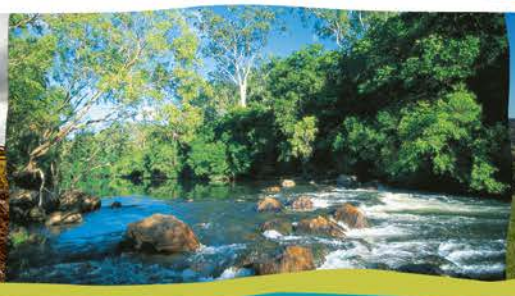
Marine methods


Great Barrier Reef
Report Card 2015

Australian Government

Queensland Government

Marine methods

Marine Monitoring Program

The Australian Government's Marine Monitoring Program assesses water quality and the long-term health of key marine ecosystems (inshore coral reefs and seagrasses) in the inshore waters of the Great Barrier Reef. The three elements of the program are outlined below.

More information about the Marine Monitoring Program is available from the Great Barrier Reef Marine Park Authority website (http://www.gbrmpa.gov.au/about-the-reef/how-the-reefs-managed/reef-rescue-marine-monitoring-program).

Inshore water quality

Monitoring of year-round water quality includes the measurement of concentrations of organic carbon, inorganic and organic nutrients (nitrogen and phosphorus), chlorophyll *a*, suspended solids (water turbidity) and pesticides. Techniques used to monitor water quality include satellite remote sensing, automated data loggers and collection of water samples from research vessels for laboratory analysis. Passive samplers are used to measure the concentration of pesticides in the water column integrated over time (Booij et al., 2007; Shaw & Mueller, 2009).

Monitoring is also conducted in the wet season as the majority of the annual pollutant load to the reef is delivered by flood events in the monsoon (Devlin et al. 2001).

Seagrass condition

Monitoring temporal and spatial variation in the status of inshore seagrass meadows in relation to changes in local water quality is essential in evaluating long-term ecosystem health and resilience.

Monitoring includes an assessment of the seagrass abundance (per cent cover) and reproductive effort, which provides an indication of the health of seagrass meadows and their capacity to regenerate following disturbances. Tissue nutrient composition is assessed in the laboratory as an indicator of nutrient enrichment relative to light available for growth.

Seagrass monitoring on the Great Barrier Reef (Image: L. McKenzie, Seagrass Watch HQ.)

Coral reef condition

Monitoring temporal and spatial variation in the status of inshore coral reef communities in relation to changes in local water quality is essential in evaluating long-term ecosystem health.

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 5 centimetres in diameter), the proportion (per cent) of cover of algae that is macroalgae, the rate of change in coral cover (as an indication of the recovery potential of the reef following a disturbance) (Thompson and Dolman, 2010) and coral community composition (Thompson et al. 2016). Comprehensive water quality measurements are also collected at many of the coral reef sites.

Coral reefs being monitored on the Great Barrier Reef (Image: Australian Institute of Marine Science).

Great Barrier Reef-wide and regional report card assessment scores

Synthesis and integration of data and information

The Great Barrier Reef Report Card provides assessment scores for the condition of inshore water quality, seagrass and coral at Great Barrier Reef-wide and regional scales. There are six natural resource management regions: Cape York, Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy and Burnett Mary.

A sub-set of indicators are used to assess and report on water quality, seagrass and coral condition. These indicators are scored on a five-point scale (very good, good, moderate, poor, very poor) and aggregated into a score that describes the overall status of the Great Barrier Reef and each individual region.

An overview of the methods used to calculate the Great Barrier Reef-wide and regional scores is provided below. Great Barrier Reef-wide scores are standardised by the area of each region, while regional scores are unweighted averages. Detailed information is available from the technical reports on the Marine Monitoring Program website (http://www.gbrmpa.gov.au/managing-the-reef/how-the-reefs-managed/reef-2050-marine-monitoring-program/marine-monitoring-program-publications). Improvements have been implemented for coral metrics for the Great Barrier Reef Report Card 2015.

Remotely sensed inshore water quality

Near-surface concentrations of chlorophyll *a* and total suspended solids from remotely sensed images are used to assess and report on inshore water quality. Chlorophyll *a* is a measure of phytoplankton biomass that is related to the amount of available nutrients in the water column and therefore the productivity of the ecosystem. Total suspended solids is a measure of all particulate matter in the water column including sediment. These two parameters are assessed against their relevant Great Barrier Reef Water Quality Guideline (GBRMPA, 2010) trigger values as the proportion of the inshore water body where the annual mean value does not exceed the Great Barrier Reef Water Quality Guidelines (the Guidelines) (GBRMPA, 2010). Inshore waters include enclosed and open coastal waters as defined in the Guidelines.

Chlorophyll *a* and total suspended solids have been chosen as the best information currently available to describe the water quality over a large spatial area with linkages to Reef Water Quality Protection Plan targets. Limitations of this approach are recognised, as there are areas with limited validation data, and temporal and spatial variability in the number of valid observations. Specifically, it is recognised that there is a high level of uncertainty associated with data for some parameters obtained from remote sensing in shallow and turbid coastal waters. This year additional technical work was undertaken by James Cook University and Australian Institute of Marine Science to improve confidence in this information, which involved:

- delineating and masking out (excluding) the shallow, turbid enclosed coastal water body
- reprocessing the relevant statistics for the year and the dry/wet seasons
- reprocessing data from previous years, to derive information on long-term trends.

However the results obtained did not improve the certainty associated with the information (Tracey et al. 2016) and for consistency, the water quality metric implemented the same method as for previous Great Barrier Reef Report Cards with the following exceptions: water quality was not evaluated at the regional level for the Cape York and Burnett Mary regions because of the limited amount of on-ground data available for validation. The uncertainty associated with water quality estimates from satellites is higher in these two regions and therefore they have been excluded from overall reef-wide assessment of water quality.

It should also be noted that the number of remotely sensed images available in the wet season is substantially lower than in the dry season due to high cloud cover, so there is greater uncertainty in the wet season. The full historical time-series was updated and presented in the Great Barrier Reef Report Card 2014. There were further updates to the archive data which affected the time-series for 2013-14 and updated the information used for this year's Great Barrier Reef Report Card. The time-series is available through the e-Reefs Marine Water Quality Dashboard (http://www.bom.gov.au/marinewaterquality/).

A project is being developed to improve the way that water quality is assessed and reported in future reports.

Site-specific water quality

Site-specific water quality data also described in the Report Card 2015, based on year-round and wet season monitoring (Lønborg et al. 2016). Trends in water quality parameters (turbidity/water clarity, chlorophyll *a* and concentrations of particulate nitrogen and phosphorus) relative to the Guidelines (GBRMPA 2010) are available in the annual report (Lønborg et al. 2016) on the Marine Monitoring Program website at http://www.gbrmpa.gov.au/managing-the-reef/how-the-reefs-managed/reef-2050-marine-monitoring-program. From 2014-15, site-specific water quality monitoring was expanded to comprehensively detect changes in water quality in four focus regions in the Wet Tropics (Tully and Russell Mulgrave) and Burdekin and Mackay Whitsunday (O'Connell).

Site-specific water quality data is not included in the water quality scores because while the overall trends are consistent with remote sensing data, the scores are not directly comparable. The method for assessing water quality will be refined for 2016 Great Barrier Reef Report Card.

Pesticides

Pesticides are monitored using two methods (Gallen et al. 2016): grab samples of pesticides collected in flood plumes during the wet season to give an indication of peak concentrations, and passive samplers provide an integrated assessment of pesticide concentrations over time in wet and dry seasons (Booij et al., 2007; Shaw & Mueller, 2009).

The most frequently detected pesticides in inshore waters include those herbicides that inhibit the photosynthetic pathway (PSII) of plants: diuron, atrazine, hexazinone, simazine and tebuthiuron (Haynes et al., 2000a; Mitchell et al. 2005; Kapernick et al. 2006; Lewis et al. 2009; Packett et al. 2009). These PSII herbicides may also have a negative impact on non-target organisms such as algae, corals and seagrass (Magnusson et al., 2008; Jones and Kerswell, 2003; Haynes et al., 2000(b)).

An index has been developed using PSII herbicide equivalent concentrations to assess the potential combined toxicity of these pesticides relative to the Guidelines. The PSII herbicide equivalent concentration incorporates the relative potency and abundance of individual PSII herbicides compared to a reference PSII herbicide, diuron. For reporting purposes, the index has five categories: concentrations detected at the lowest level (Category 5) are not expected to have an impact on seagrass or coral, while the highest level (Category 1) corresponds to the guideline for diuron set for the protection of 99 per cent of species (http://www.gbrmpa.gov.au/about-the-reef/how-the-reefs-managed/water-quality-in-the-great-barrier-reef/water-quality-guidelines-for-the-great-barrier-reef).

Table 1. PSII Herbicide Equivalent (HEq) Index developed as an indicator for reporting of PSII herbicides across the reef

Category	Concentration ($ng.L^{-1}$)	Description
5	**PSII-HEq ≤ 10**	No published scientific papers that demonstrate any effects on plants or animals based on toxicity or a reduction in photosynthesis. The upper limit of this category is also the detection limit for pesticide concentrations determined in field collected water samples.
4	**10 < PSII-HEq ≤ 50**	Published scientific observations of reduced photosynthesis for two diatoms.
3	**50 < PSII-HEq < 250**	Published scientific observations of reduced photosynthesis for two seagrass species and three diatoms.
2	**250 ≤ PSII-HEq ≤ 900**	Published scientific observations of reduced photosynthesis for three coral species.
1	**PSII-HEq > 900**	Published scientific papers that demonstrate effects on the growth and death of aquatic plants and animals exposed to the pesticide. This concentration represents a level at which 99 per cent of tropical marine plants and animals are protected, using diuron as the reference chemical. For high ecological value water bodies like the Great Barrier Reef Marine Park and the World Heritage Area, a guideline concentration that is protective of 99 per cent of species is appropriate.

Note that Category 1 is higher than Category 5 and that concentrations of pesticides at Categories 2 to 4 represent biologically relevant concentrations. However:

- The published scientific papers indicate that the reductions in photosynthesis at these concentrations are 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.

Classifying the data into index categories provides an indication of the extent and frequency of exposure to PSII herbicides at a given site (and the potential consequences for marine organisms). The PSII herbicide equivalent concentrations used in the index are calculated from the combined toxicity of diuron, hexazinone, atrazine and its breakdown products, tebuthiuron, ametryn, prometryn, simazine, metolachlor, terbutryn, flumeturon and imidacloprid, all of which are used to control weeds and other plant species in the Great Barrier Reef catchment and are regularly found in the Great Barrier Reef Marine Park. Note that reference to pesticides in the report includes all herbicides, insecticides and other chemicals used to treat pest or weed species.

Refinements are underway to evaluate pesticides using a new method termed the Multiple Substances-Potentially Affected Fraction (ms-PAF) (Traas et al., 2002). This method is also based on the additive model of mixture toxicity, but uses species sensitivity distributions (which are also used to derive water quality guidelines) to determine the equivalent pesticide concentrations. The transition from evaluation based on single species data to multiple species using species sensitivity distributions has commenced (Gallen et al. 2016), but requires additional validation prior to inclusion in the Great Barrier Reef Report Card scores. It is expected to be included in future reports.

Seagrass

Abundance, reproductive effort and tissue nutrient status are used to assess and report on inshore seagrass condition (McKenzie et al. 2016).

Seagrass abundance is an assessment of the average per cent cover of seagrass per monitoring site in relation to the Seagrass Abundance Guidelines (McKenzie 2009). The 80th, 50th and 20th percentiles were used to define the Seagrass Abundance Guidelines, as these are recommended for Queensland Water Quality Guidelines (Department of Environment and Resource Management 2009) and there is no evidence that this approach would not be appropriate for seagrass meadows in the Great Barrier Reef. Developing guidelines for individual sites requires three to 10 years of monitoring with a minimum of 18 or more observations with no identified impacts, depending on the variability for the site. The Seagrass Abundance Guidelines can then be applied to determine seagrass condition for each monitoring event. For example, if median abundance is at, or above, the 50th percentile for that site, the condition is considered 'good'.

Reproductive effort is the ratio of the average number of reproductive structures on an area basis relative to the long-term average, and provides an indication of the capacity for meadow recovery following disturbances.

The nutrient status of seagrass is based on the ratio of carbon to nitrogen in leaf tissue, and reflects the level of nutrients in the surrounding waters relative to the amount of light the plant is receiving to grow.

Seagrass monitoring takes place in four representative habitat types: estuarine, coastal intertidal, reef intertidal and reef subtidal meadows throughout the Reef in 2014-15. The additional Cape York sites (established in 2012), four subtidal sites in the Wet Tropics and Burdekin regions (established in 2008), and one intertidal site 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 (Yum Yum Beach), Wet Tropics (Midge Point), Mackay Whitsundays (Hydeaway bay) and Burnet Mary (Burrum Heads) monitored by Seagrass Watch were also included in the Great Barrier Reef Report Card 2015.

Seagrass condition assessments, which now have a greater confidence ranking, were hindcast for the entire time-series in 2013-14 so that results from previous years are comparable.

Corals

Five indicators are now 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 (Thompson et al. 2016). Coral community composition is a new indicator added for this year's Great Barrier Reef Report Card.

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 and to recover from disturbances by estimating the availability of adult broodstock (Thompson et al. 2016).

Coral change is a measure of the observed change in hard coral cover compared to modelled predictions derived from the preceding four years of information, and provides an indicator of the balance between disturbance and recovery. A healthy and resilient coral reef is expected to show an increase in coral cover during periods free from disturbances. There is now appropriate 'raw' observational data for the coral change indicator and as such the data provided are the means and standard errors of the reef level metric scores. This improvement was facilitated by the way in which this metric is now derived from a continuous rather than categorical scale (Thompson et al. 2016).

Juvenile density is a measure of the abundance of hard coral juvenile colonies (up to five centimetres in diameter) per area of available space, and indicates the potential of the community to recover from disturbances or stress (Thompson et al. 2016).

Macroalgal cover is a measure of the proportion (per cent) of cover of algae 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 (Thompson et al. 2016).

Coral community composition scores are the mean and standard error for locations of communities in multivariate space, constrained to lie along a gradient of water quality (combination of Chl and TSS). Smaller numbers represent communities typical of poorer water quality (Thompson et al. 2016).

The refinements to the assessment of these criteria implemented this year have been hindcast so that results from previous years are comparable (Thompson et al. 2016).

No coral monitoring occurs in the Cape York or Burnett Mary regions under the Marine Monitoring Program. Coral scores also incorporate monitoring of inshore reefs undertaken through the Australian Institute of Marine Science's Long-Term Monitoring Program (http://www.aims.gov.au/docs/research/monitoring/reef/reef-monitoring.html).

Qualitative confidence rankings

Remote sensed water quality

Seagrass

Coral

A multi-criteria analysis was used to qualitatively score the confidence in each indicator used in the Great Barrier Reef Report Card from low to high. The approach combined the use of expert opinion and direct measures of error for program components where available. Remote sensed water quality received a one bar confidence ranking, seagrass received a four bar confidence ranking and coral received a four bar confidence ranking.

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