DIN for freshwater basin data set (oxidised N + ammonia N);
- Calculate monthly medians;
- Calculate annual median from monthly medians;
- Compare median to guideline values;
- Calculate condition score (0 – 100) following rules and formula in Table 7 and Table 8; and
- Condition scores for indicators are aggregated into indicator category scores (see Table 9 and Table 10) and the water quality index (following decision rules for minimum information).

Table 7. Rules, formula and scoring ranges for associated grades for nutrients, sediments and phys-chem (except lower DO) indicators 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[9]	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[10] of available data)

Table 8. Rules, formula and scoring ranges for associated grades for lower DO in estuaries of the Mackay-Whitsunday report card (to meet lower DO guideline, % 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).

Rule	Formula	Scoring range	Grade
Median meets GV and ≥80% of data meets GV	Assigned 90	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[10] of available data)

Changes from the 2015 report card

In the 2015 report card: In freshwater basins and estuaries in the 2015 report card, water quality indicators that met guidelines (scored good or very good) were assigned a value of 100 and those that did not meet guidelines were scaled into a scoring range between 0 and 100 which was evenly separated into very poor, poor and moderate grades.

2016 report card: Water quality indicators now fit into the GBR report card scoring range. Those that do not meet the guideline are scaled into a scoring range between 0 and 60.9, which is evenly separated into very poor, poor and moderate grades. Those that score good are now scaled between 61 and 80.9 based on the distance the median is between the guideline and the 80th percentile. Water quality indicators that score very good are assigned the mid-point of the very good scoring range (90)[9].

A back-calculation of the 2014 and 2015 report card results using the improved scoring methods outlined in this document, along with how this compares to the original results can be seen in the Appendix.

[9] 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 7) is used to assign a score for Very Good.
[10] Scaling Factor for DO is based on the 99th percentile of all values.

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 9, with guidelines relating to the individual river or creek that was sampled. 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) that were out to public comment at the time of writing this document.

Table 9. 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	Proserpine	O'Connell (O'Connell River)	Pioneer (Pioneer River)	Plane (Sandy Creek)
Nutrients	DIN	mg/L			0.03	0.008	0.03
	FRP	mg/L			0.006	0.005	0.015
Sediment	TSS	mg/L			2	5	5

Table 10. Water quality indicator categories, associated indicators and guideline values for estuaries in the Mackay-Whitsunday report card. For DO guideline values are presented as lower-upper.

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 from all basins and the 90th percentile was used as the SF. The advantage of this approach is that the SFs were derived from the largest sample size available, the number of SF values across the report card were minimised and the assessments between basins are more consistent.

For the estuarine indicators DO, 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, values below 70% saturation occur reasonably frequently in the reference estuary, the Gregory. Use of a 90th percentile SF value would therefore put the least impacted estuary in a poor category. Therefore the SF that was adopted was the 99th percentile (~60% sat), 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 programme, 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 <u>LOR is greater than guideline value</u>, data is not used where a concentration was reported as <LOR (because this does not allow for valid interpretation of whether guidelines are met within the State of Queensland); and
- Where LOR is less than guideline value, a value of 0.5 x LOR is used for that indicator in the sample.

It should be noted that when the magnitude of difference between the guideline value and the LOR is less than two fold, using a value of 0.5 x LOR may have the impact of biasing towards better scores than is true in the field. This, and the quantity of samples where parameters are <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.

<u>Changes from the 2015 report card</u>

In the 2015 report card: The guidelines used for estuaries in the 2015 report card were used under the expectation that these guidelines would be scheduled, however there are discrepancies between the turbidity (NTU) guidelines used for estuaries in the Mackay-Whitsunday 2015 report card and those in the draft guidelines that have been released for public comment.

2016 report card: In the last report card estuaries north of Mackay were assessed against a GV of 9 NTU, but the proposed GV is 10 NTU. For estuaries south of Mackay there are no proposed turbidity guideline values, as these estuaries are considered too variable to derive guideline values. The guideline value of 10 NTU will be used for estuaries north of Mackay and no condition score for turbidity will be calculated for estuaries south of Mackay in the 2016 report card.

A back-calculation of the 2014 and 2015 report card results using the improved methods outlined in this document, along with how this compares to the original results can be seen in Appendix A.

6.1.1.2. Pesticides

The risk categories attributed to the ms-PAF metric were developed by the Water Quality and Investigations group within DSITI as part of the risk assessment for pesticides (Waterhouse et al. 2017) 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 effect 50% of species, and HU = 0.5 will effect 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 effect 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). These values (calculated for each monitoring site) were then compared to the risk categories presented in Table 11.

Table 11. Grading description for the pesticides indicator in the freshwater basin assessments.

Risk categories (% species affected)	Risk Level	Pesticides assessment	Scaling of scores for aggregation
≤ 1.0%	Very low risk	Very Good	VG = 81+ ABS((19 - ((score-0) *(19/1))))
1.01-5.0%	Low risk	Good	G= 61+ ABS((19.9 - ((score -1.01) *(19.9/3.99))))
5.01-10.0%	Moderate risk	Moderate	M=41+ ABS((19.9 - ((score -5.01) *(19.9/4.99))))
10.01-20.0%	High risk	Poor	P= 21+ ABS((19.9 - ((score -10.01) * (19.9/9.99))))
≥ 20.0%	Very high risk	Very Poor	VP=0+ABS((20.9 - ((score-20.01) *(20.9/79.99))))

6.1.2. Habitat and Hydrology

6.1.2.1. Habitat Modification/Instream Habitat modification (Freshwater Basins)

The two in-stream habitat modification indicator 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 12) 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 12. 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 the freshwater and estuaries a scoring range and subsequent score was developed for each of the three indicators (Table 13, Table 14 and Table 15). 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 16).

Table 13. Scoring range and subsequent score assigned for the barrier density indicator. Assessed on Stream Order (SO) as indicated[11].

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

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

Table 14. 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[12].

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 15. 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[12].

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 16. 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))))

6.1.2.2. Fish Barriers (Estuaries)

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

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

The condition score for the extent of riparian vegetation was determined by calculating the per cent loss of riparian vegetation since pre-development to 2013 (data repeated due to four year reporting frequency) for each basin or estuary and assigning the result a grade as per Table 17.

The condition score for the extent of wetlands in freshwater basins was determined by calculating the per cent loss of vegetated freshwater swamp (palustrine) systems with more than 30 per cent emergent vegetation cover. The 2013 extent was compared to the pre-development extent, using the RE mapping version 9 for each basin. The score was generated by subtracting the RE mapped

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

2013 per cent extent of wetland vegetation from the pre-development per cent extent of wetland vegetation, and assigning the result a grade as per Table 17.

The condition score for the mangrove/saltmarsh extent in estuaries was determined by calculating the per cent loss of mangroves and saltmarsh. The 2013 extent was compared to the pre-development extent, using the RE mapping version 9 for each basin. The score was generated by subtracting the RE mapped 2013 per cent extent of mangroves and saltmarsh from the pre-development per cent extent of mangroves and saltmarsh, and assigning the result a grade as per Table 17.

Table 17. 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))))

Changes from the 2015 report card

In the 2015 report card: The scoring ranges for riparian, wetland and mangrove/saltmarsh extent loss required review by an expert panel.

In the 2016 report card: The scoring ranges for riparian extent, wetland extent and mangrove/saltmarsh extent were reviewed by an expert panel and scoring ranges were adjusted so that they better aligned with riparian, wetland and mangrove/saltmarsh extent loss across Queensland.

The impacts that the changes to these scoring ranges has on scores from the 2014 and 2015 report cards can be seen in the Appendix.

6.1.3. Fish

The scoring methods for the freshwater fish community condition is outlined in Table 18 and Table 19. A qualitative rating scheme for native species richness (PONSE) was developed (Table 18), 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 19.

Table 18. Rating scheme for condition of native species richness using PONSE model for freshwater fish communities.

Native species richness	Grade	Scaling of scores for aggregation
>= 0.800	Very Good	VG = 81+ ABS((19 + ((score-1) *(19/0.2))))
>= 0.667	Good	G= 61+ ABS((19.9 + ((score -0.7999) *(19.9/0.1329))))
>= 0.533	Moderate	M=41+ ABS((19.9 + ((score -0.6669) *(19.9/0.1339))))
>= 0.400	Poor	P= 21+ ABS((19.9+ ((score -0.5329) * (19.9/0.1329))))
< 0.400	Very Poor	VP=ABS((20.9 + ((score-0.3999) *(20.9/0.3999))))

Table 19. Rating scheme for the modelled pest fish condition indicator for freshwater fish community.

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

6.2. Inshore and Offshore Condition Assessment

6.2.1. Inshore Water Quality

The water quality indicators were equally weighted to generate the water quality index score. Table 20 shows the relationship of indicators to the water quality index and the associated weightings.

Table 20. Relationship of selected indicators and the water quality index.

Index	Indicator	Measured indicators	Weighting of indicator within the index
Water Quality	Nutrients	PN	Equally, therefore 33.3% each when all three are measured in a zone
		PP	
		NO_x	
	Chl-*a*	Chl-*a*	Entire score
	Water clarity	TSS	Equally, therefore 33.3% each when all three are measured in a zone
		Secchi depth	
		Turbidity	
	Pesticides	PSII-HEq method	Entire score

6.2.1.1. Nutrients, chlorophyll-*a* and water clarity

For indicators of nutrients, chlorophyll-*a* and water clarity, annual medians or means were calculated (depending on relevant water area) at each site and condition scores were calculated using the relevant guideline value and the procedure below.

Guidelines used to calculate indicator scores 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 are used[13]. 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[14]).

In past report cards only 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 guidelines refined using site-specific long term water quality data collected at MMP sites (Waterhouse et al. 2017), rather than GBR wide GBRMPA (2010) guidelines. While the Mackay-Whitsunday report card has not employed the same guidelines as the MMP, preferring to use scheduled guidelines, the guidelines refined by and used by MMP are similar to the scheduled guidelines used in the Mackay-Whitsunday report card. Relevant inshore water quality guidelines used in the 2016 report card are presented in Table 21.

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

Changes from the 2015 report card

In the 2015 report card: In the 2014 and 2015 Mackay-Whitsunday report cards, the marine water quality score was reported by following the steps to calculate the 'interim site-specific water quality index' for in-situ sampling sites from the water quality monitoring program in the MMP. The steps in this calculation are described in full in Lonborg et al. (2016). The report cards also used the same guideline values reported in Lonborg et al. (2016) for score calculations. These guidelines reflected both the Water Quality Guidelines for the Great Barrier Reef Marine Park (GBRMPA 2010) and the central Queensland guidelines in the Queensland Water Quality Guidelines (DEHP 2009b).

In the 2016 report card: As a result of the changes to the use of guidelines for calculating the 'interim site-specific water quality index' for in-situ sampling sites in the 2015-16 MMP water quality report, the 2016 Mackay-Whitsunday report card follows:

- 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[15].
- For the comparison of test site monitoring data against single value guidelines, unless stated otherwise, the median water quality value (e.g. concentration) of a number (preferably five or more) of independent samples at a particular monitoring ('test') site should be compared against

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

the applicable water quality guideline.

- For the waters where three guideline values are listed, the median (i.e. middle value) is the relevant value for comparison.

The impacts that the changes to these guidelines has on scores from the 2014 and 2015 report cards can be seen in the Appendix.

Table 21. 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	<1
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. 2017):

1. For indicators where failure to meet a guideline is defined as values being *higher* than guideline values:

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

   For indicators where failure to meet a guideline is defined as values being *lower* than guideline values (for example Secchi depth):

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

   Where:

   AM is annual median or mean of 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 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 22.

Table 22. Inshore water quality grades, scoring ranges and scaling for aggregation.

Condition grade and colour	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)))

6.2.1.2. Pesticides

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

In the 2016 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 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 zone) the median sample from the wet season (Nov-Apr) was investigated for providing an overall PSII-HEq concentration result for the zone. However, there is lower confidence in results calculated using grab samples. If grab sample data was available in the same zone as passive samplers (i.e. Central zone), grab sample data was 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 23) 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.

A calculation of LOR x 0.5 was applied to samples that were below LOR before PSII-HEq concentrations were calculated from grab samples unless the LOR was unusually high. Commonly, for PSII pesticides the LOR is <0.01 µg/L (for example Gallen et al. 2013; 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 samples <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.

<u>Changes from the 2015 report card</u>

In the 2015 report card: A calculation of LOR x 0.5 was not applied to samples that were below LOR before PSII-HEq concentrations were calculated. These samples were left blank and a PSII-HEq of zero reported for that site if all samples were <LOR.

In the 2016 report card: A calculation of LOR x 0.5 is now applied to samples that are <LOR before PSII-HEq concentrations. This has not impacted grades from the 2014 and 2015 report cards.

[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 23. 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.

6.2.2. 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 24) (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) 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 6). The TSS and chlorophyll-*a* results are weighted equally (Table 24), so are averaged to provide the water quality indicator category result for the offshore zone.

Table 24. 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/

6.2.3. Coral

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

- **Coral cover:** This metric 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 metric 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 predicted change in cover derived from multi-species 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 and for the combined grouping of all other slower growing hard coral taxa; and
- **Community composition:** The basis of the metric 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 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 used along with the transect dimensions to convert juvenile abundance to the indicator juvenile density. The central zone scores are the mean of the reef level scores for each indicator.

The condition of offshore coral reefs is based on LTMP data, and the coral index for offshore reefs for the 2016 report card is based on coral cover, density of juvenile corals and the coral change index, but does not include the cover of macroalgae or the community composition indices. Methods for scoring condition of offshore reefs have changed to align with the indices used by the GBR report card and with the coral index for inshore reporting zones. For detail on the methods used in the previous report cards see the 'Development of Methods for the Mackay-Whitsunday Report card 2015'[18] document.

[18] http://healthyriverstoreef.org.au/report-card-results/

For the 2016 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 25. 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 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.

All indicators are weighted equally and the scores are then averaged to determine the overall coral index score for the reporting zone. The range between zero and 1.0 is divided into five equal bands corresponding to ratings from very poor to very good (Table 26).

Changes from the 2015 report card

In the 2015 report card: Methods for scoring condition in the offshore coral reefs matched that used in the 2014 pilot report card.

In the 2016 report card: Methods for scoring condition of offshore reefs changed to align with the indices used by the GBR report card and with the coral index for inshore reporting zones. This means that indicators for both inshore and offshore regions were scored in a similar way in the 2016 report card. Observations for each indicator were scored on a continuous scale following Thompson *et al*. (2016). The approach involves selecting bounding values for each indicator based on biology. These bounds become zero (very poor) and 1.0 (very good) on an approximately linear scale (see Section 6 of Thompson et al. 2016). This linear scale is then used to convert the value of each indicator from each reef to a value between zero and 1.0, and the values for the reefs in each reporting zone are averaged.

The impacts that the changes to coral scoring has on scores from the 2014 and 2015 report cards can be seen in the Appendix.

Table 25. 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 26. 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

6.2.4. Inshore Seagrass

6.2.4.1. Marine Monitoring Program

Through the MMP seagrass monitoring a method has been developed and documented (refer to McKenzie *et al*. 2015) to roll up seagrass data results into the GBR report card scoring range (Table 6). 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 27, reproductive effort in Table 28, and nutrient status in Table 29. 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 27. 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 28. 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 29. 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

6.2.4.2. Queensland Ports Seagrass Monitoring Program

The QPSMP uses a condition index developed for seagrass monitoring meadows based on changes in mean above-ground biomass, total meadow area and species composition relative to a baseline. 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 (Satisfactory), 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).

6.2.4.3. Combined display approach for MMP and QPSMP seagrass indicators

The combined display approach for seagrass indicators maintains the score calculation methods from each program. This ensures that the scores given in the regional report cards for a particular meadow/site remain consistent with MMP and QPSMP reporting. There is no overlap between QPSMP and MMP locations in the northern or Whitsunday inshore marine zones, but both programs have seagrass monitoring in the central zone.

The GBR report card scoring range (Table 6) 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 6). 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.

7. 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.

7.1. 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. At the time of writing this document, comment was being sought on the draft Reef 2050 Water Quality Improvement Plan 2017-2022 (Reef 2050 WQIP). The draft Reef 2050 WQIP includes updated targets for GBR basins, including those reported in the Mackay-Whitsunday report card. Following the finalisation of this document and associated targets, the Partnership will have the most up-to-date information available to determine appropriate targets for the report card based on all available information.

8. Confidence, limitations, and recommendations

8.1. Confidence associated with results

The Regional Report Cards use the 2015 Great Barrier Reef Water Quality Protection Plan report card method for communicating confidence (Australian Government and Queensland Government, 2015). 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 revised scoring approach (described in an unpublished paper submitted to the Independent Science Panel (ISP) on 28th July 2016) was used for the 2015 report card results, however this approach has been adjusted for the 2016 report card so that the confidence criteria seen to have more importance for the Mackay-Whitsunday Region have been weighted accordingly.

8.1.1. Methods

The determination of 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 targets. 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 (as defined above) into the metric 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.

8.1.1. Scoring

For all indicators where a condition score was reported, each criterion is scored 1 (lowest) to 3 (highest) as defined in Table 30. The score of each criterion is weighted accordingly and the total confidence score is calculated by adding all weighted scores for of the five criteria. The final score is assessed against a 1 to 5 qualitative confidence ranking (Table 31). 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.

Table 30. Scoring matrix for each criteria used to assess confidence.

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

8.1.1.1. 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 at 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 marine zone Ports 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 marine zone confidence is scored by considering the Ports program because it has 9 sampling sites compared to the MMP's 2 sampling sites.

8.1.1.2. 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 31). However, for presentation in the 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. Thus the freshwater fish barriers indicator score used is the median 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 31. 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 ○○○○○

<u>Changes from the 2015 report card</u>

In the 2015 report card: the weighting for representativeness was equal to the validation, directness and measured error criterion, while the maturity of methodology was weighted by half. This did not adequately embody the importance of the representativeness criteria for the Mackay-Whitsunday report card, where representativeness is considered of more importance than any of the other criteria.

2016 report card: the weighting for representativeness was increased to 2 while all other weighting relationships and methods remained the same as the scoring approach used for the 2015 report card. Changing the weightings of the confidence criteria meant that the possible range of final scores became continuous, thus the 20th percentile cut-offs that determine the rankings were also revised (Table 31).

A back-calculation of the 2015 report card confidence rankings using the changed weightings of confidence criteria and adjusted rankings outlined in this document, along with how this compares to the original confidence rankings can be seen in Appendix A.

8.2. Limitations and recommendations

The spatial representativeness of the water quality monitoring data in all the freshwater basins and the temporal representativeness of water quality monitoring data in the Northern inshore marine zone are a major limitation to the condition reporting in the 2016 report card. Data gaps in the southern inshore zone and a lack of consistent monitoring of pesticides across the inshore zones are also major limitations to condition reporting. There are also limitations associated with 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 its Partners have been working towards addressing some of these limitations:

- In the next report card more data will be available throughout the reporting period for the Northern inshore marine zone, as the monitoring program will have data across the full reporting period and the LOR for indicators will have been lowered to allow for valid interpretation of all the data (directed by NQBP);
- Additional GBRCLMP sites established in the Andromache River and Plane Creek will improve spatial representation of water quality monitoring for the O'Connell and Plane basins in future report cards (directed by the Queensland and Australian Governments);
- GBRCLMP sites established at the Don and Proserpine Rivers will allow for water quality reporting in these basins for the first time (directed by the Queensland and Australian Governments);
- Baseline water quality monitoring, coral monitoring and seagrass monitoring will be initiated in September 2017 in the southern inshore Region which will contribute data towards reporting on these indicators in the 2018 and 2019 report cards (directed by the Partnership);
- Improved integration of the different seagrass indicators programs is being addressed by the seagrass working group as part of RIMMReP (directed by GBRMPA); and
- Indicator selection and methodology for assessing freshwater flows for basins and estuaries is underway and is expected to be available by the next report card (directed by the Partnership and the Wet Tropics Healthy Waterways Partnerships).

Further improvements to the report card have been identified for the future:

- Moving towards inclusion of reporting progress-to-targets;
- Review of inshore marine water quality condition scoring (exploration of the option to use modelling as part of condition assessments);
- Expansion of freshwater basin and estuary habitat assessments to include condition (and possibly invasive weeds) with current extent assessments;
- Investigation of a groundwater indicator;
- Expansion of passive samplers across the four inshore reporting regions;
- Expansion of water quality monitoring in freshwater basins to include the upper and middle of catchments; and
- Exploration of estuary and marine fish indicators using available data in collaboration with DAF.

References

Agostinho, A., Pelicice, F., & Gomes, L., 2008. Dams and the fish fauna of the Neotropical region: impacts and management related to diversity and fisheries**.** *Brazilian Journal of Biology*, 68(4): 1119-1132.

ANZECC and ARMCANZ. 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Vol. 1. The Guidelines*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

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

Brodie, J., & Mitchell, A. 2005. Nutrients in Australian tropical rivers: changes with agricultural development and implications for receiving environments. *Marine and Freshwater Research*, 56: 279-302.

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

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

Carter, A., Bryant, C., Davies, J., & Rasheed, M. 2016a. *Gladstone Healthy Harbour Partnership 2016 Report Card, ISP011: Seagrass.* Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 16/23, James Cook University, Cairns, 62 pp.

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

Carter, J., Tait, J., Kapitzke, R., & Corfield, J. 2007. *Burdekin Dry Tropics NRM Region Fish Passage Study*. Alluvium.

DAFF (Department of Agriculture, Fisheries and Forestry). 2013. *Guide for the determination of waterways using the spatial data layer Queensland waterways for waterway barrier works*. Queensland Government.

DEHP (Department of Environment and Heritage Protection). 2009a. *Monitoring and Sampling Manual 2009, Version 2, July 2013*. Queensland Government.

DEHP (Department of Environment and Heritage Protection). 2009b. *Queensland Water Quality Guidelines 2009, Version 3*. Queensland Government.

Devlin, M., Lewis, S., Davis, A., Smith, R., Negri, A., Thompson, M., & Poggio, M. 2015. *Advancing our understanding of the source, management, transport and impacts of pesticides on the Great Barrier*

Reef 2011-2015. A report for the Queensland Department of Environment and Heritage Protection. Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication, James Cook University, Cairns, 134 pp.

Diaz-Pulido, G., & McCook, L. 2008. *Macroalgae (Seaweeds).* In Chin., A., (ed) The State of the Great Barrier Reef On-line, Great Barrier Reef Marine Park Authority, Townsville. Available at: http://www.gbrmpa.gov.au/__data/assets/pdf_file/0019/3970/SORR_Macroalgae.pdf

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

DPC (Department of the Premier and Cabinet). 2013. *Reef Water Quality Protection Plan 2013, Securing the health and resilience of the Great Barrier Reef World Heritage Area and adjacent catchments.* Reef Water Quality Protection Plan Secretariat, Brisbane. Available at: http://www.reefplan.qld.gov.au/resources/assets/reef-plan-2013.pdf.

Folkers, A., Rohde, K., Delaney, K., & Flett, I. 2014. *Water Quality Improvement Plan 2014-2021 Mackay, Whitsunday, Isaac*. Reef Catchments Ltd, Mackay.

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

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

GBRMPA (Great Barrier Reef Marine Park Authority). 2010. Water quality guidelines for the Great Barrier Reef Marine Park. Revised edition 2010. Great Barrier Reef Marine Park Authority, Townsville.

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

Jonker, M., Johns, K., & Osborne, K. 2008. *Surveys of be*nthic reef communities using digital photography and counts of juvenile corals. AIMS, Townsville. Available at: http://www.aims.gov.au/documents/30301/23354/Long+term+Monitoring+GBR+Standard+Operational+Procedure+10/34301565-3820-4c49-9087-7f3f15f1962a

Kennedy, K., Paxman, C., Dunn, A., O'Brien, J., Mueller, J. 2010. *Monitoring of organic chemicals in the Great Barrier Reef Marine Park and selected tributaries using time integrated monitoring tools (2008-2009)*. Brisbane (QLD), Australia: National Research Centre for Environmental Toxicology University of Queensland (Entox), University of Queensland.

Lewis, S., Brodie, J., Bainbridge, T., Rohde, K., Davis, A., Masters, B., Maughan, M., Devlin, M., Mueller, J., Schaffelke, B. 2009. Herbicides : A new threat to the Great Barrier Reef. *Environmental Pollution*, 157(8–9), pp.2470–2484. Available at: http://dx.doi.org/10.1016/j.envpol.2009.03.006.

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

Lønborg, C., Devlin, M., Waterhouse, J., Brinkman, R., Costello, P., Silva, E., Davidson, J., Gunn, K., Logan, M., Petus, C., Schaffelke, B., Skuza, M., Tracey, D., Wright, M., Zagorskis, I. 2016. *Marine Monitoring Program: Annual Report for inshore water quality monitoring: 2014 to 2015.* Report for the Great Barrier Reef Marine Park Authority, Townsville.

McKenna, S., Sozou, A., Scott, E., & Rasheed, M. 2016a. *Port of Abbot Point Long-Term Seagrass Monitoring: Annual Report 2014-2015.* Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 16/21, James Cook University, Cairns, 47pp.

McKenna, S., Sozou, A., Scott, E., & Rasheed, M. 2016b. *Annual Seagrass Monitoring in the Mackay-Hay Point Region – 2015'.* Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 16/11, James Cook University, Cairns, 36pp.

McKenzie, L. 2009. *MTSRF Milestone report for June 2009: Seagrass indicators, distribution and thresholds of potential concern*. Available at: http://rrrc.org.au/wp-content/uploads/2014/06/113-QDPIF-McKenzie-L-2009-May-Milestone-Report.pdf.

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

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

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

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

Moore, M. 2015b. *Mackay Whitsunday Region freshwater fish community health report*. Catchment Solutions.

Moore, M. 2015c. *Mackay Whitsunday Region freshwater fish barrier prioritisation*. Catchment Solutions.

Moore, M. 2016. *HR2R- Freshwater and Estuary Fish Barrier Metrics Report*. Catchment Solutions.

Neale, S. 2016. *Hay Point Ambient Coral Monitoring March 2015 – March 2016*. Advisian, Brisbane.

Newham, M., Moss, A., Moulton, D., Honchin, C., Thames, D., Southwell, B. Department of Science, Information Technology and Innovation, Queensland. (2017). *Draft environmental values and water quality guidelines: Don and Haughton River basins, Mackay-Whitsunday estuaries, and coastal/marine waters* (draft, March, 2017).

Rohde, K., Masters, B., Brodie, J., Faithful, J., Noble, R., & Carroll, C. 2006. *Fresh and marine water quality in the Mackay Whitsunday region 2004/2005.* Mackay Whitsunday Natural Resource Management Group. Mackay, Australia.

Safe, S. 1998. *Hazard and risk assessment of chemical mixtures using the toxic equivalency factor approach*. Environ Health Perspect, 106(Suppl 4): 1051-1058.

Schaffelke, B., Collier, C., Kroon, F., Lough, J., McKenzie, L., Ronan, M., Uthicke, S., Brodie, J., 2017. *Scientific Consensus Statement 2017. Scientific Consensus Statement 2017: A synthesis of the science of land-based water quality impacts on the Great Barrier Reef, Chapter 1: The condition of coastal and marine ecosystems of the Great Barrier Reef and their responses to water quality and disturbances*. State of Queensland, 2017.

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

Smith, R., Warne, M.StJ., Mengersen, K., & Turner, R. (2017). *An improved method for calculating toxicity-based pollutant loads: Part 1. Method development.* Integrated Environmental Assessment and Management, 13(4): 746-753.

Smith, R., Middlebrook, R., Turner, R., Huggins, R., Vardy, S., Warne, M. 2012. Large-scale pesticide monitoring across Great Barrier Reef catchments – Paddock to Reef Integrated Monitoring, Modelling and Reporting Program. *Marine Pollution Bulletin*, 65(4–9), pp.117–127. Available at: http://dx.doi.org/10.1016/j.marpolbul.2011.08.010.

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

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

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

Vision Environment. 2016. *Abbot Point Ambient Water Quality Monitoring October 2015 to October 2016*. North Queensland Bulk Ports, Gladstone Australia.

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

Waltham, N., McKenna, S., York, P., Devlin, M., Campbell, S., Rasheed, M., Da Silva, E., Petus, C., Ridd, P. 2015. *Port of Mackay and Hay Point Ambient Marine Water Quality Monitoring Program (July 2014 to July 2015)*. Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) Publication 15/16, James Cook University, Townsville, 96 pp.

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

Waterhouse, J., Brodie, J., Tracey, D., Smith, R., Vandergragt, M., Collier, C., Petus, C., Baird, M., Kroon, F., Mann, R., Sutcliffe, T., Waters, D., Adame, F., 2017. *Scientific Consensus Statement 2017: A synthesis of the science of land-based water quality impacts on the Great Barrier Reef, Chapter 3: The risk from anthropogenic pollutants to Great Barrier Reef coastal and marine ecosystems*. State of Queensland, 2017.

Waterhouse J, Lønborg C, Logan M, Petus C, Tracey D, Lewis S, Tonin H, Skuza M, da Silva E, Carreira C, Costello P, Davidson J, Gunn K, Wright M, Zagorskis I, Brinkman R, Schaffelke B,. 2017. *Marine Monitoring Program: Annual Report for inshore water quality monitoring, 2015-2016. Report for the Great Barrier Reef Marine Park Authority.* Australian Institute of Marine Science and JCU TropWATER, Townsville xxxpp. (draft version).

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

Appendix

In the following tables, data from 2015 and 2014 report cards are back-calculated using improved scoring methods and compared to scores calculated with superseded methods from the 2015 report card.

Mackay-Whitsunday freshwater basin back-calculated scores for 2015 and 2014 report cards.

Water quality

Table A 1. Sediment indicator scores in freshwater basins for the 2015 and 2014 report cards, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card.

Basin	2015 report card (2014-15 data)		2014 report card (2013-14 data)	
	Back-calculated	Original	Back-calculated	Original
	Sediment (TSS)	Sediment (TSS)	Sediment (TSS)	Sediment (TSS)
Don				
Proserpine				
O'Connell	58	**96**	55	**90**
Pioneer	59	**97**	53	**88**
Plane	61	**100**	51	**85**

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100 (where Good and Very Good grades were differentiated by whether 50% or 80% of data respectively, met guideline values).

*improved methods included: revised freshwater and estuary water quality scoring approach; standardization of scores into the GBR range before rolling up.

Table A 2. Nutrient indicator scores in freshwater basins for the 2015 and 2014 report cards, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card.

Basin	2015 report card (2014-15 data)						2014 report card (2013-14 data)					
	Back-calculated			Original			Back-calculated			Original		
	DIN	FRP	Nutrients	DIN	FRP	Nutrients	DIN	FRP	Nutrients	DIN	FRP	Nutrients
Don												
Proserpine												
O'Connell	90	90	**90**	100	100	**100**	56	53	**55**	93	87	**90**
Pioneer	48	59	**53**	79	97	**88**	33	59	**46**	55	97	**76**
Plane	17	37	**27**	29	61	**45**	3	28	**16**	6	47	**26**

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100 (where Good and Very Good grades were differentiated by whether 50% or 80% of data respectively, met guideline values).

*improved methods included: revised freshwater and estuary water quality scoring approach.

Table A 3. Pesticides indicator scores in freshwater basins for the 2015 and 2014 report cards, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card.

	2015 report card (2014-15 data)						2014 report card (2013-14 data)		
	Back-calculated (13 pesticides)		Back-calculated (5 pesticides)		Original		Back-calculated (5 pesticides)		Original
Basin	ms-PAF	Pesticides	ms-PAF	Pesticides	ms-PAF	Pesticides	ms-PAF	Pesticides	Pesticides
Don									
Proserpine									
O'Connell	10.1	**40**	7.9	**49**	8	**81**	3.9	**66**	**100**
Pioneer	14.5	**31**	16.9	**27**	17	**44**	24.6	**19**	**31**
Plane	37.9	**16**	30.9	**18**	31	**29**	35.9	**16**	**26**

ms-PAF (% species affected): ■ Very Poor = ≥ 20.0% | ■ Poor = >10 to 20% | ■ Moderate = >5 to 10.0% | ■ Good = >1 to 5.0%| ■ Very Good = ≤1.0%

Back-calculated pesticides: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original pesticides: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100

*improved methods included: inclusion of 13 herbicides (instead of 5 PSII herbicides) for ms-PAF calculations; standardization of scores into the GBR range before rolling up.

Table A 4. Water quality indicator category scores and water quality index in freshwater basins for the 2015 and 2014 report cards, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card.

	2015 report card (2014-15 data)								2014 report card (2013-14 data)							
	Back-calculated				Original				Back-calculated				Original			
Basin	Sediment	Nutrients	Pesticides	Water quality	Sediment	Nutrients	Pesticides	Water quality	Sediment	Nutrients	Pesticides	Water quality	Sediment	Nutrients	Pesticides	Water quality
Don																
Proserpine																
O'Connell	58	90	40	**63**	96	100	81	**92**	55	55	66	**59**	90	90	100	**93**
Pioneer	59	53	31	**48**	97	88	44	**76**	53	46	19	**40**	88	76	31	**65**
Plane	61	27	16	**35**	100	45	29	**58**	51	16	16	**28**	85	26	26	**46**

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100 (where Good and Very Good grades were differentiated by whether 50% or 80% of data respectively, met guideline values).

*improved methods included: revised freshwater and estuary water quality scoring approach; inclusion of 13 herbicides (instead of 5 PSII herbicides) for ms-PAF calculations; standardization of scores into the GBR range before rolling up.

Habitat and hydrology

Table A 5. In-stream habitat modification indicator scores in freshwater basins for the 2015 report card, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card. NB data for fish barriers was not available for the 2014 pilot report card, thus only impoundment contributed to the 2014 pilot report card score for in-stream habitat modification.

Basin	Back-calculated			Original		
	Impoundment	Fish barriers	In-stream habitat modification	Impoundment	Fish barriers	In-stream habitat modification
Don	100	60	**80**	100	99	**99**
Proserpine	43	50	**47**	71	83	**77**
O'Connell	70	60	**65**	100	99	**99**
Pioneer	22	21	**21**	36	33	**34**
Plane	60	40	**50**	99	67	**83**

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100

*improved methods included: standardization of scores into the GBR range before rolling up.

Table A 6.Habitat extent (% loss since pre-development) indicator scores in freshwater basins for the 2015 report card, back-calculated using updated scoring range compared to original scores using superseded scoring range from the 2015 report card. NB data from these indicators is repeated from the 2014 pilot report card.

Basin	Back-calculated		Original	
	Riparian Extent	Wetland Extent	Riparian Extent	Wetland Extent
Don	29.7	48.0	29.7	48.0
Proserpine	22.7	14.0	22.7	14.0
O'Connell	22.0	56.0	22.0	56.0
Pioneer	20.0	83.0	20.0	83.0
Plane	29.5	45.0	29.5	45.0

Back-calculated scoring range: ■ Very Poor = >50% | ■ Poor = >30 to 50% | ■ Moderate = >15 to 30% | ■ Good = >5 to 15% | ■ Very Good = 0 to 5%

Original scoring range: ■ Very Poor = >35% | ■ Poor = >25 to 35%| ■ Moderate = >15 to 25% | ■ Good = 5 to 15% | ■ Very Good = <5%

Table A 7. Standardised habitat extent indicator scores in freshwater basins for the 2015 report card, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card. NB data from these indicators is repeated from the 2014 pilot report card.

Basin	Back-calculated		Original	
	Riparian Extent	**Wetland Extent**	**Riparian Extent**	**Wetland Extent**
Don	41	22	51	27
Proserpine	50	62	74	100
O'Connell	51	18	77	23
Pioneer	54	7	83	9
Plane	41	25	52	28

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100

*improved methods included: updated riparian extent and wetland extent scoring ranges; standardization of scores into the GBR range before rolling up.

Table A 8. Standardised habitat and hydrology indicator category scores in freshwater basins for the 2015 report card, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card. NB riparian and wetland extent indicators were repeated between 2014 and 2015 report cards.

Basin	2015 report card (2014-15 data)										2014 report card (2013-14 data)			
	Back-calculated					Original					Back-calculated		Original	
	In-stream habitat modification	Flow	Riparian extent	Wetland extent	Habitat and hydrology	In-stream habitat modification	Flow	Riparian extent	Wetland extent	Habitat and hydrology	In-stream habitat	Habitat and hydrology	In-stream habitat	Habitat and hydrology
Don	80		41	22	48	99		51	27	**59**	100	**54**	100	**59**
Proserpine	47		50	62	53	77		74	100	**84**	43	**52**	71	**82**
O'Connell	65		51	18	45	99		77	23	**66**	70	**46**	100	**66**
Pioneer	21		54	7	27	35		83	9	**42**	22	**27**	36	**43**
Plane	50		41	25	39	83		52	28	**54**	60	**42**	99	**60**

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100

*improved methods included: updated riparian extent and wetland extent scoring ranges; standardization of scores into the GBR range before rolling up.

Fish

Table A 9. Standardised fish indicator scores in freshwater basins for the 2015 report card, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card. NB there was no fish scores reported in the 2014 pilot report card.

Basin	Back-calculated			Original		
	Native fish richness	Pest fish	Fish	Native fish richness	Pest fish	Fish
Don						
Proserpine						
O'Connell	73	58	**65**	100	95	**98**
Pioneer	53	43	**48**	88	71	**80**
Plane	71	87	**79**	100	100	**100**

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100

*improved methods included: standardization of scores into the GBR range before rolling up.

Final basin scores for 2014 and 2015

Table A 10. Final scores in freshwater basins for the 2015 and 2014 report cards, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card.

Basin	2015 report card								2014 report card							
	Back-calculated				Original				Back-calculated				Original			
	Water quality	Habitat and hydrology	Fish	Final	Water quality	Habitat and hydrology	Fish	Final	Water quality	Habitat and hydrology	Fish	Final	Water quality	Habitat and hydrology	Fish	Final
Don		48		**48**		59		**59**		54		**54**		59		**59**
Proserpine		53		**53**		84		**84**		52		**52**		82		**82**
O'Connell	62	45	65	**57**	92	66		**79**	59	46		**52**	93	66		**80**
Pioneer	48	27	48	**41**	76	42		**59**	40	27		**34**	65	43		**54**
Plane	35	39	79	**51**	58	54		**56**	28	42		**35**	46	60		**53**

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100

*all improved methods included.

Mackay-Whitsunday estuaries back-calculated scores for 2015 and 2014 report cards.

Water quality

Table A 11. Chlorophyll-*a* indicator scores in Mackay-Whitsunday estuaries for the 2015 report card, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card. NB data from these indicators is repeated from the 2014 pilot report card.

Estuary	Back-calculated	Original
Gregory	90	100
O'Connell		
St Helens/Murray	62	100
Vines	90	100
Sandy	63	100
Plane	69	100
Rocky Dam	90	100
Carmila	62	100

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100 (where Good and Very Good grades were differentiated by whether 50% or 80% of data respectively, met guideline values).

*improved methods included: revised freshwater and estuary water quality scoring approach.

Table A 12. Nutrients indicator scores in Mackay-Whitsunday estuaries for the 2015 report card, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card. NB data from these indicators is repeated from the 2014 pilot report card.

Estuary	Back-calculated			Original		
	DIN	FRP	Nutrients	DIN	FRP	Nutrients
Gregory	90	90	**90**	100	100	**100**
O'Connell	66	90	**78**	100	100	**100**
St Helens/Murray	50	75	**62**	83	100	**92**
Vines	39	90	**64**	65	100	**83**
Sandy	20	62	**41**	33	100	**67**
Plane	58	90	**74**	96	100	**98**
Rocky Dam	43	90	**66**	71	100	**85**
Carmila	59	71	**65**	97	100	**99**

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100 (where Good and Very Good grades were differentiated by whether 50% or 80% of data respectively, met guideline values).

*improved methods included: revised freshwater and estuary water quality scoring approach.

Table A 13. Phys-chem indicator scores in Mackay-Whitsunday estuaries for the 2015 report card, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card. NB data from these indicators is repeated from the 2014 pilot report card.

Estuary	Back-calculated				Original			
	DO lower	Turb	DO upper	Phys-chem	DO lower	Turb	DO upper	Phys-chem
Gregory	80	90	90	**85**	100	100	100	**100**
O'Connell	90	43	64	**53**	100	61	100	**80**
St Helens/Murray	90	73	90	**81**	100	100	100	**100**
Vines	78	90	90	**84**	100	100	100	**100**
Sandy	90		90	**90**	100	100	100	**100**
Plane	90		67	**67**	100	100	100	**100**
Rocky Dam	90		90	**90**	100	100	100	**100**
Carmila	90		65	**65**	100	100	100	**100**

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100 (where Good and Very Good grades were differentiated by whether 50% or 80% of data respectively, met guideline values).

*improved methods included: revised freshwater and estuary water quality scoring approach; updated turbidity guideline values for turbidity (original GV=9 NTU, back-calculated GV=10 NTU).

Table A 14. Pesticides indicator scores in estuaries for the 2015 report card, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card. NB data from these indicators is repeated from the 2014 pilot report card.

Estuary	Back-calculated (13 pesticides)		Back-calculated (5 pesticides)		Original	
	ms-PAF	Pesticides	ms-PAF	Pesticides	ms-PAF	Pesticides
Gregory	12.5	**36**	16.4	**28**	16.4	**45**
O'Connell*	10.1	**40**	7.9	**49**	7.9	**81**
St	5.3	**59**	9.7	**42**	9.7	**69**
Vines	1.3	**79**	1.1	**80**	1.1	**100**
Sandy	23.4	**20**	28.0	**18**	28.0	**30**
Plane	6.1	**56**	6.8	**53**	6.8	**88**
Rocky Dam	20.2	**20**	23.9	**19**	23.9	**32**
Carmila	4.9	**61**	4.8	**62**	4.8	**100**

ms-PAF (% species affected): ■ Very Poor = ≥ 20.0% | ■ Poor = >10 to 20% | ■ Moderate = >5 to 10.0% | ■ Good = >1 to 5.0%| ■ Very Good = ≤1.0%

Back-calculated pesticides: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original pesticides: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100

*improved methods included: inclusion of 13 herbicides (instead of 5 PSII herbicides) for ms-PAF calculations; standardization of scores into the GBR range before rolling up.

Table A 15. Water quality indicator category scores and water quality index in estuaries for the 2015 report card, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card. NB data from these indicators is repeated from the 2014 pilot report card.

Estuary	Back-calculated					Original				
	Phys-chem	Nutrients	Pesticides	Chl-*a*	Water quality	Phys-chem	Nutrients	Pesticides	Chl-*a*	Water quality
Gregory	85	90	36	90	**75**	100	100	45	100	**86**
O'Connell*	53	78	40		**57**	80	100	81		**87**
St Helens/Murray	81	62	59	62	**66**	100	92	69	100	**90**
Vines	84	64	79	90	**79**	100	83	100	100	**95**
Sandy	90	41	20	63	**53**	100	67	30	100	**74**
Plane	67	74	56	69	**66**	100	98	88	100	**96**
Rocky Dam	90	66	20	90	**66**	100	85	32	100	**79**
Carmila	65	65	61	62	**63**	100	99	100	100	**99**

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100

*improved methods included: revised freshwater and estuary water quality scoring approach; updated turbidity guideline values for turbidity (original GV=9 NTU, back-calculated GV=10 NTU) used in phys-chem; inclusion of 13 herbicides (instead of 5 PSII herbicides) for ms-PAF calculations; standardization of scores into the GBR range before rolling up.

Habitat and hydrology

Table A 16. Fish barriers indicator category scores in estuaries for the 2015 report card, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card. NB data from these indicators is repeated from the 2014 pilot report card.

Estuary	Back-calculated	Original
Gregory	**80**	**100**
O'Connell	**70**	**100**
St Helens/Murray	**41**	**67**
Vines	**80**	**100**
Sandy	**41**	**67**
Plane	**21**	**33**
Rocky Dam	**61**	**100**
Carmila	**100**	**100**

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100

*improved methods included: standardization of scores into the GBR range before rolling up.

Table A 17. Habitat extent (% loss since pre-development) indicator scores in estuaries for the 2015 report card, back-calculated using updated scoring range compared to original scores using superseded scoring range from the 2015 report card. NB data from these indicators is repeated from the 2014 pilot report card.

Estuary	Back-calculated		Original	
	Mangrove/saltmarsh extent	Riparian extent	Mangrove/saltmarsh extent	Riparian extent
Gregory	3.1	4.9	3.1	4.9
O'Connell	3.3	61.6	3.3	61.6
St Helens/Murray	1.0	25.5	1.0	25.5
Vines	11.9	18.1	11.9	18.1
Sandy	5.8	39.4	5.8	39.4
Plane	2.1	17.0	2.1	17.0
Rocky Dam	5.0	4.7	5.0	4.7
Carmila	3.0	0.0	3.0	0.0

Back-calculated mangrove/saltmarsh and riparian extent (% loss): ■ Very Poor = >50% | ■ Poor =>30 to 50% | ■ Moderate = >15 to 30% | ■ Good = >5 to 15% | ■ Very Good ≤5%

Original mangrove/saltmarsh extent (% loss): ■ Very Poor = >20% | ■ Poor = >10 to 20%| ■ Moderate = >5 to 10% | ■ Good = 2 to 5% | ■ Very Good = <2%

Original riparian extent (% loss): ■ Very Poor = >35% | ■ Poor = >25 to 35%| ■ Moderate = >15 to 25% | ■ Good = 5 to 15% | ■ Very Good = <5%

*improved methods included: updated mangrove/saltmarsh and riparian extent scoring ranges.

Table A 18. Standardised habitat extent indicator scores in estuaries for the 2015 report card, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card. NB data from these indicators is repeated from the 2014 pilot report card.

Estuary	Back-calculated		Original	
	Mangrove/saltmarsh extent	Riparian extent	Mangrove/saltmarsh extent	Riparian extent
Gregory	88	81	100	100
O'Connell	87	16	100	20
St Helens/Murray	96	46	100	65
Vines	67	56	60	90
Sandy	79	31	94	31
Plane	91	58	100	93
Rocky Dam	81	82	100	100
Carmila	88	100	100	100

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100

*improved methods included: updated mangrove/saltmarsh and riparian extent scoring ranges; standardization of scores into the GBR range before rolling up.

Table A 19. Standardised habitat and hydrology indicator category scores in estuaries for the 2015 report card, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card. NB data from these indicators is repeated from the 2014 pilot report card.

Estuary	Back-calculated					Original				
	Riparian extent	Mangrove/ saltmarsh extent	Flow	Fish barriers	Habitat and hydrology	Riparian extent	Mangrove/ saltmarsh extent	Flow	Fish barriers	Habitat and hydrology
Gregory	81	88		80	**83**	100	100		100	**100**
O'Connell	16	87		70	**58**	20	100		100	**100**
St Helens/Murray	46	96		41	**61**	65	100		67	**83**
Vines	56	67		80	**68**	90	60		100	**80**
Sandy	31	79		41	**50**	31	94		67	**81**
Plane	58	91		21	**57**	93	100		33	**67**
Rocky Dam	82	81		61	**74**	100	100		100	**100**
Carmila	100	88		100	**96**	100	100		100	**100**

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100

*improved methods included: updated mangrove/saltmarsh and riparian extent scoring ranges; standardization of scores into the GBR range before rolling up.

Final estuary scores for 2014 and 2015

Table A 20. Table A4. Water quality and habitat and hydrology index scores and rolled up final scores in Mackay-Whitsunday estuaries in 2015 compared to revised water quality and habitat and hydrology index scores and rolled up final scores.

Estuary	Back-calculated				Original			
	Water quality	Habitat & hydrology	Fish	Final	Water Quality	Habitat & Hydrology	Fish	Final
Gregory	75	83		**79**	86	100		**93**
O'Connell	57	58		**57**	87	100		**94**
St Helens/Murray	66	61		**63**	90	83		**87**
Vines	79	68		**73**	95	80		**88**
Sandy	53	50		**52**	74	81		**77**
Plane	66	57		**61**	96	67		**81**
Rocky Dam	66	74		**70**	79	100		**90**
Carmila	63	96		**79**	99	100		**99**

Back-calculated scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Original scoring range: ■ Very Poor = 0 to 33.3 | ■ Poor = 33.4 to 66. 7 | ■ Moderate = 66.7 to <100 | ■ Good = assigned 100 | ■ Very Good = assigned 100

*improved methods included: updated mangrove/saltmarsh and riparian extent scoring ranges; standardization of scores into the GBR range before rolling up.

Mackay-Whitsunday marine back-calculated scores for 2015 and 2014 report cards.

Marine water quality

Table A 21. Comparison of water quality indicator scores in inshore marine zones for the 2015 and 2014 report cards, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card.

Inshore zone	2015 report card (2014-15 data)													
	Back-calculated							Original						
	Nutrients				Water clarity			Nutrients				Water clarity		
	PN	PP	NOx	Chl-a	TSS	Turbidity	Secchi	PN	PP	NOx	Chl-a	TSS	Turbidity	Secchi
Northern sites														
Daydream	-0.59	0.04	-0.64	-0.59	0.04	-0.64	-0.59	0.26	0.04	0.95	0.06	0.51		-0.46
Double Cone	-0.72	-0.33	-0.83	-0.72	-0.33	-0.83	-0.72	-0.11	-0.10	0.76	0.64	1.00		-0.46
Pine Island	-1.00	0.04	-1.00	-1.00	0.04	-1.00	-1.00	0.26	-0.70	0.56	-0.06	0.91		-0.68
Seaforth	-0.07	0.31	-1.00	-0.07	0.31	-1.00	-0.07	0.53	0.55	-0.05	-0.15	0.63		-1.00
Repulse Islands dive mooring	-1.00	-0.60	-1.00	-1.00	-0.60	-1.00	-1.00	-0.38	-0.77	0.53	-1.00	-1.00		-1.00
AMB1	-0.81	-0.25		-0.99	-1.00		-1.00	-0.25	-0.81	-1.00	-0.99	-1.00		-1.00
AMB2	0.23	-0.10		-0.25	-0.26		0.17	-0.10	0.23	-1.00	-0.05	-0.26		0.42
AMB3	0.05	0.49		0.19	-0.37		-0.11	1.00	0.95	-0.42	1.00	-0.45		-0.56
AMB4								-0.10	-0.50	-0.29	0.27	-0.28		0.00
AMB5	-0.06	1.00	-0.06		-0.10	0.03		1.00	0.21	-0.64	0.12	0.23		-0.54
AMB6	-0.47	1.00	-0.47		-0.28	-0.63		1.00	-0.47	-0.42	-0.09	-0.63		0.52
AMB7								0.26	-0.71	-1.00	-0.76	-0.14		0.68
AMB8	1.00	1.00		1.00	0.38			1.00	1.00	-1.00	1.00	0.38		-0.62
AMB9								1.00	0.35	-0.15	0.79	0.13		-1.00
AMB10	-0.62	0.75		-1.00	-0.32		-1.00	0.75	-0.62	-0.42	-1.00	-0.32		-1.00
AMB11			0.86	0.66				0.26	-0.93	-1.00	-1.00	-0.68		-0.69
AMB12	0.58	1.00		0.31	0.25			0.75	0.02	-0.15	0.31	-1.00		-1.00

Inshore zone	2014 report card (2013-14 data)													
	Back-calculated							Original						
	Nutrients				Water clarity			Nutrients				Water clarity		
	PN	PP	NOx	Chl-a	TSS	Turbidity	Secchi	PN	PP	NOx	Chl-a	TSS	Turbidity	Secchi
Northern sites			-0.96	-0.95	0.78	-1.00				-0.96	-0.95	0.78	-1.00	
Daydream	-0.63	-0.63	-0.77	-1.00	-1.00	-1.00	-1.00	-0.31	-0.77	-1.00	-0.56	-1.00		-1.00
Double Cone	-1.00	-1.00	-0.89	-1.00	-0.46	-0.46	-1.00	-0.47	-0.66	-0.08	-0.71	-0.16		-1.00
Pine Island	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-0.43	-0.71	-1.00	-0.57	-1.00		-1.00
Seaforth														
Repulse Islands dive mooring														
AMB1														
AMB2														
AMB3														
AMB4														
AMB5														
AMB6														
AMB7														
AMB8														
AMB9														
AMB10														
AMB11														
AMB12														

Scoring range: ■ Very Poor = <-0.66 to -1 | ■ Poor = <-0.33 to -0.66 | ■ Moderate = <0 to -0.33 | ■ Good = 0 to 0.5 | ■ Very Good = >0.5 to 1

*Back-calculated scores using: 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[19] (instead of GBRMPA 2010 guidelines); including turbidity data; excluding discontinued sites (AMB4, AMB7, AMB9).

[19] https://www.legislation.qld.gov.au/LEGISLTN/SLS/2013/13SL158.pdf

Table A 22. Comparison of water quality indicator category scores in marine zones for the 2015 and 2014 report cards, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card.

Marine zone	2015 report card (2014-15 data)										2014 report card (2013-14 data)									
	Back-calculated					Original					Back-calculated					Original				
	Nutrients	Chl-*a*	Water clarity	Pesticides	Final WQ	Nutrients	Chl-*a*	Water clarity	Pesticides	Final WQ	Nutrients	Chl-*a*	Water clarity	Pesticides	Final WQ	Nutrients	Chl-*a*	Water clarity	Pesticides	Final WQ
Northern											2	3	54	100	**40**	3	3	55	100	**40**
Whitsunday	31	49	47		**42**	71	66	63	93	**73**	7	0	7		**4**	25	24	9	91	**37**
Central	67	52	32	68	**55**	57	55	36	68	**54**				68					69	
Southern																				
Offshore																				

*Back-calculated scores using: 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[20] (instead of GBRMPA 2010 guidelines); including turbidity data; excluding discontinued sites (AMB4, AMB7, AMB9); excluding pesticides in Whitsunday zone.

[20] https://www.legislation.qld.gov.au/LEGISLTN/SLS/2013/13SL158.pdf

Offshore marine coral

Table A 23. Coral indicator scores for the offshore marine zone (Long Term Monitoring Program monitoring program) comparing indicator scores from 2014 and 2015 back-calculated to account for updated analysis approach.

Year	Cover	Macroalgae	Juvenile	Change	Coral index
New methods					
2015	34		87	38	**53**
2014	32		68	33	**44**
Old methods (2014 & 2015)					
2015	28	31	88		**49**
2014	25	22	69		**39**

Scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 – 100

Final marine scores for 2014 and 2015

Table A 24. Comparison of final scores for marine zones for the 2015 and 2014 report cards, back-calculated using improved methods* compared to original scores using superseded methods from the 2015 report card.

Marine zone	2015 report card (2014-15 data)										2014 report card (2013-14 data)									
	Back-calculated					Original					Back-calculated					Original				
	Water quality	Coral index	Seagrass	Fish	Final	Water quality	Coral index	Seagrass	Fish	Final	Water quality	Coral index	Seagrass	Fish	Final	Water quality	Coral index	Seagrass	Fish	Final
Northern			21		**21**			21		**21**	40				**40**	40				**40**
Whitsunday	42	58	16		**39**	73	58	16		**49**	4	55	24		**28**	37	56	24		**39**
Central	55		49		**52**	54		49		**51**			25		**25**			26		**26**
Southern																				
Offshore	94	53			**73**	94	49			**71**	94	44			**69**	94	39			**67**

Scoring range: Very Poor = 0 to <21 | Poor = 21 to <41 | Moderate = 41 to <61 | Good = 61 to <81 | Very Good = 81 – 100

*Back-calculated scores using: all changes to water quality methods and changes to offshore coral.

Confidence scoring

Based on revised weightings for representativeness and associated adjusted weightings for the other confidence criteria, the rankings for indicators presented in the 2015 Mackay-Whitsunday report card have been calculated and compared to the original rankings. Rankings have been colour coded for easy comparison in the appendix, otherwise confidence scores are not colour coded for presentation in the report card or technical reports.

Table A 25. Final confidence rankings and final confidence scoring range based on original 20th percentiles and revised and 20th percentiles. Colour coded for ease of comparison.

Ranking	Original final scoring range	Revised final scoring range
One	≤6	4.5 to 6.3
Two	6.5 to 8	>6.3 to 8.1
Three	8.5 to 9.5	>8.1 to 9.9
Four	10 to 11.5	>9.9 to 11.7
Five	≥12	>11.7 to 13.5

Table A 26. Impact of revised confidence weightings on rankings for freshwater basin indicators in the 2015 Mackay-Whitsunday report card compared to original rankings. The confidence of the result associated with the Don basin is in parenthesis when it is different from the other four basins. Otherwise, confidence in results is the same across all basins.

Indicator	Maturity of methodology	Validation	Represent-ativeness	Directness	Measured error	Final original score*	Original rank	Final revised score^	Revised rank
Sediment	3	3	1	3	1	9.5	3	8.1	2
Nutrients	3	3	1	3	1	9.5	3	8.1	2
Pesticides	1	2	1	2	1	6.5	2	5.9	1
Impoundment	2	2	3	2	1	9	3	10.3	4
Fish barriers	1	2 (1)	3 (1)	2	2(1)	9.5 (5.5)	3 (1)	10.6 (5.2)	4 (1)
Riparian	2	2	2	2	2	9	3	9	3
Wetland	2	2	2	2	2	9	3	9	3
Fish	2	2	2	2	2	9	3	9	3

*Original confidence weightings: maturity of methodology (0.5); all other criteria (1).
^Revised confidence weightings: maturity of methodology (0.36); representativeness (2); all other criteria (0.71).

Table A 27. Impact of revised confidence weightings on rankings for estuary indicators in the 2015 Mackay-Whitsunday report card compared to original rankings. The confidence of the result associated with the O'Connell estuary is in parenthesis when it is different from the other eight estuaries. Otherwise, confidence in results is the same across all eight estuaries.

Indicator	Maturity of methodology	Validation	Represent-ativeness	Directness	Measured error	Final original*	Rank original	Final revised score^	Revised rank
Phys-chem	3	3	2 (1)	3	1	10.5 (9.5)	4 (3)	10.1 (8.1)	4 (2)
Nutrients	3	3	2 (1)	3	1	10.5 (9.5)	4 (3)	10.1 (8.1)	4 (2)
Chl-a	3	3	2 (1)	3	1	10.5 (9.5)	4 (3)	10.1 (8.1)	4 (2)
Pesticides	1	2	1	2	1	6.5	2	5.9	1
Fish barriers	1	2	3	2	1	8.5	3	9.9	4
Mangrove/saltmarsh	2	2	2	1	2	8	2	8.3	3
Riparian	2	2	2	1	2	8	2	8.3	3

*Original confidence weightings: maturity of methodology (0.5); all other criteria (1).

^Revised confidence weightings: maturity of methodology (0.36); representativeness (2); all other criteria (0.71).

Table A 28. Impact of revised confidence weightings on rankings for marine indicators in the 2015 Mackay-Whitsunday report card compared to original rankings. The confidence of the result associated with the Central inshore zone is in parenthesis when it is different from the Whitsunday inshore zone. Otherwise, confidence in results is the same across marine zones.

Indicators	Maturity of methodology	Validation	Represent-ativeness	Directness	Measured error	Final original score*	Original rank	Final revised score^	Revised rank
Nutrients inshore	1 (3)	3	1 (2)	3	2 (3)	9.5 (12.5)	3 (5)	8.1 (11.5)	2 (4)
Water clarity inshore	1 (3)	3	1 (2)	3	2 (3)	9.5 (12.5)	3 (5)	8.1 (11.5)	2 (4)
Chl-*a* inshore	1 (3)	3	1 (2)	3	2 (3)	9.5 (12.5)	3 (5)	8.1 (11.5)	2 (4)
Pesticides	2	2	1	2	1	7	2	6.3	1
TSS offshore	2	1	2	1	1	6	1	6.9	2
Chl-*a* offshore	1	1	2	1	1	5.5	1	6.5	2
coral cover inshore	3	3	2	3	2	11.5	4	10.8	4
coral change inshore	3	3	2	3	2	11.5	4	10.8	4
juvenile coral inshore	3	3	2	3	2	11.5	4	10.8	4
coral macroalgae inshore	3	3	2	3	2	11.5	4	10.8	4
coral composition inshore	3	3	2	3	2	11.5	4	10.8	4
coral cover offshore	3	3	1	3	3	11.5	4	9.5	3
coral change offshore	3	3	1	2	2	9.5	3	8.1	2
coral macroalgae offshore	3	3	1	3	3	11.5	4	9.5	3
juvenile coral offshore	3	2	1	3	2	9.5	3	8.1	2
seagrass abundance	3	3	2	3	2	11.5	4	10.8	4
seagrass reproductive effort	3	3	2	3	2	11.5	4	10.8	4
seagrass nutrient status	3	3	2	3	2	11.5	4	10.8	4
seagrass biomass	3	3	2	3	2	10.5	4	8.8	3
seagrass area	3	3	2	3	2	10.5	4	8.8	3
seagrass species composition	2	3	1	3	2	10	4	8.4	3

*Original confidence weightings: maturity of methodology (0.5); all other criteria (1).

^Revised confidence weightings: maturity of methodology (0.36); representativeness (2); all other criteria (0.71).

Table A 29. Impact of revised confidence weightings on rankings for stewardship in the 2015 Mackay-Whitsunday report card compared to original rankings.

Industry	Maturity of methodology	Validation	Represent-ativeness	Directness	Measured error	Final original score*	Original rank	Final revised score^	Revised rank
Agricultural	1	2	2	2	1	7.5	2	7.9	2
Non-agricultural	1	2	3	1	1	7.5	2	9.2	3

*Original confidence weightings: maturity of methodology (0.5); all other criteria (1).

^Revised confidence weightings: maturity of methodology (0.36); representativeness (2); all other criteria (0.71).

Table A 30. Impact of revised confidence weightings on rankings for indigenous cultural heritage indicators in the 2015 Mackay-Whitsunday report card compared to original rankings.

Indicators	Maturity of methodology	Validation	Represent-ativeness	Directness	Measured error	Final original score*	Original rank	Final revised score^	Revised rank
Spiritual/social values	2	2	3 (1)	2	1	9 (7)	3 (2)	10.3 (6.3)	4 (1)
Scientific value of sites	2	2	3 (1)	2	1	9 (7)	3 (2)	10.3 (6.3)	4 (1)
Physical condition of sites	2	2	3 (1)	2	1	9 (7)	3 (2)	10.3 (6.3)	4 (1)
Protection of sites and zones	2	2	3 (1)	2	1	9 (7)	3 (2)	10.3 (6.3)	4 (1)
Land use within zones	2	2	3 (1)	2	1	9 (7)	3 (2)	10.3 (6.3)	4 (1)
Cultural maintenance of sites and zones	2	2	3 (1)	2	1	9 (7)	3 (2)	10.3 (6.3)	4 (1)

*Original confidence weightings: maturity of methodology (0.5); all other criteria (1).

^Revised confidence weightings: maturity of methodology (0.36); representativeness (2); all other criteria (0.71).