



Australian Government



Queensland Government

Marine Monitoring

Methods

Reef Water Quality Report Card 2017 and 2018

Reef 2050 Water Quality Improvement Plan



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MARINE MONITORING PROGRAM

This report summarises the data and methods used for monitoring and reporting within the Marine Condition – Marine Monitoring Program reported in the Reef Water Quality Report Card 2017 and 2018 (Figure 1 - elements other than eReefs marine modelling).

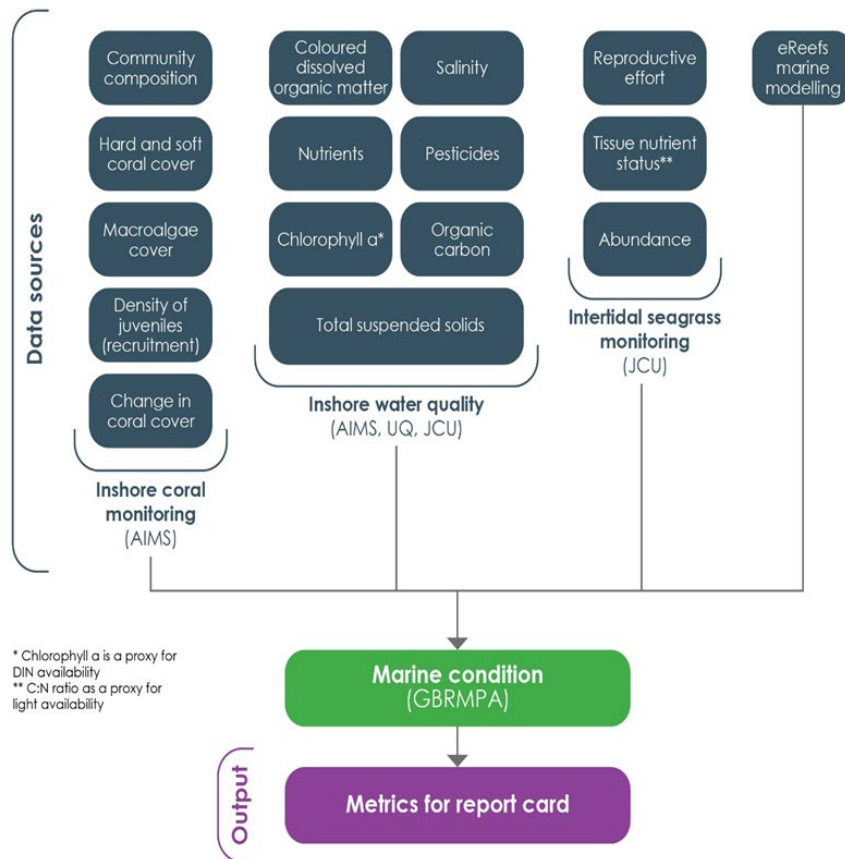


Figure 1. Main data sources, inputs and outputs for the Marine Monitoring Program, which include inshore coral, inshore water quality and inshore seagrass monitoring. The Marine Modelling Program provides the water quality metric based on eReefs model output.

The Marine monitoring program is one line of evidence used to report on progress towards the Reef 2050 Water Quality Improvement Plan (Reef 2050 WQIP) (Australian and Queensland governments, 2018) (formerly Reef Water Quality Protection Plan 2013), 2025 water quality outcome and objectives for marine condition. This Tier 2 report is underpinned by detailed annual technical reports (referred to as Tier 3 reports) that undergo independent peer review before being published on the Great Barrier Reef Marine Park Authority's eLibrary website.

The Marine modelling program (the [eReefs](#) marine modelling referenced in Figure 1) provides the water quality scores which are combined with coral and seagrass scores to inform the marine condition and metrics for the Reef Water Quality Report Card 2017 and 2018 (Tier 1).

The outcome and objectives from the Reef 2050 WQIP are:

Outcome

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

Objectives

- Improved coral condition
- Improved seagrass condition

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 delivery. A summary of the indicators and methods used to derive Reef Water Quality Report Card 2017 and 2018 scores are outlined below.

Detailed methods are available in the annual technical reports published on The Great Barrier Reef Marine Park Authority's website <www.gbrmpa.gov.au/our-work/our-programs-and-projects/reef-2050-marine-monitoring-program>.

The inshore Marine monitoring program has three sub-components:

- water quality (Waterhouse et al. 2018, Gruber et al. 2019), including pesticides (Grant et al. 2018, Gallen et al. 2019)
- seagrass condition (McKenzie et al. 2018, McKenzie et al. 2019)
- coral reef condition (Thompson et al. 2018, Thompson et al. 2019).

Since the 2015-2016 water year, the Reef Water Quality Report Card 2017 and 2018 (Tier 1) has been based on averaging the scores for water quality from the eReefs models (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 (Figure 1) provides data on exposure and risk to marine communities from the analysis of flood plumes and pesticide concentrations as well as *in situ* measurements to detect long-term trends at specific locations and in three natural resource management regions.

Inshore water quality, including pesticides

The objectives for the inshore water quality sub-component are listed below (State of Queensland 2018).

1. Monitor, assess and report the three-dimensional extent and duration of flood plumes and link concentrations of suspended sediment and nutrients to end-of-catchment loads, and end-of-catchment pesticide concentrations to marine concentrations.
2. Monitor, assess and report trends in inshore concentrations of sediment, chlorophyll *a*, nutrients and pesticides against the water quality guidelines (Great Barrier Reef Marine Park Authority 2018) and water quality guidelines (Australian and New Zealand governments 2018) for the Great Barrier Reef Marine Park.
3. Monitor, assess and report trends in turbidity and light attenuation for key Great Barrier Reef inshore habitats against established thresholds.

In situ water quality monitoring

Monitoring of year-round in situ water quality parameters in 2016-2017 and 2017-2018 includes the measurement of concentrations of organic carbon, inorganic and organic nutrients (nitrogen and phosphorus), silica, coloured dissolved organic matter, chlorophyll *a*, total suspended solids, turbidity, Secchi depth, salinity and 30 pesticides.

Water quality monitoring is conducted in four of the regions (Figure 2):

- Cape York (four transects added in 2016-2017: off the Pascoe, Normanby-Kennedy, Annan-Endeavour and Stewart Rivers)
- Wet Tropics:
 - Mossman basin
 - Mulgrave-Russell basin
 - Barron-Daintree basin
 - Tully basin
 - Herbert basin
- Burdekin
- Mackay Whitsunday
 - Proserpine/O'Connell basin
 - Pioneer basin
 - Plane basin

The Barron-Daintree sub-region is reported from the collection of data under an independent AIMS program along the long-term Cairns transect where sampling started in 1989.

Techniques used to monitor *in situ* water quality include automated data loggers and collection of water samples in the field for laboratory analysis (Waterhouse *et al.* 2018, Gruber *et al.* 2019).

More intensive monitoring is conducted in the wet season because the majority of the annual pollutant load to the Great Barrier Reef is delivered then. Specific event sampling is also conducted throughout the wet season in the focus regions (Waterhouse *et al.* 2018, Gruber *et al.* 2019). Sampling follows transects extending from rivers chosen according to flow characteristics in a particular year.

Exceedances of individual water quality parameters at specific sites is reported against the Environmental Protection (Water) Policy (EPP) water quality objectives (State of Queensland 2016), as well as for any adjacent commonwealth-only waters (Great Barrier Reef Marine Park Authority 2018), in [annual technical reports](#) (Gruber *et al.* 2019).

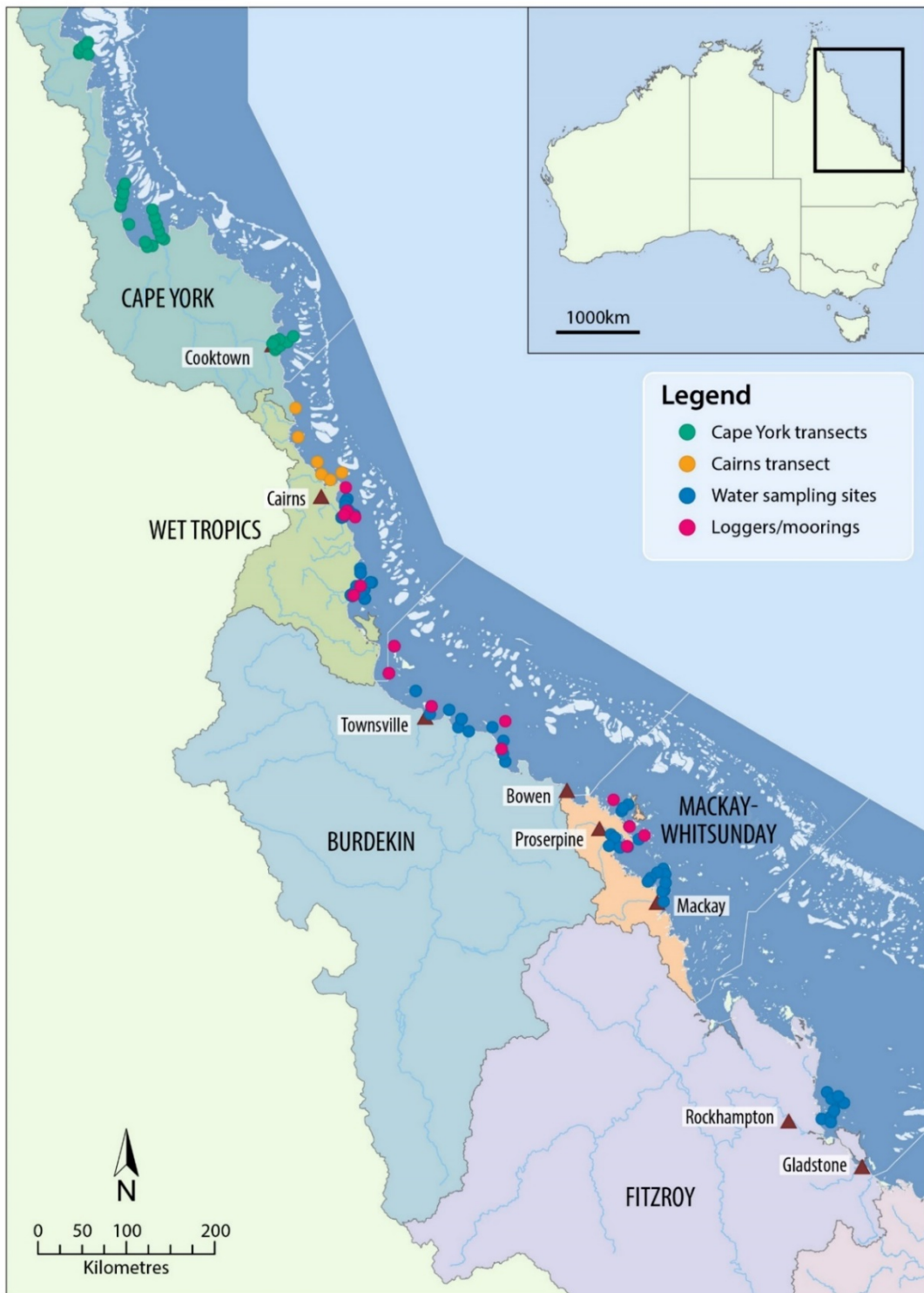


Figure 2. Marine monitoring program water quality monitoring locations and sampling strategy from 2015 onwards. Note: The Cape York transects were added in 2016–2017. Natural Resource Management region boundaries are represented by coloured catchment areas. Source: (Waterhouse et al. 2018, Gruber et al. 2019).

Two versions of a water quality index are prepared as an interpretation tool to visualise trends in the suite of water quality variables measured, and to compare monitored water quality to existing water quality guidelines (Great Barrier Reef Marine Park Authority 2018).

The water quality index uses a set of five key indicators:

- water clarity (total suspended solid concentrations, Secchi depth and turbidity measurements by FLNTUSB instruments, where available)
- chlorophyll *a* concentrations
- particulate nitrogen concentrations
- particulate phosphorus concentrations
- oxidised nitrogen concentrations.

For each monitoring site, these indicators are compared to water quality guidelines (Great Barrier Reef Marine Park Authority 2018), scored based on performance relative to these objectives, and aggregated to give an overall site-specific score. Sites are then aggregated within a region or sub-region to give a regional score.

The water quality index is calculated using two different methods due to changes in the Marine monitoring program design that occurred in 2015, as well as concerns that the index was not responsive to changes in environmental pressures of each year. The changes in design included increased number of sites, increased sampling frequency and a higher sampling frequency during December to April to better represent wet season variability. Thus, statistical comparisons between Marine monitoring program data from 2005-2015 to 2015-onwards must account for these changes. The two versions of the water quality index have different purposes:

1. **Long-term trend:** This version is based on the pre-2015 Marine monitoring program sampling design and uses only the original sites and three sampling dates per year. This sampling design had low temporal and spatial resolution and was aimed at detecting long-term trends in inshore water quality. Key aspects of this version are:
 - annual water quality guideline values are used for comparison with monitoring data
 - only Australian Institute of Marine Science monitoring data are used
 - a four-year running mean is applied to reduce the effect of sampling time on the index
 - the Index is an average of scores for five indicators.
2. **Annual condition:** This version is based on the post-2015 Marine monitoring program sampling design and uses all sites and sampling dates per year. Key aspects of this version are:
 - seasonal water quality guidelines (Great Barrier Reef Marine Park Authority 2018) are used for comparison with monitoring data (i.e. wet season data are compared to a wet season water quality guideline and dry season data are compared to a dry season water quality guideline)
 - both Australian Institute of Marine Science and James Cook University monitoring data are used

- a running mean is not applied
- the index is a hierarchical combination of scores for five indicators.

Further details can be found in Marine monitoring program [annual technical reports](#).

In situ water quality data are not used to generate the water quality metric scores for the Reef Water Quality Report Card 2017 and 2018, but have been included among the data streams used to validate the modelled outputs from the eReefs models.

Satellite remote sensing

At the Great Barrier Reef-wide scale, information is also sourced from satellite remote sensing, which provides the density of observations required to report on such a vast area (Petus et al. 2018, Petus et al. 2019). Remote sensing products including a range of wet-season maps derived from satellite imagery (weekly composites, frequency maps and surface exposure maps) are used to report water quality conditions in the Great Barrier Reef (Waterhouse et al. 2018, Gruber et al. 2019).

Wet season water type maps were produced using MODIS-Aqua (hereafter, MODIS) quasi true colour (hereafter true colour) imagery reclassified to six distinct colour classes defined by their colour properties (Álvarez-Romero et al. 2013) and typical of colour gradients existing across coastal waters, including river plumes, during the wet season (Figure 3). These characteristics vary the impact on the underlying ecological systems.

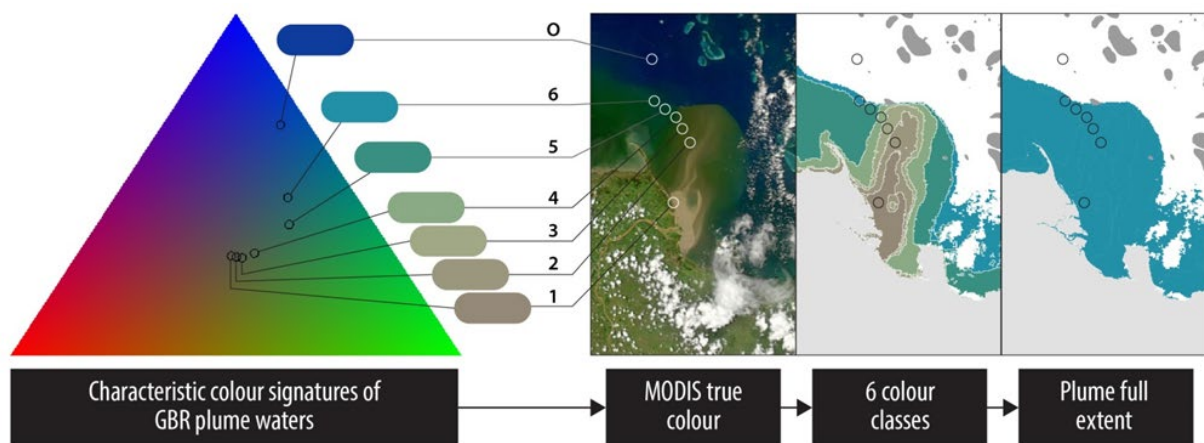


Figure 3. Triangular colour plot showing the characteristic colour signatures of the six wet season water types in the Red-Green-Blue (RGB or true colour) space. The colour of coastal waters depends on concentrations of optically active components (e.g. total suspended solids, colour dissolved organic matter, and chlorophyll *a*), which influence light attenuation (Petus et al. 2018, Petus et al. 2019), as well as different pollutant concentrations. These characteristics vary the impact on the underlying ecological systems.

The six wet season colour classes were further grouped into three wet season water types to assess the broadscale coastal water quality during the wet season, including the composition and spatial variability of river plumes and resuspension processes:

- primary—classes 1 to 4

- secondary—class 5
- tertiary—class 6.

The three water types have the following characteristics:

- **Primary water type:** the brownish to brownish-green turbid waters are typical for inshore regions of Great Barrier Reef river plumes and nearshore marine areas with high concentrations of resuspended sediments found during the wet season. These water bodies in flood waters typically contain high nutrient and phytoplankton concentrations but are also enriched in sediment and dissolved organic matter resulting in reduced light levels. A further break-down into four colour classes is provided for this water type.
- **Secondary water type:** the greenish-to-greenish-blue turbid waters are typical of coastal waters rich in algae (chlorophyll *a*) and also containing dissolved matter and fine sediment. This water body is found in the Great Barrier Reef open coastal waters as well as in the mid-shelf water at times. It has relatively high nutrient availability and light levels favour productivity as suspended sediments are largely settled out (Bainbridge et al. 2012).
- **Tertiary water type:** the greenish-blue waters whilst discernible, have low or no risk of detrimental ecological effects. This water body is typical for areas towards the open sea or offshore regions seaward of river flood plumes and is distinguishable due to the presence of colour dissolved organic matter.

The frequency of the presence of these three wet season water types is assessed on a weekly basis. To evaluate the potential exposure of Great Barrier Reef communities to degraded water quality, the frequency maps are overlaid with coral reef and seagrass meadow distributions to identify which communities are likely exposed to different wet season water quality conditions. The lowest exposure categories are characterised by low exposure frequencies of the primary and secondary water types, and the highest exposure categories are characterised by high exposure frequencies of primary and secondary water types. The exposure information is based on surface water quality conditions, which does not necessarily represent the exposure of benthic communities (Waterhouse et al. 2018; Gruber et al. 2019). The exposure categories have yet to be validated against ecological response data, so they represent relative levels of potential risk.

Pesticides

Pesticides are monitored using two methods (Grant et al. 2018, Gallen et al. 2019):

1. Passive samplers are deployed in both wet and dry seasons and provide time-averaged pesticide concentrations (i.e. the average concentration over the deployment period; typically one or two months) (Booij et al. 2007; Shaw et al. 2009).
2. Grab samples are collected in flood plumes during the wet season, during periods of high freshwater river discharge to provide single 'point in time' concentrations of pesticides in water and capture potential peaks.

Passive samplers are deployed at 11 fixed monitoring sites (Figure 2) and are analysed for a suite of 30 pesticides. Five sites have been continuously monitored between eight and twelve years. A further six sites were introduced more recently (2013 to 2015) to build direct linkages between land-based activities and marine ecosystem health, as well as identify the potential exposure risks in regions of known high pesticide use. These recent sites provide pesticide

concentration information in areas where seagrass, coral reef and catchment monitoring activities are also being conducted.

Specific in situ flood plume sampling is also conducted throughout the wet season in the focus regions. In both 2016-2017 and 2017-2018, flood plume monitoring was undertaken along transects extending from the mouths of two rivers in the Wet Tropics region – the Tully and Russell-Mulgrave rivers and from Barratta Creek mouth within the Burdekin focus area during early-season discharge events. In addition, in 2016-2017 grab samples were collected following tropical cyclone Debbie along nearshore transects extending from the Proserpine/O'Connell River catchments and the Pioneer River catchment in the Mackay Whitsunday region, and the Fitzroy River catchment (Waterhouse et al. 2018, Gruber et al. 2019).

Pesticide concentration data are evaluated in two ways:

- **Exceedances:** Individual pesticide concentrations are compared against water quality guidelines that are set for the protection of high ecological value marine ecosystems; i.e. protection of at least 99% of species (Australian and New Zealand governments 2018).
- **Mixtures:** The 2017-2018 year is the first year for reporting using a new method – the multisubstance potentially affected fraction (msPAF) method (Traas et al. 2002, Warne et al. 2018). Measured concentrations of 19 pesticides in Table 1 in a given sample are combined mathematically to predict the per cent of species protected (and conversely that may be affected) by mixtures of the pesticides detected. The remaining 11 pesticides do not have all the available information required to be able to include them in the assessment.

Table 1. Pesticides detected in passive sampler devices that were assessed using the msPAF method for multiple pesticides. Not all of the listed pesticides were necessarily detected in collected water samples.

Name of pesticide	Type	Mode of action
Chlorpyrifos	Insecticide	Acetylcholine esterase (AChE) inhibitor
Imidacloprid	Insecticide	Nicotinic receptor agonist
Haloxypop	Herbicide	Acetyl-coenzyme A carboxylase (ACCase) inhibitor
Imazapic	Herbicide	Group 1 Acetolactate synthase (ALS) inhibitor
Metsulfuron-methyl	Herbicide	Group 2 Acetolactate synthase (ALS) inhibitor
Pendimethalin	Herbicide	Microtubule synthesis inhibitor
Metolachlor	Herbicide	Acetolactate synthase (ALS) inhibitor
Ametryn	Herbicide	Group 1 PSII inhibitor
Atrazine	Herbicide	
Terbutylazine	Herbicide	
Tebuthiuron	Herbicide	
Simazine	Herbicide	Group 2 PSII inhibitor
Diuron	Herbicide	Group 3 PSII inhibitor
Terbutryn	Herbicide	
Hexazinone	Herbicide	Group 4 PSII inhibitor
Metribuzin	Herbicide	Group 5 PSII inhibitor
2,4-D	Herbicide	Group 1 auxins (Phenoxy-carboxylic acid auxins)
MCPA	Herbicide	
Fluroxypyr	Herbicide	Group 2 auxins (Pyridine-carboxylic acid auxins)

Water quality guideline values for the protection of high ecological value aquatic ecosystems are set to protect at least 99% of species (i.e. no more than 1% of species affected), the highest protection value possible, in recognition of the marine park and world heritage status of the Great Barrier Reef.

The results of the msPAF analysis are categorised according to the risk categories in Table 2. These categories are consistent with the ecological condition categories used in the Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters.

Table 2 Risk categories for pesticide mixtures.

Risk categories (% species affected)	Risk categories (% species protected)	Risk category	Risk Level
≤1.0%	≥99%	5	Very low risk
>1 – <5%	>95 – <99%	4	Low risk
5 – <10%	>90 – 95%	3	Moderate risk
10 – <20%	>80 – 90%	2	High risk
≥20.0%	≤80%	1	Very high risk

Marine results are not directly comparable with the end-of-catchment results due to differences in the sampling approach. However, they provide insight into the transport and fate of pesticides, from the end of rivers to marine sites, and the potential risk to marine ecosystems from the mixture of pesticides. The key differences are:

- three of the pesticides, fipronil, isoxaflutole and triclopyr, are not included in the analysis suite for the marine samples (i.e. 19 of the 22 pesticides analysed at the end-of-catchment are analysed for in marine samples). This may mean that the mixture toxicity is underestimated (relative to the catchment monitoring results). However, this is likely to be a minor underestimation as only isoxaflutole is regularly detected at the end-of-catchment (i.e. in Mackay Whitsunday catchments) at concentrations that exceed draft ecosystem protection guidelines for protection of 99% species (0.33 µg/L) and is unlikely to contribute significantly to overall pesticide toxicity in inshore marine waters (Great Barrier Reef Catchment Loads Monitoring Program, pers comm).
- passive samplers are deployed throughout the year providing an ~monthly average concentration of pesticides during both wet and dry seasons. In contrast, end-of-catchment pesticide results are based on high frequency, point in time, grab samples primarily targeting the wet season. Given there is a range of risk reported across the deployments, averages based on passive sampling would likely result in a reduced overall risk.
- the end of catchment pesticide data is converted to a single value representing the time-averaged¹ per cent of species protected during a standardised wet season period (182 days = 6 months). Passive sampler concentrations are converted to a per cent of species protected during each passive sampler deployment.

In the coming years we will explore methods to increase the comparability of the marine and end of catchment pesticide reporting. In the interim, we are reporting the msPAF value of what we know is the minimum protection level achieved during a deployment (i.e. the passive samplers with the highest concentrations and highest msPAF scores at each site).

¹ The average is calculated from a multiple imputation approach that uses statistical distributions to infill missing days of data.

Seagrass condition

The objectives for the seagrass condition sub-component are listed below (State of Queensland 2018).

1. Monitor, assess and report the condition and trend of Great Barrier Reef inshore seagrass meadows along identified or expected gradients in water quality in relation to the desired Reef 2050 Long Term Sustainability Plan ecosystem health outcomes.
2. Monitor, assess and report the extent, frequency and intensity of acute and chronic impacts on the condition of Great Barrier Reef inshore seagrass meadows from sediment, nutrients and pesticides.
3. Monitor, assess and report the recovery of Great Barrier Reef inshore seagrass meadows from exposure to flood plumes, sediment, nutrients and pesticides.

Monitoring is conducted in six natural resource management regions, in each major seagrass habitat type where possible (estuarine, coastal intertidal, coastal subtidal, reef intertidal and reef subtidal) (Figure 3). However, monitoring is conducted predominately at intertidal meadows (lower littoral - only exposed to air at the lowest of low tides), with eight locations also including shallow subtidal meadows. The additional Cape York sites (established in 2012), four subtidal sites in the Wet Tropics and Burdekin regions (established in 2008), and two intertidal sites in the Burdekin region (established in 2012) were included in the overall assessments of Great Barrier Reef seagrass ecosystem condition. Additional sites in Cape York (Lloyd Bay), Wet Tropics (Goold Island and Missionary Bay), Burdekin (Shelley Beach), Mackay-Whitsunday (Hydeaway Bay, Pioneer Bay, Tongue Bay, and Newry Bay) and Burnett-Mary (Burrum Heads) monitored by Seagrass-Watch and Queensland Parks and Wildlife Service drop-camera programs, including presence of foundation and other seagrass species, were also included in the Great Barrier Reef Report Card (McKenzie *et al.* 2019).

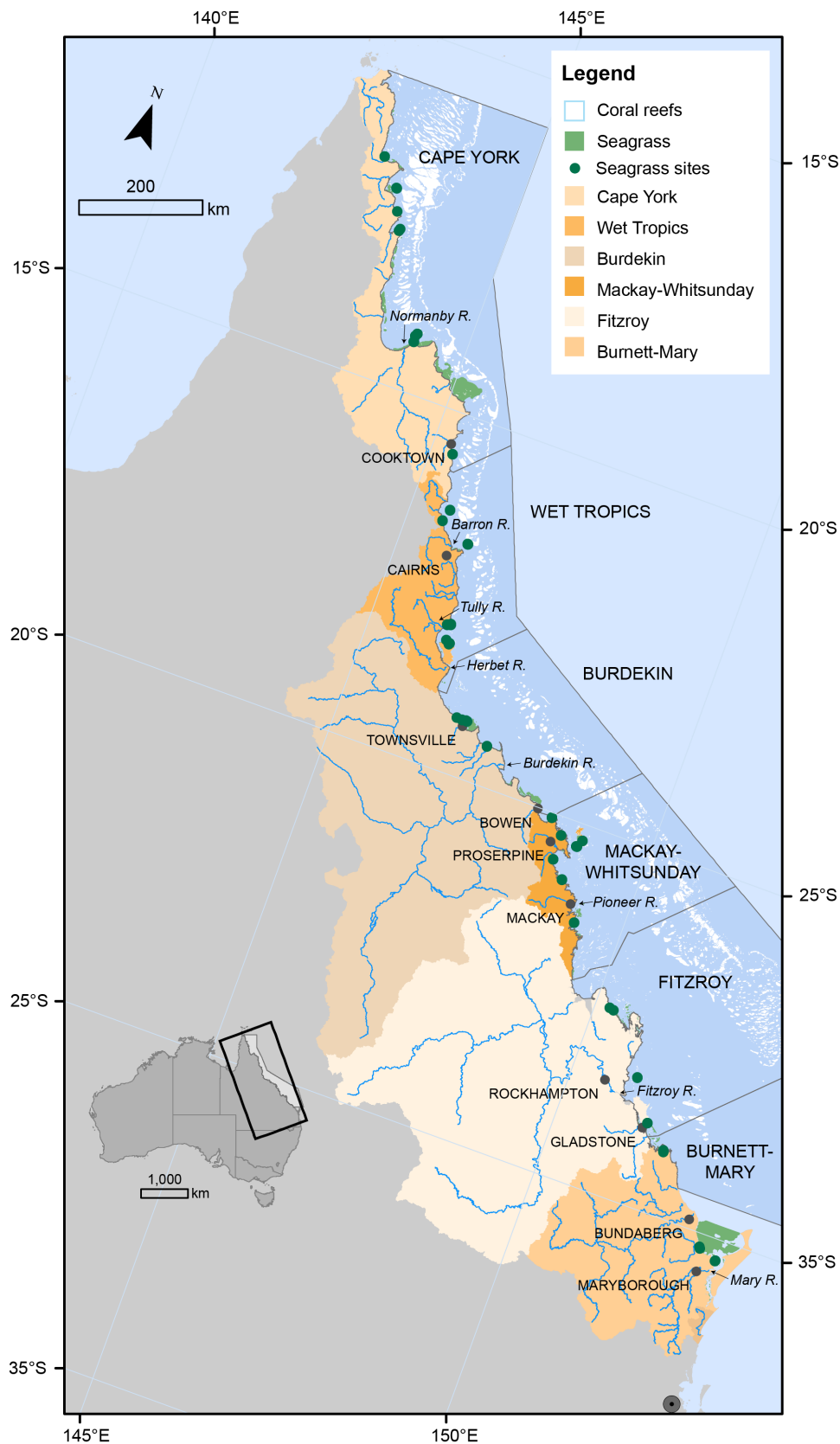


Figure 4. Marine Monitoring Program seagrass monitoring locations (including Queensland Parks and Wildlife Service and Seagrass-Watch). Source: (McKenzie et al. 2019)

Monitoring includes an assessment of three indicators:

- seagrass abundance (per cent cover) is an assessment of the average per cent cover of seagrass per monitoring site in relation to the Seagrass Abundance Guidelines (McKenzie 2009)
- reproductive effort is the ratio of the average number of reproductive structures (spathe, fruits, female and male flowers) of plants on an area basis relative to the long-term average, and provides an indication of the capacity for meadow recovery following disturbances
- tissue nutrient composition as an indicator of nutrient enrichment relative to light available for growth (McKenzie et al. 2019).

Additional indicators of seagrass condition and resilience include species composition, relative meadow extent and density of seeds in the seed bank (McKenzie et al. 2019).

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 discussed 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). 40°C is a critical canopy temperature threshold for photoinhibition and acute temperature stress for seagrass (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 be 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 sub-program (McKenzie et al. 2019).

Coral reef condition

The objectives for the coral reef condition sub-component are listed below (State of Queensland 2018).

1. Monitor, assess and report the condition and trend of Great Barrier Reef inshore coral reefs along identified or expected gradients in water quality in relation to the desired Reef 2050 Long Term Sustainability Plan ecosystem health outcomes.
2. Monitor, assess and report the extent, frequency and intensity of acute and chronic impacts on the condition of Great Barrier Reef inshore coral reefs from sediment, nutrients and pesticides.
3. Monitor, assess and report the recovery of Great Barrier Reef inshore coral reefs from exposure to flood plumes, sediment, nutrients and pesticides.
4. Monitor, assess and report trends in coral reef resilience indicators: resistant coral species, temperature variability, nutrients, sedimentation, coral diversity, coral disease, macroalgae, crustose coralline algae and coral eating crown-of-thorns starfish.

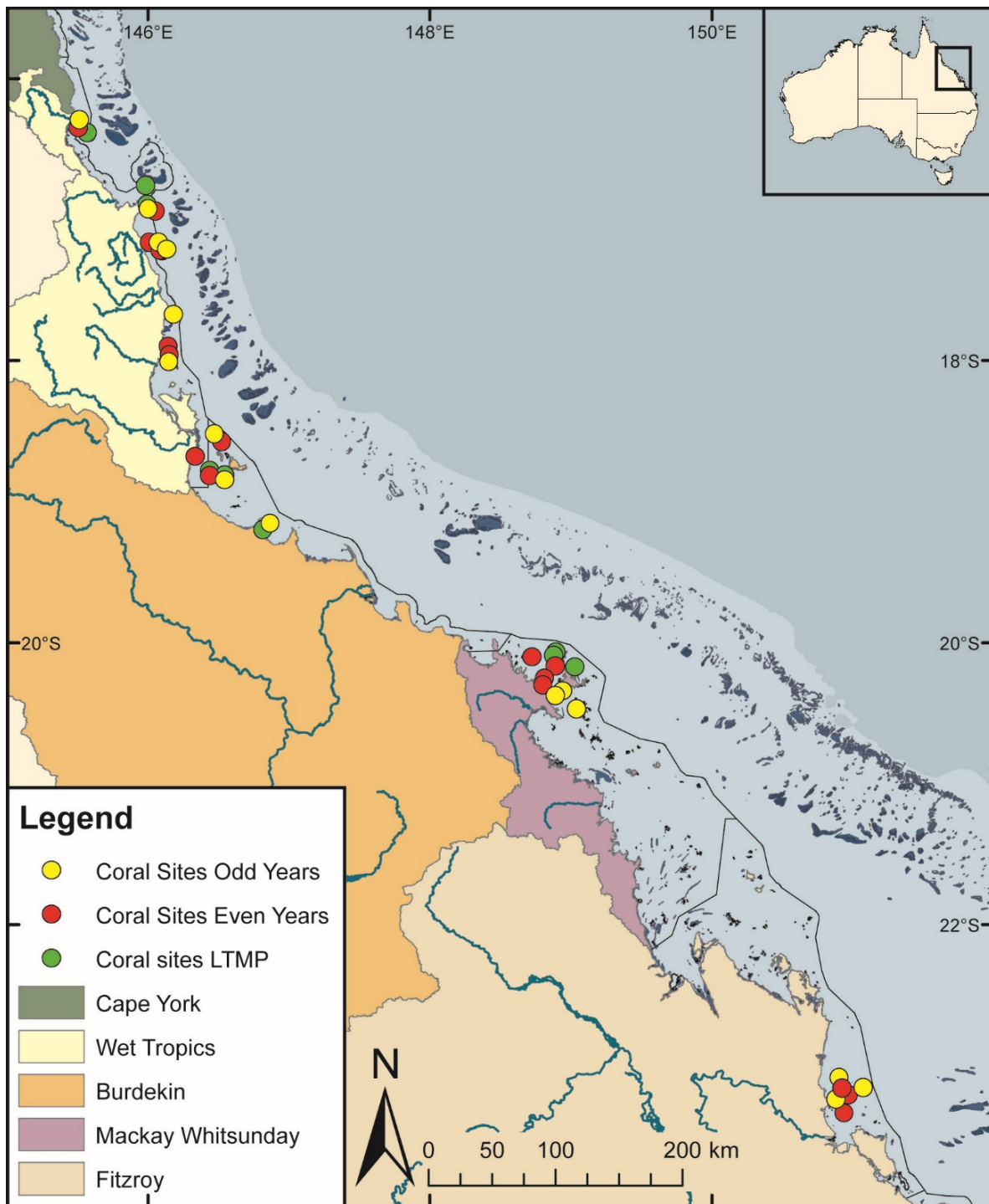


Figure 5. Sampling locations of the Marine monitoring program coral monitoring. Reefs are scheduled to be monitored biannually. Yellow indicates sites scheduled to be monitored in even years, and red dots are scheduled to be monitored in odd years. Green dots indicate sites monitored as part of the long-term monitoring program (LTMP) conducted by Australian Institute of Marine Science. Natural Resource Management region boundaries are represented by coloured catchment areas. Source: (Thompson et al. 2019).

Coral reef condition monitoring of inshore coral reef communities occurs at reefs adjacent to the Wet Tropics, Burdekin, Mackay Whitsunday and Fitzroy natural resource management regions (Figure 4). No reefs are included adjacent to Cape York due to logistic and occupational health and safety issues relating to diving in coastal waters in this region. Limited development of coral reefs in nearshore waters adjacent to the Burnett Mary natural resource management region currently precludes sampling in these locations. Sub-regions are included in the Wet Tropics natural resource management to more closely align reefs with the combined catchments of the Barron and Daintree rivers, the Johnstone and Russell-Mulgrave rivers, and the Herbert and Tully rivers (Thompson et al. 2019).

There are 32 reefs monitored at 2m and 5m depths by the Marine monitoring program, with an additional nine inshore reefs monitored at single depths by the Australian Institute of Marine Science – Long-Term Monitoring Program (LTMP). These are included in the annual assessment of coral condition, although not all reefs are currently sampled every year (Thompson et al. 2019).

Monitoring covers a comprehensive set of community attributes including the assessment of hard and soft coral cover, the number of hard coral juvenile colonies (up to 5cm in diameter), the proportion (per cent) of macroalgae cover, the 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. 2019).

These indicators are formulated around the concept of community resilience:

- Coral cover is a measure of the abundance of hard and soft corals, and indicates the capacity of coral to persist under the current environmental conditions. Coral cover also represents the availability of brood-stock required for the ongoing supply of future coral generations.
- Coral change is a measure of the observed change in hard coral cover compared to modelled predictions. A healthy and resilient coral reef is expected to show an increase in coral cover during periods free from disturbances and this indicator directly assesses the rate of coral cover increase over the rolling four years of monitoring.
- Juvenile density is a measure of the abundance of hard coral juvenile colonies (up to 5cm in diameter) standardised to space available for coral settlement and indicates the ongoing replacement of corals necessary to recover from disturbances or stress.
- Macroalgal cover is a measure of the proportion of algae cover that is classified as large, fleshy algae. A low score for macroalgae (i.e. poor or very poor) means macroalgal cover is high, which is indicative of poor water quality. Conversely, a high score for macroalgae (i.e. good or very good) means cover is low. High macroalgal cover, once established, reduces the recovery of corals by denying space or producing chemical deterrents that limit coral recruitment and growth.
- Coral community composition scores reflect changes in the relative abundance of coral species from a baseline set at the beginning of the Marine monitoring program. If the composition of communities moves beyond the standard error of their baseline condition toward a community indicative of higher concentrations of nutrients and turbidity, a score of zero is returned. Conversely a score of one is given if the change is toward a community predicted by improved water quality conditions. Comprehensive water quality measurements and environmental parameters are also collected at many of the coral reef sites (Thompson et al. 2019).

Assessing status against the objectives

Improved seagrass condition

Three primary indicators are used to assess and report inshore seagrass condition: abundance, reproductive effort and tissue nutrient status. Trend graphs show the combined score of the indicators over time (colour-graded circles) as well as the indicators contribution to the scores (lines).

Further detail about the selection and scoring of these indicators is documented in [annual technical reports](#) (McKenzie et al. 2019).

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 macroalgal cover. Trend graphs show the combined score of the indicators over time (colour-graded circles) as well as the indicators contribution to the scores (lines).

Further detail about the selection and scoring of these indicators is documented in [annual technical reports](#) (Thompson et al. 2019).

Synthesis and integration of data and information

The Reef Water Quality Report Card 2017 and 2018 (Tier 1) provides assessment scores for the condition of inshore water quality, seagrass and coral at Great Barrier Reef-wide and regional scales.

Inshore Reef scores are standardised by the area of seagrass and coral reef in the inshore area of each region, while regional scores are unweighted averages. Detailed information is available from [annual technical reports](#) on the Marine monitoring program website.

The eReefs marine modelling program provides the water quality metric for the inshore Reef score based on open coastal waters (Robillot et al. 2018; Robillot et al. 2019).

Qualitative confidence rankings

A multi-criteria analysis was used to qualitatively score the confidence in each indicator used in the Reef Water Quality Report Card 2017 and 2018, from low to high. The approach combined expert opinion and direct measures of error for program components where available. Seagrass received a four-bar confidence ranking and coral received a four-bar confidence ranking (Figure 6)..

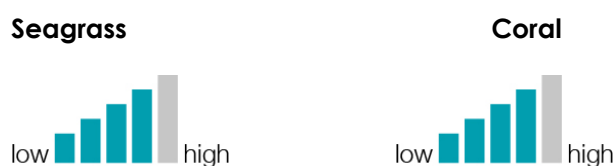


Figure 6. Qualitative confidence rankings for seagrass and coral scores Source: Refer to Appendix 1.

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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 qualitatively 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. 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 determination of confidence for the report card used five criteria:

- maturity of methodology (the score is weighted half for this 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 x 0.5 = 1.5	3	2	3	2

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

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 x 0.5 = 1.5	3	2	3	2

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

Glossary

ECO FLNTUSB instrument: Combination fluorometer and scattering meter deployed to measure chlorophyll fluorescence and turbidity

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/>>

Exposure categories: the proportional exceedance of the guideline values (of sediment and nutrient parameters during the wet season and focuses on total suspended solids, chlorophyll *a*, particulate phosphorus and particulate nitrogen concentrations) multiplied by the likelihood of exposure in each of the water types. Overall exposure scores are categorised into four equally-distributed potential risk categories (I to IV). Exposures risk is termed 'potential' because the risk from surface plumes is not proven in ecosystem response data to confirm the ecological consequences.

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

MODIS: Moderate Resolution Imaging Spectroradiometer

msPAF: multisubstance-potentially affected fraction

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 Plan: Reef Water Quality Protection Plan

Reef 2050 Plan: Reef 2050 Long-Term Sustainability Plan

Secchi depth: A measure of the clarity of water based on the Secchi disk.

Turbidity: A measure of light scattering caused by fine suspended particles, such as clay and silt, detritus, microbes and phytoplankton and zooplankton. Turbidity is affected by a wide range of factors, including natural ones such as wind, waves and currents, as well as anthropogenic ones such as dredging and increased land-based run-off

Water quality index: Metric based on five indicators measured *in situ*

Water quality objective: are long-term goals for water quality management. They are numerical concentration levels or narrative statements of indicators established for receiving waters to support and protect the designated environmental values for those waters. Water quality objectives are not individual point source emission objectives, but the receiving water quality objectives. They are based on scientific criteria or water quality guidelines but may be modified by other inputs (e.g. social, cultural, economic).

Wet season water types: There are three water types: primary, secondary, and tertiary referred to in this report. The term refers to waters that are distinguishable from true color satellite imagery interpretation, and grouped into colour classes according to their optical properties. Primary, secondary and tertiary water types equate to the brownish, greenish and paler greenish-blue waters from the imagery, respectively.