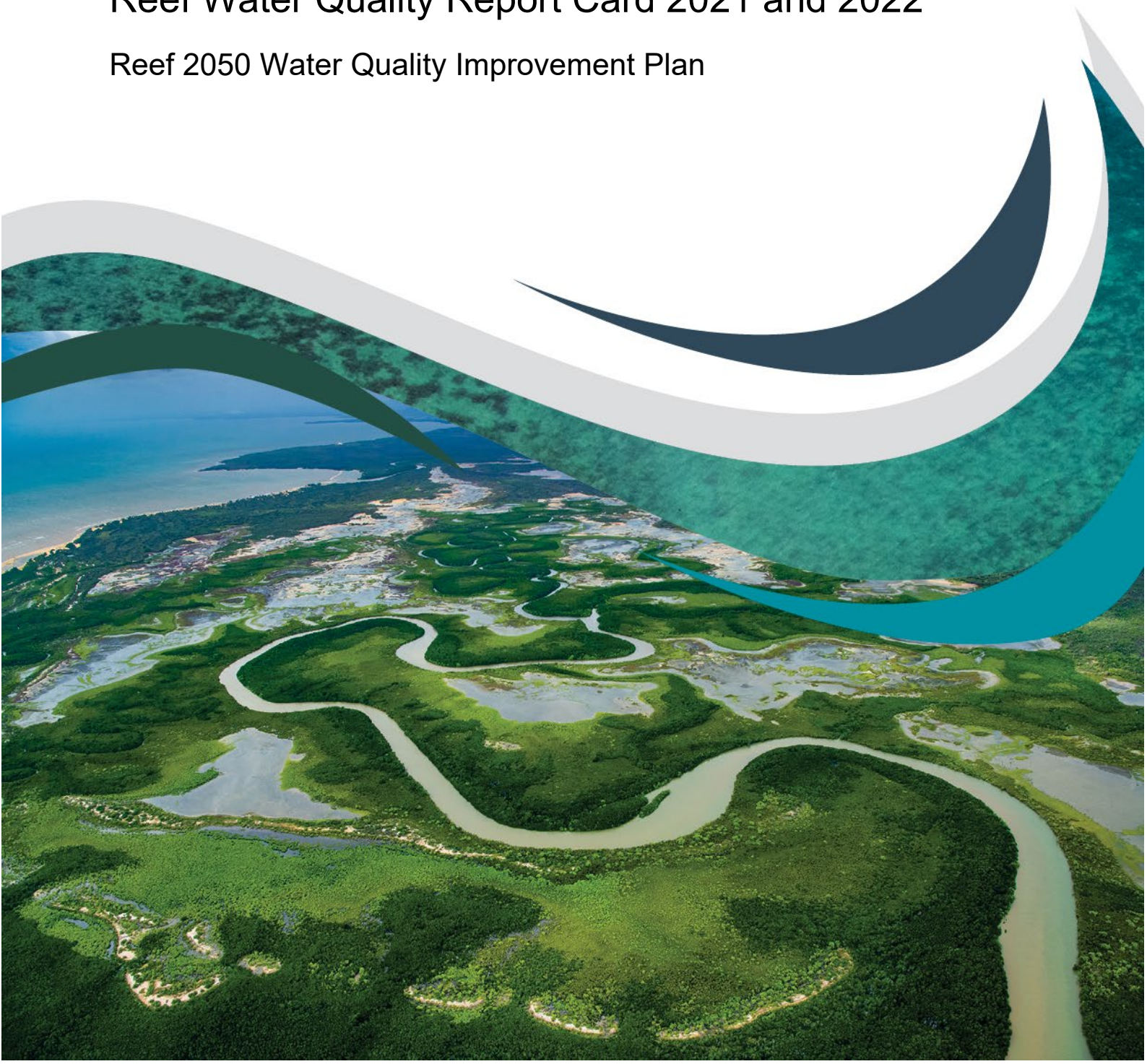
Australian Government

Queensland Government

Great Barrier Reef Marine Monitoring Program Methods

Reef Water Quality Report Card 2021 and 2022

Reef 2050 Water Quality Improvement Plan



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Marine monitoring methods

This report summarises the coral and seagrass data and methods used for monitoring and reporting within the Great Barrier Reef Marine Monitoring Program (MMP) managed by the Great Barrier Reef Marine Park Authority and reported in the Reef Water Quality Report Card 2021 and 2022. Detailed methods are available in the Marine Monitoring Program annual technical report series that undergo independent peer review before being published in the Great Barrier Reef Marine Park Authority's eLibrary.

The Marine Monitoring Program was established in 2005 and assesses trends in ecosystem health and resilience indicators for the inshore Great Barrier Reef in relation to water quality and its linkages to end-of-catchment pollutant loads. The inshore Marine Monitoring Program has three sub-components:

Water quality (Moran *et al.* 2023);

Seagrass condition (McKenzie et al. 2023); and

Coral reef condition (Thompson *et al.* 2023).

The Marine Monitoring Program is one line of evidence describing the condition and trend of key coral reef and seagrass meadows used to report progress towards the Reef 2050 Water Quality Improvement Plan (Reef 2050 WQIP) (Australia and Queensland governments 2018) 2025 water quality outcome:

Good water quality sustains the outstanding universal value of the Great Barrier Reef, builds resilience, improves ecosystem health and benefits communities.

The Marine Monitoring Program objectives are:

Assess temporal and spatial trends in inshore marine water quality and link pollutant concentrations to end-of-catchment loads.

Monitor, assess and report the condition and trend of inshore coral reefs in relation to the extent, frequency and intensity of acute and chronic impacts.

Monitor, assess and report the condition and trend of inshore seagrass meadows in relation to the extent, frequency and intensity of acute and chronic impacts.

Since the 2015-2016 water year, the Reef Water Quality Report Card marine result has been based on averaging the scores for water quality from the eReefs model output (Robillot et al. 2018) with scores for coral and seagrass condition from the Marine Monitoring Program.

The inshore water quality component of the Marine Monitoring Program provides data on physico-chemical water quality parameters including nutrients and sediment concentrations in four Natural Resource Management (NRM) regions, and wet season flood plume exposure and risk to marine communities. Details are not provided in this report and can be found in the annual technical report for inshore water quality (Moran *et al.* 2023).

Seagrass condition

Approximately 77% of the Reef seagrass meadows occur in the inshore water body (Moran et al 2023). Seagrasses are fundamental to fisheries productivity and the main food source of dugongs and turtles. Monitoring was conducted at 75 sites across 35 locations during the 2021-22 monitoring period, (McKenzie et al. 2023) (see Figure 1). Five major seagrass habitat types (estuarine, coastal intertidal, coastal subtidal, reef intertidal and reef subtidal) are assessed where possible

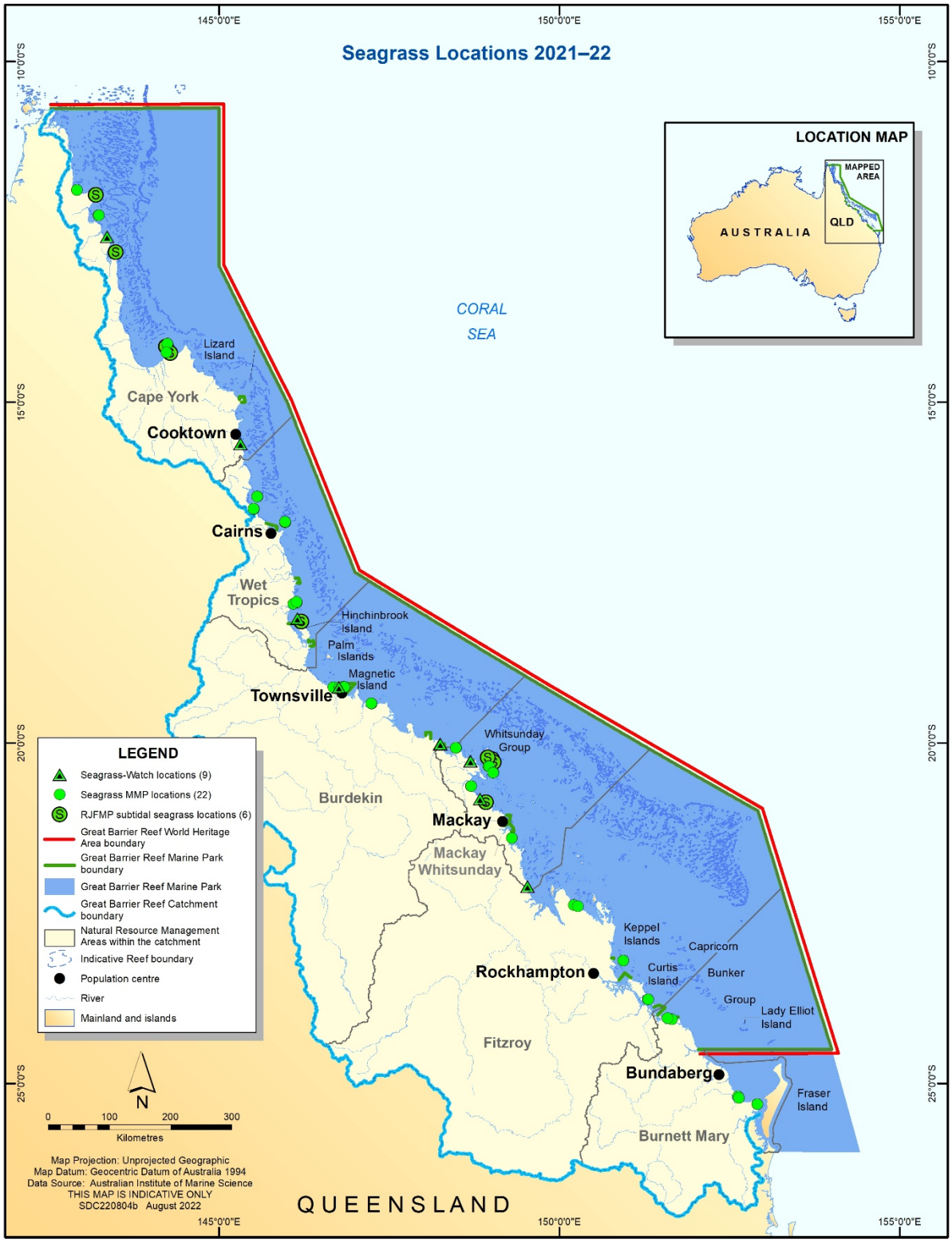

Figure 1. Marine Monitoring Program seagrass survey locations

(including Reef Joint Field Management Team and Seagrass-Watch). *Not all sites are surveyed every year.* Source: (McKenzie et al. 2023).

Sampling was undertaken at fifteen coastal, four estuarine and twelve reef locations (i.e. two or three sites at each location). Reef intertidal sites in the Burdekin and Wet Tropics were paired with a subtidal site. At each location, with the exception of subtidal sites, sampling included two sites nested within 500m of each other. Subtidal sites were not always replicated within locations. Intertidal sites were defined as a 5.5ha area within a relatively homogenous section of a representative seagrass community/meadow. Monitoring occurred in the late dry season (September-November 2021) and late wet season (March-May 2022).

Two indicators were assessed:

- Seagrass abundance (per cent cover) is an assessment of the average per cent cover of seagrass at a monitoring site in relation to the Seagrass Abundance Guidelines (McKenzie 2009)
- The resilience indicator takes a subset of measurable characteristics for which long-term data is available to develop a score and includes seagrass meadow species composition, relative abundance and reproductive status, and was backdated to 2005. The resilience score was determined using a multi-faceted resilience metric informed by existing metrics, historical data, and a conceptual understanding of resilience. Resilience can be considered as having two main elements (e.g. Timpane-Padgham et al. 2017; Connolly et al. 2018): an ability to resist disturbance; and the capacity to recover from disturbances. A decision tree approach was developed, which includes thresholds defining the splits, and methods for calculating scores. The methods used to arrive at each step are outlined in detail in Collier et al. (2021), and describe the following two components working both individually and in collaboration to provide the best estimate of resilience:
    - a ‘resistance’ component that assesses the seagrass meadow capacity to cope with disturbance based on their seagrass abundance and species composition. A low resistance site is one that has very low abundance based on the history of that site and/or has a high proportion of colonising species. These meadows are considered to be highly vulnerable to disturbances and, therefore, to have very low resilience.
    - a ‘reproduction' component that is based around likelihood of producing seed banks given the presence and count of reproductive structures. These are scored based on the levels of expected reproductive effort given the life history strategy of the species present. For example, some ‘persistent’ species such as *Thalassia* are not expected to have a high number of reproductive structures, and nor does it depend on them quite as much for long-term survival compared to ‘colonising’ species.

Additional indicators of seagrass condition and resilience include species composition, relative meadow extent and density of seeds in the seed bank (McKenzie *et al.* 2023).

Environmental pressures are also recorded including within-canopy water temperature, within-canopy benthic light, sediment composition as well as macroalgae and epiphyte abundance.

- Within-canopy benthic light is compared to long-term recorded light levels at individual sites as well as daily light thresholds likely to support long-term growth requirements of the species in these habitats (Collier *et al.* 2016)
- Within-canopy temperature is considered in context of the number of days above 35°C. Growth reduction can occur in some species from prolonged warm water exposure (Collier *et al.* 2011; Collier *et al.* 2016). The critical canopy temperature threshold for photoinhibition and acute temperature stress for seagrass is 40°C (Campbell *et al.* 2006)
- Changes in sediment composition can be an indicator of broader environmental changes (such as sediment and organic matter loads and risk of anoxia) and an early-warning indicator of changing species composition.

Additional data on climate and water quality is obtained from the Bureau of Meteorology and from the Marine Monitoring Program inshore water quality component (Moran *et al.* 2023).

Coral reef condition

Coral reefs comprise 7% of total area of the Great Barrier Reef Marine Park, 3.6% of coral reefs are in the inshore water body.

Monitoring of inshore coral reef communities occurs routinely in the dry season at reefs adjacent to four regions: Wet Tropics, Burdekin, Mackay Whitsunday and Fitzroy (see Figure 2). No reefs are included in Cape York due to logistic and occupational health and safety issues relating to diving in coastal waters in this region.

Thirty reefs are monitored biennially at two depths under the program, with an additional six inshore reefs monitored at single depths under the Australian Institute of Marine Science – Long Term Monitoring Program. All are included in the annual assessment of coral condition, although not all reefs are sampled every year (Thompson *et al.* 2023).

Figure 2: Marine Monitoring Program coral survey locations. Reefs were scheduled to be monitored biennially. Purple dots indicate locations monitored as part of the Long Term Monitoring Program conducted by the Australian Institute of Marine Science. Source: (Thompson *et al.* 2023).

Two sites at each reef are permanently marked with fence posts at the beginning of five, 20m-long transects with smaller steel rods at the midpoint and end of each transect. Monitoring is conducted by divers along these transects. They assess community attributes including hard and soft coral cover, the number of hard coral juvenile colonies (up to 5cm in diameter), proportion (per cent) of macroalgae cover, rate of change in coral cover (as an indication of the recovery potential of the reef following a disturbance) and coral community composition (Thompson *et al.* 2023).

Assessing status against the objectives

Improved seagrass condition

Seagrass indicators were changed for reporting in 2021, with tissue nutrient status being removed, abundance remaining and reproductive effort being calculated as part of a new resilience decision-making tree and relevant resilience indicator, backdated to 2005. This change was driven by scientific concern about the Great Barrier Reef's seagrass meadow resilience, and the lack of specific relevance of the tissue nutrient status indicator with the need to develop a more representative metric for management purposes.

Resilience can be described as the capacity of an ecosystem to cope with disturbance (Connolly *et al.* 2018), and to adapt to change without switching to an alternative state (Holling 1973; Unsworth *et al.* 2015). For monitoring and reporting, *'a set of measurable biological characteristics that exemplify seagrass meadows' resistance to pressures and essential mechanisms for recover'* are required to assess resilience (Udy *et al.* 2018).

Hence, two indicators are used to assess and report inshore seagrass condition: abundance, and resilience. Further detail about the selection and scoring of these indicators is available in the annual technical report (McKenzie *et al.* 2023).

The overall grade is the average of the scores of the two indicators for the monitoring year (colour-graded coaster) for the inshore Reef and regions. To calculate the overall score for seagrass, the regional scores were weighted by the relative proportion of World Heritage Area seagrass (shallower than 15m) within that region (see Table 1).

*Table 1: Area of seagrass shallower than 15m in each region within the boundaries of the Great Barrier Reef World Heritage Area**

Region	Area of seagrass (km^2)	Weighting factor (per cent)
Cape York	2,078	60
Wet Tropics	207	6
Burdekin	587	17
Mackay Whitsunday	215	6
Fitzroy	257	7
Burnett Mary	120	3
World Heritage Area	3,464	100

* Derived from (McKenzie, Yoshida, Grech *et al.* 2014; McKenzie, Yoshida, and Unsworth 2014; Carter *et al.* 2016; Waterhouse *et al.* 2016).

The online Report Card also shows a graph of the abundance indicator over time (dark blue circles) for the inshore Reef and regions.

Improved coral condition

Five indicators are used to assess and report on inshore coral reef condition: coral cover, coral cover change, juvenile coral density, coral community composition and proportional macroalgae cover.

Further detail about the selection and scoring of these indicators is available in the annual technical report (Thompson *et al.* 2023).

The overall grade is the average of the scores of the five indicators for the monitoring year (colour-graded coaster) for the inshore Reef and regions. To calculate the overall score for coral, the regional scores were weighted by the relative proportion of the total inshore Reef area in the Great Barrier Reef Marine Park that is represented by each of the four monitored regions (see Table 2).

*Table 2: Area of inshore reef in each region within the Marine Park**

Region	Area of inshore reef (km^2)	Weighting factor (per cent)
Cape York	265	
Wet Tropics	64	20.9
Burdekin	28	9.2
Mackay Whitsunday	117	38.1
Fitzroy	98	31.8
Burnett Mary	5	
Marine Park	577	100

* Area statistics supplied by the Authority's Spatial Data Centre, 2011

The online Report Card also shows a graph of the coral cover indicator over time (light blue circles) for the inshore Reef and regions.

Synthesis and integration of data and information

The Reef Water Quality Report Card 2021 and 2022 provides scores for the condition of inshore water quality, seagrass and coral at Great Barrier Reef-wide and regional scales.

Reef-wide and regional marine scores are unweighted averages of these three indicator scores.

The Marine Monitoring Program provides the coral and seagrass scores, based on annual technical reports published in the Great Barrier Reef Marine Park Authority's eLibrary.

The eReefs Marine Modelling Program provides the water quality metric for the inshore Reef score based on open coastal waters (Robillot *et al.* 2018).

Semiquantitative confidence rankings

A multi-criteria analysis was used to score the confidence in each indicator used in the report card from low to high. The approach combined expert opinion and direct measures of error for program components where available. Seagrass and coral both received a four-dot confidence ranking (see Figure 3).

Figure 3: Semiquantitative confidence rankings for seagrass and coral scores. Source: Refer to Appendix A.

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Appendix A: Derivation of confidence ranking

A multi-criteria analysis approach was endorsed by the Independent Science Panel in July 2016 and used to score the confidence for each key indicator used in the report card. The approach enables the use of expert opinion and measured data.

A multi-criteria analysis identifies the key components that contribute to a problem. These are known as criteria. Each criterion is then scored using a defined set of scoring attributes. 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 determination of confidence for the report card used five criteria:

Maturity of methodology (the score is weighted half for these criteria so not to outweigh the importance of the other criteria)

Validation

Representativeness

Directness

Measured error

Seagrass

Maturity of methodology (weighting 0.5)	Validation	Representativeness	Directness	Measured error
New or experimental methodology	Survey with no ground truthing	Less than 10% of population survey data	Measurement of data that have conceptual relationship to reported indicator	Error not measured or >25% error
Peer reviewed method	Survey with ground-truthing (not comprehensive)	**10%-30% of population survey data**	Measurement of data that have a quantifiable relationship to reported indicators	**10-25% error**
Established methodology in published paper	**Survey with extensive on ground validation or directly measured data**	30-50% of population	**Direct measurement of reported indicator with error**	Less than 10% error
3 x0.5 = 1.5	3	2	3	2

Bolded and grey shading in cells indicates assessment ranking. Total score = 11.5, equates to **Four dots**.

Coral

Maturity of methodology (weighting 0.5)	Validation	Representativeness	Directness	Measured error
New or experimental methodology	Survey with no ground truthing	Less than 10% of population survey data	Measurement of data that have conceptual relationship to reported indicator	Error not measured or >25% error
Peer reviewed method	Survey with ground-truthing (not comprehensive)	**10%-30% of population survey data**	Measurement of data that have a quantifiable relationship to reported indicators	**10-25% error**
Established methodology in published paper	**Survey with extensive on ground validation or directly measured data**	30-50% of population	**Direct measurement of reported indicator with error**	Less than 10% error
3 x0.5 = 1.5	3	2	3	2

Bolded and grey shading in cells indicates assessment ranking. Total score = 11.5, equates to **Four dots**.

Glossary

Ecosystem: dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit.

Ecosystem health: ecological processes, biodiversity and function of biological communities is maintained.

eReefs: coupled hydrodynamic and biogeochemical models of water quality and ecosystem condition for the Marine Park <https://research.csiro.au/ereefs/models/>.

Guideline value: a measurable quantity (e.g. concentration) or condition of an indicator for a specific community value below which (or above which, in the case of stressors) there is considered to be a low risk of unacceptable effects occurring to that community value.

Inshore: the enclosed coastal and open coastal water bodies combined. These terms are defined and mapped under schedules in the Environmental Protection (Water) Policy.

Marine Park: Great Barrier Reef Marine Park.

Pollutant: a substance that is present in concentrations that may harm organisms or exceed an environmental quality standard. In this program, the term refers primarily to nutrients, sediment and pesticides.

Reef 2050 WQIP: Reef 2050 Water Quality Improvement Plan.

Reef 2050 Plan: Reef 2050 Long-Term Sustainability Plan.