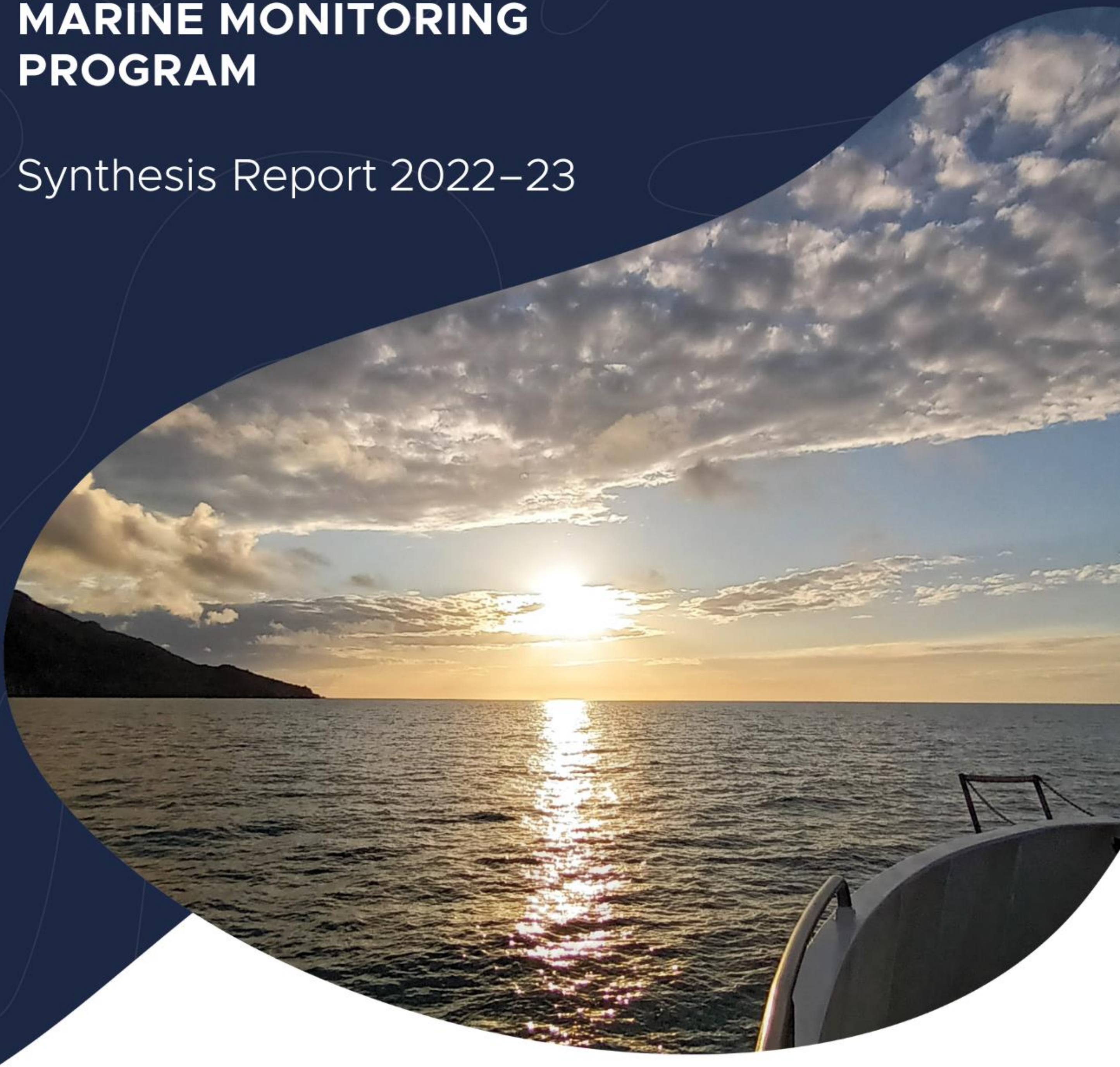
Australian Government
Great Barrier Reef Marine Park Authority

Reef Authority

GREAT BARRIER REEF MARINE MONITORING PROGRAM

Synthesis Report 2022–23



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Front cover photography: Sunset at Cape Cleveland, Burdekin region. © Australian Institute of Marine Science. Photo credit: Kathy Lisa Connellan.

The Great Barrier Reef Marine Park Authority acknowledges the continuing Sea Country management and custodianship of the Great Barrier Reef by Aboriginal and Torres Strait Island Traditional Owners whose rich cultures, heritage values, enduring connections and shared efforts protect the Reef for future generations.

DISCLAIMER

Comments and questions regarding this document are welcome and should be addressed to:

Great Barrier Reef Marine Park Authority
Director, Science for Management
235 Stanley Street Townsville QLD | PO Box 1379 Townsville QLD 4810

Contents

Glossary

Abundance indicator	One of two indicators included in the calculation of the Seagrass Index, measured using the median seagrass percentage cover relative to the site or reference guideline.
AIMS	The Australian Institute of Marine Science
Annual Water Quality Index	Metric based on five indicators measured *in-situ:* water clarity, Chl-*a*, NO_x, PN and PP.
Coral cover indicator	One of five indicators included in the calculation of the Coral Index, based on the level of coral cover derived from point intercept transects.
Cover change indicator	One of five indicators included in the calculation of the Coral Index, derived from a comparison of the change in hard coral cover observed *in-situ* between two visits without disturbance, and the change in hard coral cover predicted by modelling, averaged over a four-year period. It is an indicator of the recovery potential of coral communities due to growth.
Coral Index	Average score of the five coral indicators: Coral cover, Cover change, Composition, Macroalgae, and Juvenile coral.
Composition indicator	One of five indicators included in the calculation of the Coral Index, which compares the composition of hard coral communities at each reef to a baseline composition at that reef. It is an indicator of selective pressures imposed by the environmental conditions at a reef.
Macroalgae indicator	One of five indicators included in the calculation of the Coral Index, which considers the proportional representation of macroalgae in the algal community, based on cover estimates derived from point intercept transects. It is an indicator of competition with corals.
JCU	James Cook University
Juvenile coral indicator	One of five indicators included in the calculation of the Coral Index, which is based on the number of juvenile (up to 5 cm diameter) hard coral colonies that have successfully survived early life cycle stages converted to a density per m^2 of available space for settlement, which indicates the coral population's ability to recover from disturbance events.
Ecosystem health	Ecological processes, biodiversity and function of biological communities is maintained.
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. The water quality guideline values describe the concentrations of sediment, nutrients and pesticides that are needed for the protection and maintenance of marine species and the Reef's ecosystem health.

Inshore	The enclosed coastal and open coastal water bodies combined. These terms are defined and mapped under schedules in the *Environmental Protection (Water) Policy.*
Long-term Water Quality Index	Metric based on three indicators measured *in-situ*: water clarity, productivity and particulate nutrients.
LTMP	Long-Term Monitoring Program
MMP	Great Barrier Reef Marine Monitoring Program
Marine Park	Great Barrier Reef Marine Park
NO_x	Nitrogen oxides (the sum of nitrate and nitrite)
PN	Particulate nitrogen
PO_4	Phosphate (dissolved inorganic phosphorus)
PP	Particulate phosphorus
Pollutants	This synthesis report refers to excess suspended (fine) sediments, nutrients (nitrogen, phosphorus), as well as the presence of pesticides as ‘pollutants’. Within this report we explicitly mean enhanced concentrations of, or exposures to, these pollutants, which are derived from human activities (directly or indirectly) in the Great Barrier Reef ecosystem or adjoining catchments.
The Reef	Great Barrier Reef
Reef Authority	Great Barrier Reef Marine Park Authority
Reef 2050 WQIP	Reef 2050 Water Quality Improvement Plan
Seagrass Index	Average score of the two seagrass condition indicators: Abundance and Resilience
Resilience indicator	Seagrass resilience indicator is calculated based on proportion of colonising species and the number of reproductive structures observed (inflorescence, fruit, spathe, seed)
Secchi depth	A measure of the clarity of water based on the Secchi disk.
TSS	Total suspended solids
Water types	Reef WT1, WT2 and WT3 refer to the classification of waterbodies with different colour characteristics and concentrations of optically active components, water quality indicators and light attenuation typically found in the Reef during the wet season.

Acknowledgements

The Great Barrier Reef Marine Monitoring Program (MMP) is a collaboration between the Great Barrier Reef Marine Park Authority, the Australian Institute of Marine Science (AIMS), James Cook University (JCU), and the Cape York Water Partnership, with important contributions from Traditional Custodians, the Reef Joint Field Management Program, Seagrass Watch and community volunteers.

We thank our long-term research partners and collaborators for their dedication to monitoring, evaluation and synthesis of science about the Great Barrier Reef. We also acknowledge the Australian Institute of Marine Science's Long-Term Monitoring Program (LTMP) for providing information that is integrated into our annual technical reports.

We would also like to thank our partners in the Paddock to Reef Integrated Monitoring, Modelling and Reporting program, of which the MMP is a component, for ongoing collaboration. Finally, we acknowledge the contextual information, including rainfall and sea-surface temperature data provided by the Australian Bureau of Meteorology, and river discharge data provided by the Queensland Government Department of Regional Development, Manufacturing and Water.

Executive summary

The Great Barrier Reef Marine Monitoring Program reports on the annual and long-term condition of inshore water quality, coral reef and seagrass ecosystems in the Great Barrier Reef (the Reef) with reference to 18 years of monitoring data. This summary presents the results for the 2022–23 monitoring year (1 October 2022 to 30 September 2023).

In the marine monitoring season of 2022–23, no cyclone crossed the inshore Reef, but significant river floods were detected in the northern regions. Above-average rainfall was predominantly concentrated in the Cape York region, northern Wet Tropics basins, Burdekin, and northern Mackay–Whitsunday basins in the 2022–23 wet season. Overall, rainfall and river discharge were just above the long-term median for the Reef, at about 1.4 times the long-term median. On a regional basis, discharge was either at or above the long-term median apart from the Burnett–Mary region, where it was below the long-term median.

Sea-surface temperatures over the 2022–23 summer were above the long-term median across the Marine Park. Temperatures moderated over summer and, while generally above median levels, were below those expected to cause coral bleaching. Temperatures within seagrass canopies across the inshore Reef were also slightly lower than the 2021–22 season, but still 0.4 degrees above long-term average.

Four components of the inshore marine environment were quantified by the Marine Monitoring Program in the 2022–23 season: water quality, pesticides, coral and seagrass conditions. Key results for the 2022–23 monitoring season are summarised below.

Water Quality

- Annual condition Index scores were ‘good’ in Cape York and ‘moderate’ in the Wet Tropics, Burdekin and Mackay–Whitsunday regions, and ‘good’ in the Fitzroy region (Figure 1). Scores were generally similar to the 2021–22 monitoring year, which is likely related to similar amounts of river discharge in both monitoring years.
- Long-term Index scores showed trends of improvement over the last five years in the Wet Tropics, Burdekin, and Mackay–Whitsunday regions (Figure 2).
- Chlorophyll *a* (Chl-*a*) met local water quality guideline values in all regions.
- Particulate phosphorus and nitrogen, dissolved phosphorus, and total suspended solids met local water quality guideline values in most regions.
- Nitrate/nitrite and Secchi depth did not meet water quality guideline values in any region.
- Most water quality indicators are showing trends of improvement or stability over the last five years, in contrast with trends of degradation in condition from 2008 to 2015 in many regions. The only exception is particulate nitrogen in the Tully sub-region, which has shown a trend of deterioration in recent years.
- Remote sensing analysis is used to characterise the Reef into three water types, depending on their water quality characteristics. In the 2022–23 wet season, the visible satellite images indicate that only four per cent of the total area of the Reef was exposed to Reef WT1 (brownish waters enriched in sediment and dissolved organic matter) and included mainly inshore areas. Approximately 21 per cent of the total Reef

area was exposed to Reef WT2 (greenish waters enriched in algae and dissolved organic matter) and 62 per cent of the total Reef area was exposed to Reef WT3 (greenish blue waters, low risk of detrimental ecological effects) (Figure 2).

- Building on these methods, the area exposed to a potential exposure risk to poor water quality in the 2022–23 monitoring year was estimated at nine per cent of the total area of the Reef (waters), representing an area of approximately 31,102 square kilometres. However, approximately 69 per cent of seagrasses were exposed to a potential risk of poor water quality, in contrast to only seven per cent of coral reefs.

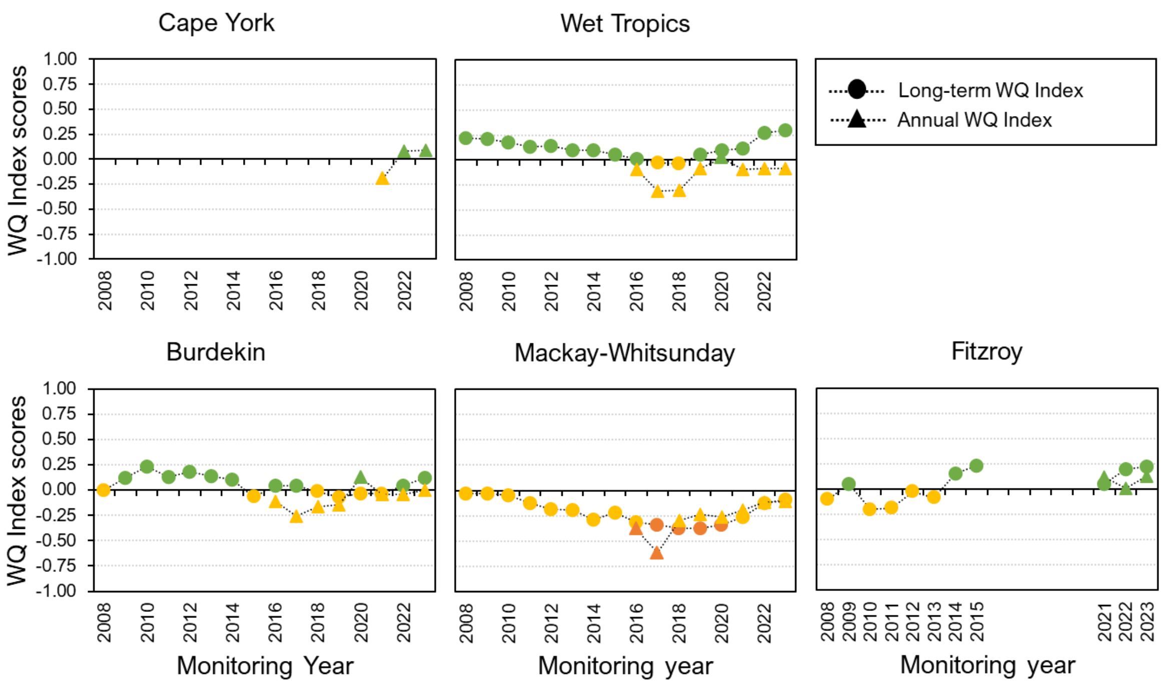

Figure 1. Trends in the regional Annual Water Quality (WQ) Index scores for the Cape York, Wet Tropics, Burdekin and Mackay–Whitsunday regions and Long-term WQ Index scores for the Wet Tropics, Burdekin, Mackay–Whitsunday and Fitzroy regions. Values are indexed scores scaled from -1.0 to 1.0 and graded: ■ = very good (1 to 0.5), ■ = good (0.5 to 0), ■ = moderate (< 0 to -1/3), ■ = poor (< -1/3 to -2/3), ■ = very poor (< -2/3 to -1). Note scores are unitless. Data source: Gruber *et al.* [1].

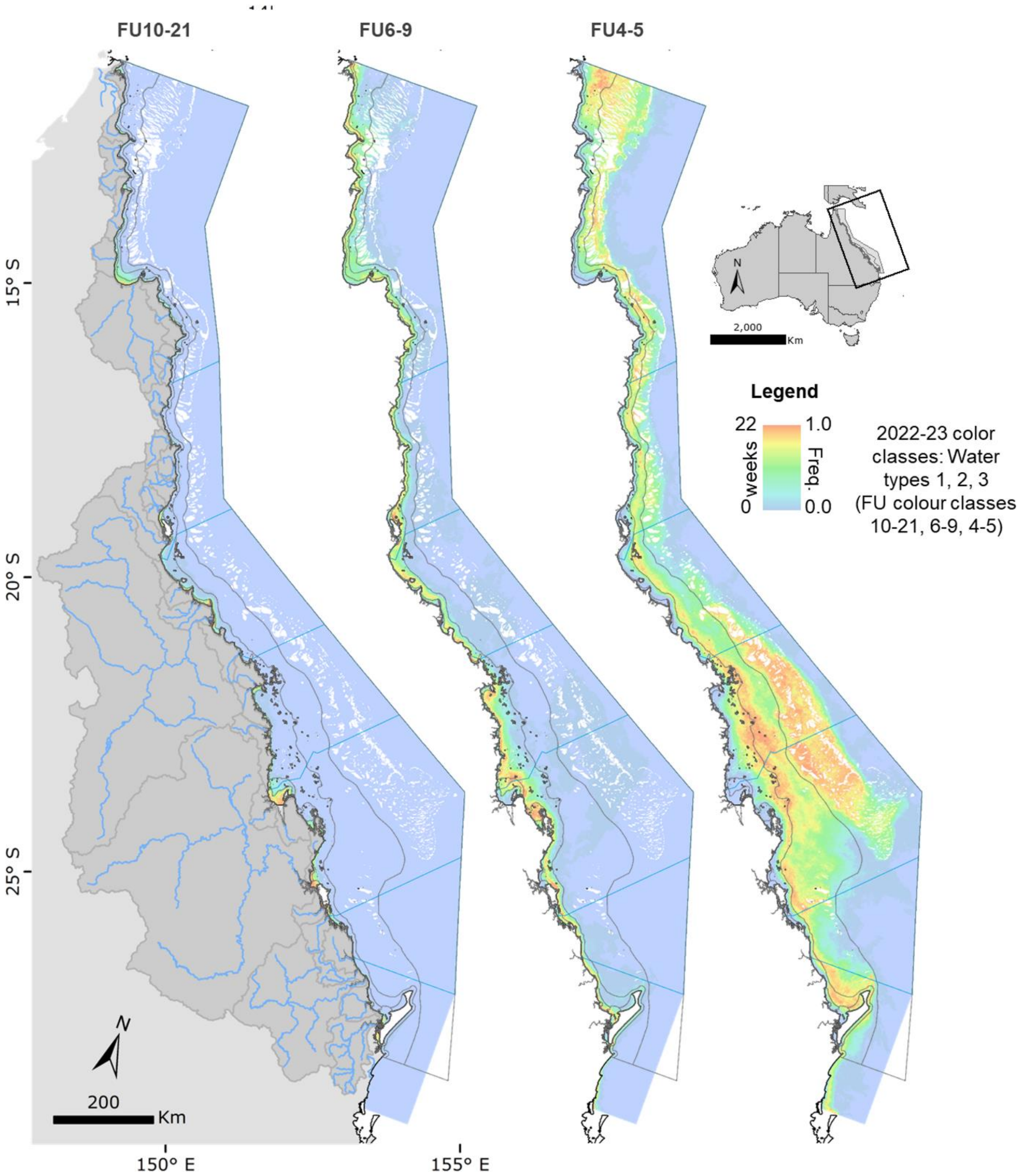

Figure 2. Map showing the frequency of Reef WT1, WT2 and WT3 in the 2022–23 wet season based on the weekly composites of satellite images. The highest frequency is shown in orange and the lowest frequency is shown in blue. These maps are used in the exposure assessment to represent the spatial likelihood of exposure of each of the wet season water types in 2022–23. Image extracted from Gruber *et al.* [1] .

Seagrass condition

Reef-wide inshore seagrass condition marginally declined, with the condition score remaining 'moderate', but with variation among regions (Figure 3). At a region level:

- Seagrass condition has improved in Mackay–Whitsunday, remained relatively stable in Cape York and Wet Tropics, and deteriorated in the remaining regions, particularly in the Fitzroy and Burnett–Mary.
- Seagrass Index scores across Cape York decreased slightly but remained 'moderate' due to lower scores in the resilience, which was predominately offset by improvements in the Abundance indicator.
- In the Wet Tropics, overall seagrass condition remained 'moderate' and stable. Meadows in the northern Wet Tropics improved from to 'good', while southern meadows remained 'poor'.
- Seagrass condition declined slightly but remained 'moderate' in the Burdekin region as meadows still recover from the effects of above-average discharge from rivers in early 2019. Above-average discharge resulted in further exposure of these meadows to turbid waters in 2022–23.
- Seagrass condition improved in the Mackay–Whitsunday region but remained 'moderate' despite river discharge being more than two times the long-term average.
- Seagrass Index scores for the Fitzroy and Burnett–Mary declined. Despite decline, seagrass condition remained in a 'poor' rating in the Fitzroy but declined further to 'very poor' state in the Burnett–Mary.

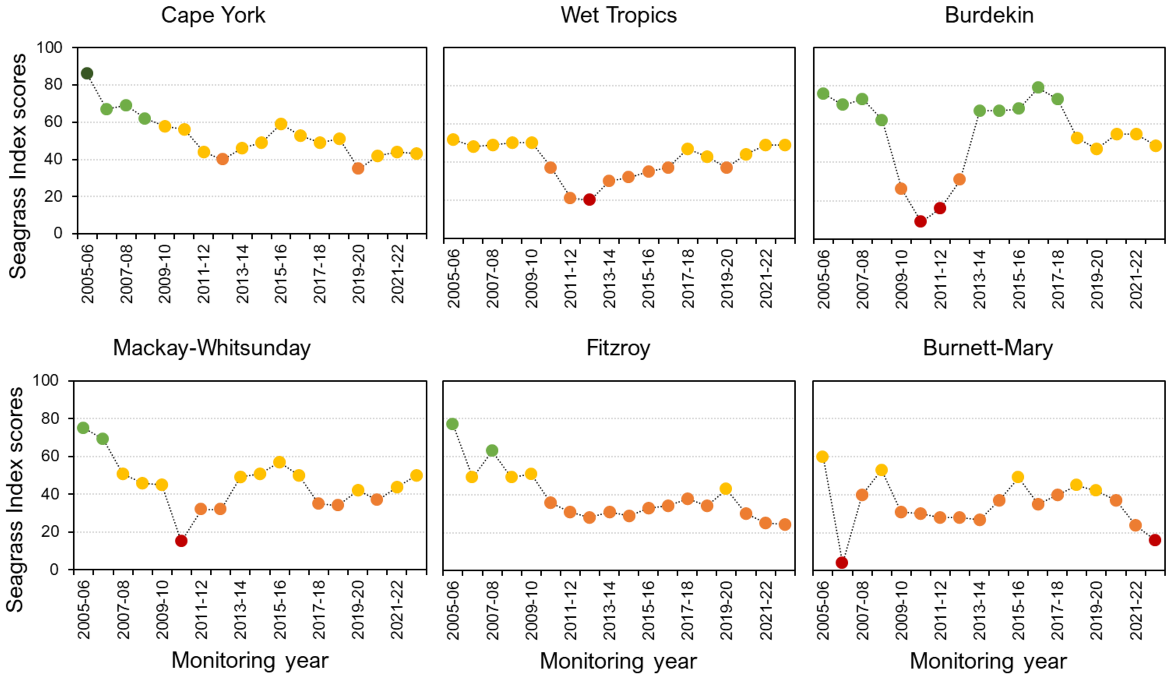

Figure 3. Temporal trend in regional Seagrass Index scores from 2005–06 to 2022–23. Values are indexed scores scaled from 0–100 and graded: ■ = very good (81–100), ■ = good (61–80), ■ = moderate (41–60), ■ = poor (21–40), ■ = very poor (0–20). Note scores are unitless. Data source: McKenzie *et al.* [2].

Coral condition

Reef-wide inshore reefs have remained in an overall 'poor' condition since 2019. However, there are regional differences, with northern regions faring better than their southern counterparts. At a regional level:

- Coral condition remains 'moderate' in the northern regions and 'poor' in the southern regions (Figure 4).
- In the Wet Tropics, Coral Index scores have remained 'moderate' and stable since 2016, with a slight decrease between 2022 and 2023.
- The Coral Index for the Burdekin region remained below a high point observed in 2020 but was still within the 'moderate' condition range.
- The Coral Index score in Mackay–Whitsunday region remained 'poor', although the Juvenile coral indicator continued to improve.
- In the Fitzroy region, the Coral Index score remained 'poor' in 2023 with no improvement following a period of recovery from 2014 to 2020.

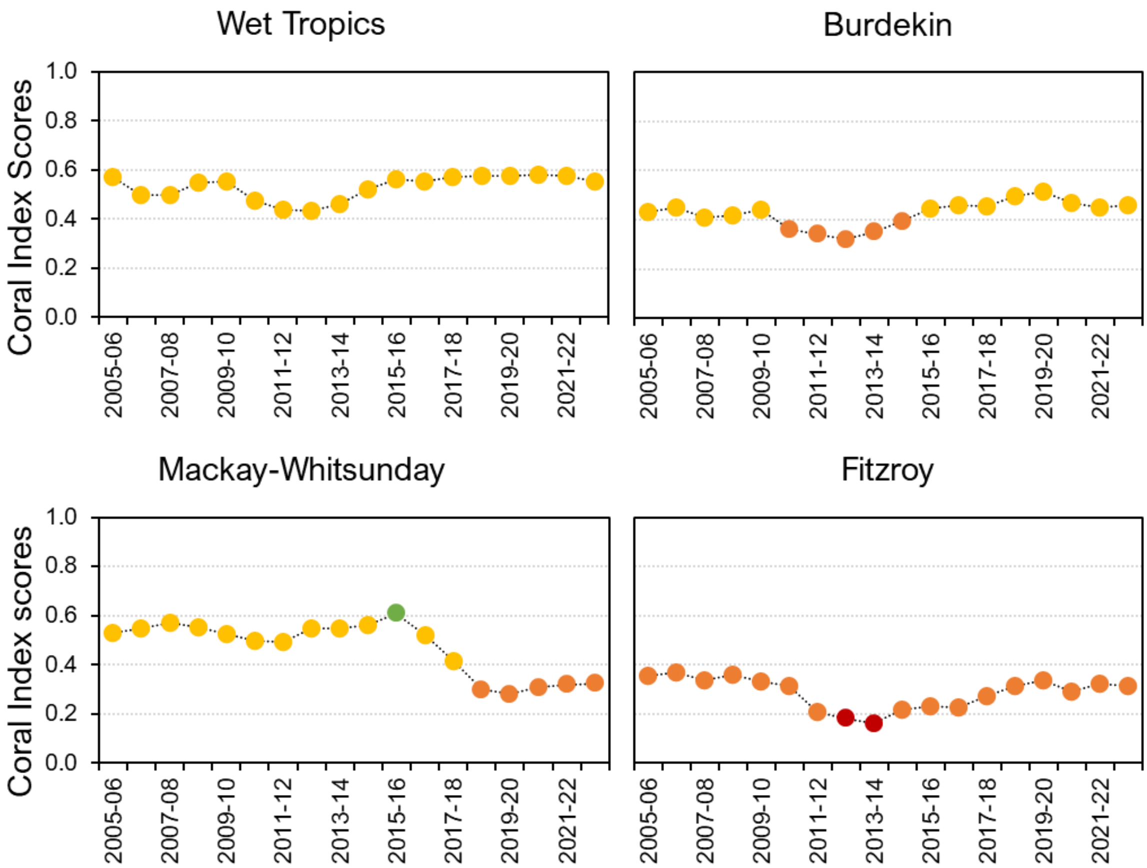

Figure 4. Temporal trend in regional Coral Index scores from 2005–06 to 2022–23. Values are indexed scores scaled from 0.00–1.00 and graded: ■ = very good (0.81–1.00), ■ = good (0.61–0.80), ■ = moderate (0.41–0.60), ■ = poor (0.21–0.40), ■ = very poor (0.00–0.20). Note scores are unitless. Data source: Thompson *et al.* [3]

Pesticides

Presence of pesticides, including herbicides and insecticides, was monitored using passive samplers and grab samples at 10 fixed monitoring sites in inshore areas between November 2022 and May 2023. Pesticides were detected at all sites, but the types varied. The most frequently detected pesticides in both passive samplers and grab samples were atrazine, diuron, hexazinone and tebuthiuron.

Pesticides were ubiquitously found in the inshore marine environment, however concentrations of individual pesticides did not exceed the default guideline values threshold of 99 per cent, which aims to protect 99 per cent of species, at the majority of sites except for one grab sample from Sarina Inlet collected in January 2023. Overall, total pesticide concentrations were highest at sites in the Mackay–Whitsunday region (Sarina Inlet, Flat Top Island, and Repulse Bay).

In addition to individual levels of toxicity for each pesticide, the risk posed by a mixture of these chemicals was also estimated through the calculation of the Pesticide Risk Metric (PRM). The PRM considers the cumulative impact of multiple pesticides within a sample, since ecosystems are often exposed to mixtures of pesticides rather than to individual pesticides. Based on this metric, in combination, pesticides posed a generally 'very low' risk, except in the sites in the Mackay-Whitsunday region, where the risk ranged from 'very low' to 'moderate'. For example, and it was around 15 per cent in the Whitsunday Channel site and the coastal site off Sarina Inlet, for example, reflecting pesticide usage and land management in the area.

Introduction

Water quality is a key issue for the health of the Great Barrier Reef (the Reef), its catchments and for the communities, industries and ecosystems that rely on good water quality [4]. Substantial investment is being undertaken to halt and reverse the decline of water quality entering the Reef by Australian and Queensland governments [5].

The Great Barrier Reef Marine Monitoring Program (MMP) was established in 2005 to assess the long-term status and health of inshore ecosystems. It is an integral component of the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program in the assessment of long-term improvement in regional marine water quality that will occur as best land management practices are adopted across catchments under the Reef 2050 Water Quality Improvement Plan [5].

The 2022–23 Synthesis Report summarises the latest results on the condition and trend of coral and seagrass, as well as water quality in the inshore areas of the Reef, and explores linkages to catchment runoff and other environmental pressures.

The information underpinning this Synthesis Report was provided by the 2022–23 Annual Reports, and are available on the Reef Authority's eLibrary:

- Gruber, R., Waterhouse, J., Petus, C., Howley, C., Lewis, S., Moran, D., James, C., Logan, M., Bove, U., Brady, B., Choukroun, S., Connellan, K., Davidson, J., Mellors, J., O'Callaghan, M., O'Dea, C., Shellberg, J., Tracey, D., Zagorskis, I. 2024. *Great Barrier Reef Marine Monitoring Program: Inshore Water Quality Monitoring Annual Report 2022–23*. Great Barrier Reef Marine Park Authority, Townsville. [1]

- McKenzie, L.J., Collier, C.J, Langlois, L.A., Brien, H., Yoshida, R.L. 2024. *Great Barrier Reef Marine Monitoring Program: Inshore Seagrass Monitoring Annual Report 2022–23*. Great Barrier Reef Marine Park Authority, Townsville. [2]

- Thompson, A., Davidson, J., Logan, M., Thompson, C. *Great Barrier Reef Marine Monitoring Program: Inshore Coral Reef Monitoring Annual Report 2022–23*. Great Barrier Reef Marine Park Authority, Townsville. [3]

- Kaserzon, S., Shiels, R., Elisei, G., Paxman, C., Li, Y., Carswell, C., Xia, S., Prasad, P., Gallen, M., Reeks, T., Thompson, K., Taucare, G., Marano, K., Gorji, S. G., Mueller, J. 2024. *Great Barrier Reef Marine Monitoring Program: Inshore Pesticides Monitoring Annual Report 2022–23*. Great Barrier Reef Marine Park Authority, Townsville. [6]

A brief overview of the design and methods of the MMP is provided in the next section of this report. For comprehensive information on each of the monitoring sub-programs, including objectives and detailed methods, refer to the individual sub-program reports cited above as well as the latest Marine Monitoring Program Quality Assurance and Quality Control Manual [7].

Methods

This section briefly describes the field methods used in the MMP to collect data on inshore marine water quality, and condition of coral and seagrass (Figure 5), and the list of water quality and ecosystem health indicators measured under the MMP. A subset of these indicators is used to calculate the inshore marine water quality, seagrass, and coral indices scores. Specific and detailed information on data analyses and calculation of the scores, synthesis and integration of data can be found in each of the annual reports, which are referenced above. The calculated coral and seagrass scores mentioned here are incorporated into the Reef Water Quality Report Card. However, the Water Quality Index scores reported here are a specific tool developed by AIMS for the MMP to visualise trends in the suite of water quality variables.

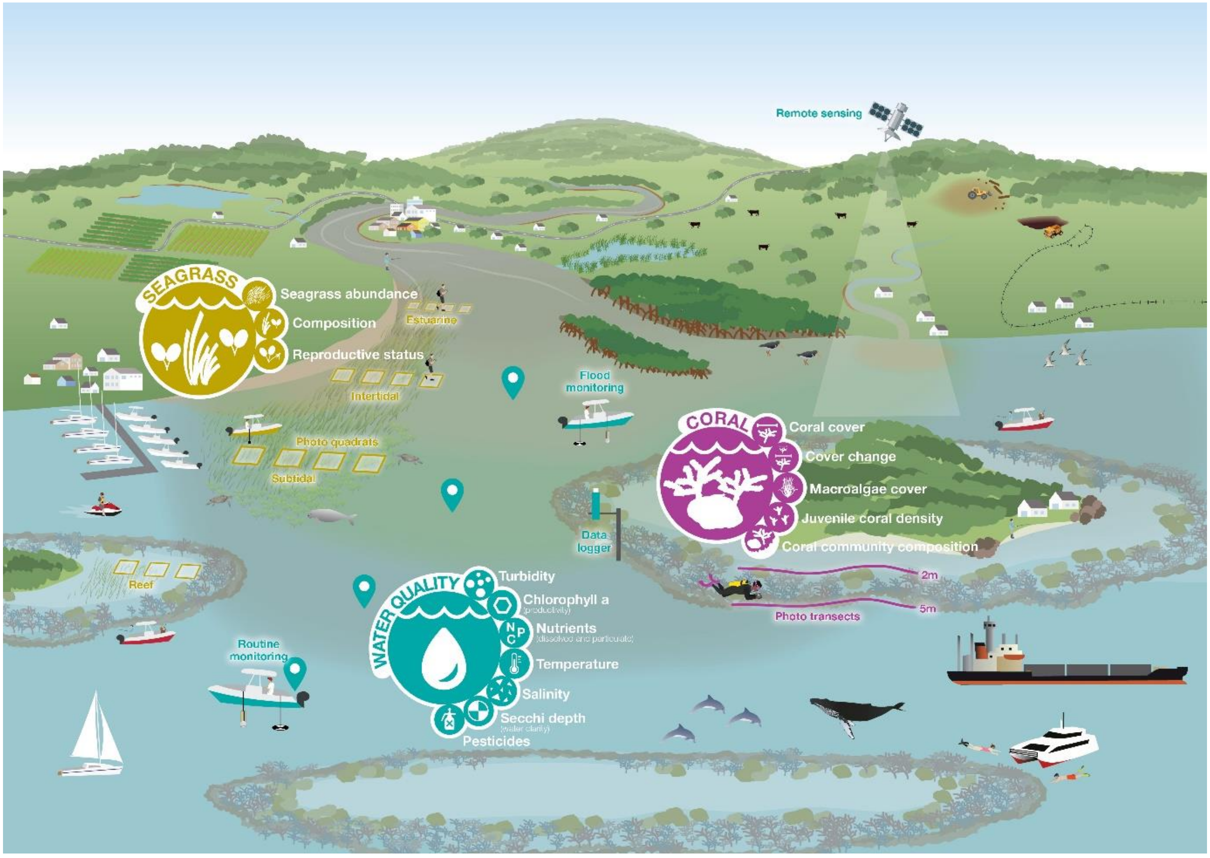

Figure 5. Conceptual diagram representing the main components monitored under the Marine Monitoring Program.

Water quality monitoring

Water quality monitoring is carried out in the inshore waters of Cape York, Wet Tropics, Burdekin, and Mackay-Whitsunday regions to assess changes over time in concentrations of relevant water quality indicators throughout the year (Figure 6) as part of the MMP. Water quality monitoring in the Fitzroy region is conducted through the Fitzroy Basin Marine Monitoring Program (more details below) and reported in the MMP Water Quality Annual Report. The MMP does not conduct water quality monitoring in the Burnett-Mary region.

Additionally, specific monitoring of the wet season includes direct sampling in flood plumes (resulting from river flood events) and analysis of satellite imagery. Detailed information on inshore marine water quality monitoring and data analyses can be found in Gruber *et al.* 2024[1].

Monitoring at inshore sites includes the following parameters:

- concentrations of dissolved and particulate nitrogen and phosphorus species
- turbidity, Secchi depth, and concentration of total suspended solids as a proxy for water clarity
- concentration of chlorophyll *a* as proxy for productivity
- temperature, salinity, and coloured dissolved organic matter
- remote sensing analysis to determine spatial and temporal variation in Reef water quality during the wet season, and the exposure of coral and seagrass ecosystems to terrestrial run-off.

A subset of these indicators is used to calculate the Water Quality Indices, measured against established local water quality guideline values [8]. Different water quality parameters are used to calculate the Water Quality Indices, which communicate the long-term trend (insensitive to year-to-year variability) and annual condition (sensitive to year-to-year variability) of water quality relative to those guideline values [1].

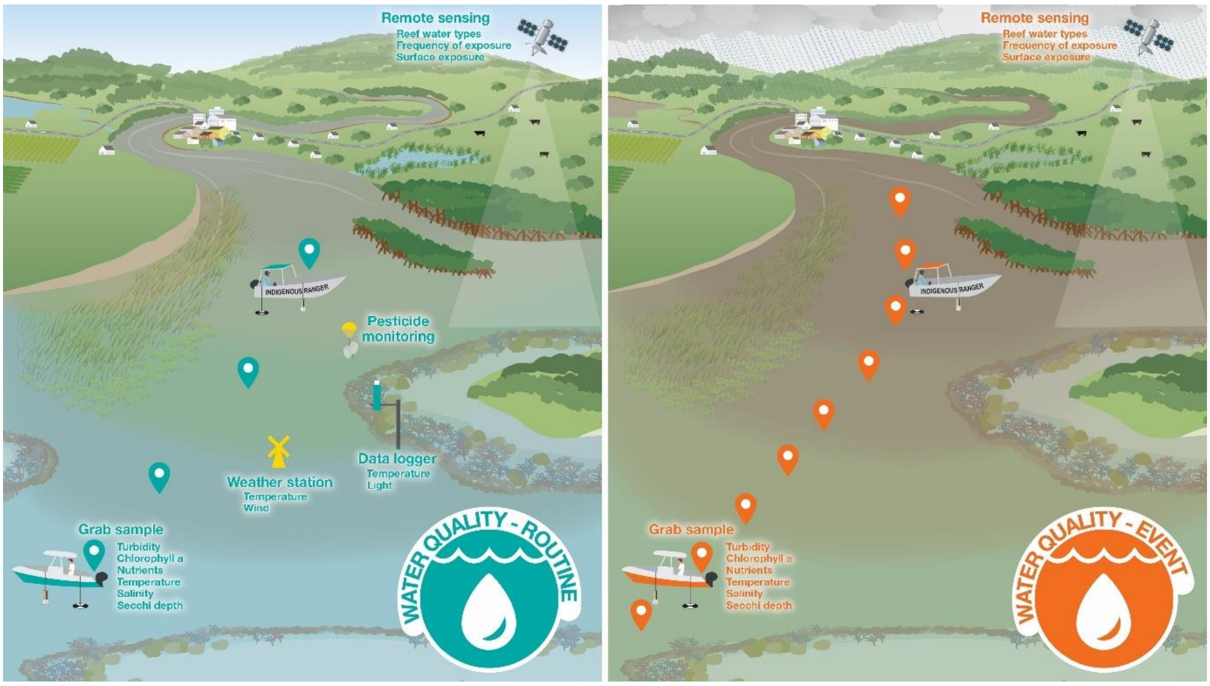

Figure 6. Water quality monitoring is routinely undertaken during wet and dry seasons (left), along permanent transects located from river mouths to open coastal areas. Additionally, monitoring of flood plumes is conducted during flood events (right).

Remote sensing

Satellite imagery is used to interpret where and when three specific water types, reflecting different water quality conditions, are present in the Reef during the wet season (22 weeks from November to May):

- Reef WT1—brownish, turbid waters, which are rich in sediment and dissolved organic matter from river flood plumes, typically found inshore in enclosed and open coastal waters.
- Reef WT2—less turbid part of flood plumes, which are greenish waters rich in algae and dissolved organic matter, typically found in open coastal and midshelf waters.
- Reef WT3—greenish-blue waters with suspended sediment slightly above ambient conditions and enriched with nutrients, typically found offshore towards the open sea.

Satellite imagery and modelling outputs are then linked with *in-situ* monitoring to estimate the exposure of inshore areas to end-of-catchment loads from rivers through exposure maps and assessment. The exposure assessment estimates the magnitude and likelihood of exposure to pollutants mapped through Reef WT1, WT2 and WT3. By overlaying the exposure maps with information on the spatial distribution of coral reefs and seagrass meadows, the areas and percentages of these ecosystems that may experience exposure to pollutants during the wet season can be identified [1]. The exposure categories are not validated against ecological health data and represent relative exposure and potential risk categories for seagrass and coral reef ecosystems. Category I (no or very low risk) represents waters with ambient or detectable but low pollutant concentrations and therefore low risk of any detrimental ecological effect. The areas and percentages of ecological communities affected by the different categories of exposure were calculated as a relative measure between sampling regions and comparison to the long-term average.

Pesticides

The 2022–23 monitoring season marked the re-instatement of inshore marine pesticide monitoring, after a brief one-year gap in the 2021–22 season. In the 2022–23 wet season, passive samplers were deployed at 10 fixed monitoring sites within the inshore Reef area, and was closely aligned with the original pesticide monitoring design that occurred between 2008 and 2018 where appropriate. The current pesticide sampling design was informed by an independent expert panel assembled by the Reef Authority with scientists from JCU, the Commonwealth Scientific and Industrial Research Organisation, the University of Queensland, and the Queensland's Department of Environment and Science. The current design was also informed by the latest scientific evidence on the distribution and trends of pesticides in the Reef [9,10]. The design includes the use of Empore™ Disk (ED) based passive water samplers, with collection of an *in-situ* grab sample when the samplers are retrieved. Grab samples represents a single-time snapshot of pesticide levels, and often fails to detect trace levels, but are efficient in detecting 'first flush' events. Passive samplers allows time for pesticides to be accumulated into the sampler, and resulting in a greater number of compounds to be detected. ED samplers are designed to detect the presence of hydrophilic organic chemicals with relatively low octanol-water partition coefficients, including photosystem II (PSII) inhibiting herbicides such as diuron, and are typically deployed for 4 to 5 weeks.

In the 2022–23 wet season, a total of 57 ED based passive water samplers (including 5 duplicates) were deployed between November 2022 and May 2023 at 10 fixed monitoring sites. The duration of deployments varied between 20 and 54 days. Monitoring sites were located at four locations in the Wet Tropics (Low Isles, High Island, Dunk Island, and Lucinda jetty), two locations in the Burdekin region (Haughton River Mouth and Euri Creek), and four in the Mackay–Whitsunday region (Whitsunday Channel, Repulse Bay, Flat Top Island, and Sarina Inlet). A total of 56 grab samples were collected from the 10 fixed sampling sites upon retrieval of passive samplers. Additionally, 26 flood monitoring grab samples were collected at additional sites in Cape York and Mackay–Whitsunday regions during event monitoring in January 2023.

In the 2022–23 monitoring season, a suite of 25 pesticides were analysed including PSII inhibiting herbicides such as diuron, atrazine and its metabolites, ametryn, hexazinone, and tebuthiuron. These PSII-inhibiting herbicides negatively affect photosynthesis and are commonly detected due to their, high usage in adjacent catchments, and their high solubility. Other pesticides monitored include those that have non-photosynthetic effects such as the insecticide imidacloprid and metolachlor, and knockdown herbicides such as 2,4-D. Detailed information on inshore marine pesticide monitoring and data analyses can be found in Kaserzon *et al*. 2024 [6].

Using results from passive samplers from each monitoring site, the Pesticide Risk Metric (PRM) [11,12,13] was calculated utilising the available quantified pesticides with concentrations above the detection limit. The PRM was designed for the Reef, and its values are useful to assess the risk of pesticides (and pesticide mixtures) in the Reef. The risk is expressed as the percentage of species potentially affected (or conversely, protected) by the combined toxicity of a selection of 22 pesticides [11], including many quantified here.

Seagrass monitoring

Monitoring of seagrass extent and condition is conducted in all six NRM regions and covers each major seagrass habitat type where possible: estuarine, coastal intertidal, coastal subtidal, reef intertidal and reef subtidal (Figure 7). Detailed information on inshore seagrass monitoring and data analyses can be found in McKenzie *et al*. 2024 [2].

Monitoring occurred at sites in the late dry season (September–November 2022) and late wet season (March–April 2023). In summary, monitoring occurred in 69 sites across 30 locations assessed during the 2022–23 monitoring season. In each site, two indicators were assessed:

- Abundance—an assessment of the average percentage cover of seagrass per monitoring site in relation to the Seagrass Abundance Guidelines (McKenzie 2009).
- Resilience—an assessment of reproductive effort, species trait, relative meadow extent and density of seeds in the seed bank, which are used to infer capacity of a meadow to resist or recover following a disturbance event.

These indicators are weighed equally and used to calculate the Seagrass Index score.

The site sampling strategy covered 14 coastal, four estuarine and 12 reef locations (two or three sites at each location). Reef intertidal sites in the Burdekin and Wet Tropics were paired with a subtidal site [2].

At each location, apart from subtidal sites, sampling included two sites nested within 500 metres of each other. Subtidal sites were not always replicated within locations. Intertidal sites were defined as a 5.5 hectare area within a relatively homogenous section of a representative seagrass community/meadow.

Figure 7. Seagrass meadows are monitored in coastal and reefal habitats of the inshore region using metrics to assess abundance and resilience.

Coral reef monitoring

Monitoring of inshore coral reef communities occurs yearly at reefs adjacent to four regions: Wet Tropics, Burdekin, Mackay–Whitsunday and Fitzroy. No reefs in Cape York region are included due to logistic and occupational health and safety issues relating to diving in coastal waters in this region. In addition, there is little coral reef development in inshore waters of the Burnett–Mary region, and therefore there are no established monitoring sites in this area. Detailed information on inshore coral reef monitoring and data analyses can be found in Thompson *et al*. 2024 [3].

Thirty reefs are monitored at two metre and five metre depth, with an additional eight inshore reefs monitored at a single depth under the AIMS Long-Term Monitoring Program. All are included in the annual assessment of coral condition. Coral monitoring for the 2022–23 report occurred between April and August 2023 allowing detection of any impacts from disturbances common in the wet season, such as bleaching and cyclones.

At each monitoring site, five 20 metre-long transects were deployed at each depth and five indicators assessed using methods detailed in Thompson *et al.* 2024 (Figure 8):

- hard and soft coral cover
- number of juvenile hard coral colonies (up to 5 centimetres diameter)

- proportion of macroalgae cover within the cover of all benthic algae
- rate of change in coral cover (as an indication of the recovery potential of the reef following a disturbance)
- coral community composition

These indicators were weighed equally and used to calculate the Coral Index score.

Figure 8. The condition of inshore coral reefs is assessed along fixed transects to monitor abundance and composition of key benthic organisms (soft coral, hard coral, and macroalgae) and hard coral recruitment.

Reef-wide environmental conditions

Rainfall and riverine discharge

Wet season (December to April) rainfall in the 35 major basins that discharge into the Reef in 2022–23 was similar to the long-term average of wet seasons from 1961–1990. Above-average rainfall was predominantly concentrated in the Cape York region, northern Wet Tropics basins, Burdekin, and northern Mackay–Whitsunday basins in the 2022–23 wet season (Figure 9).

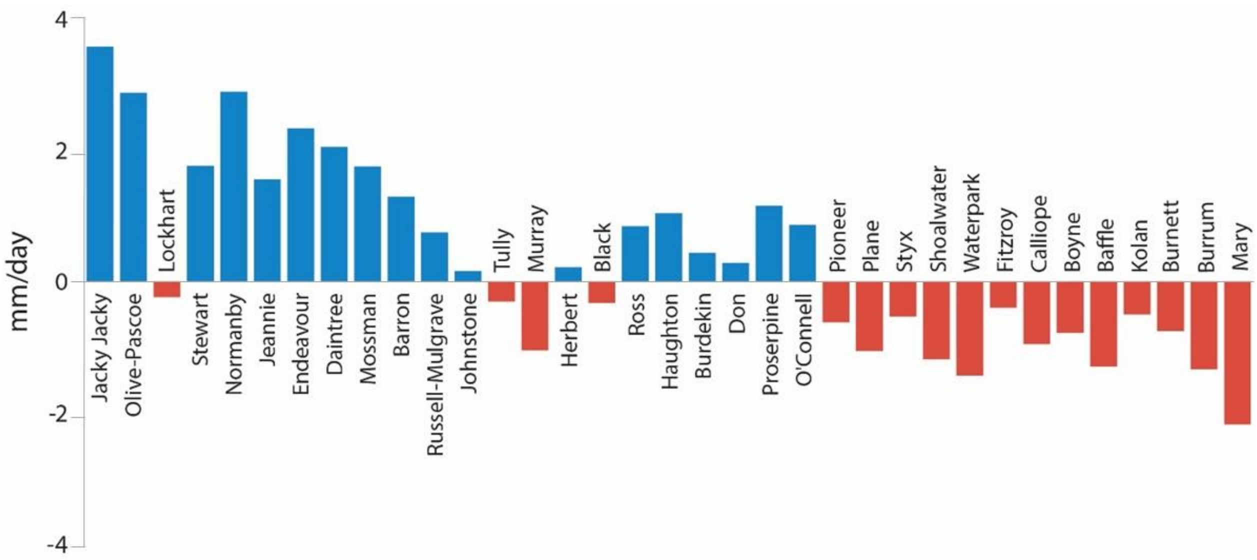

Figure 9. Difference between daily average wet season rainfall (December 2022–April 2023) and the long-term wet season rainfall average (from 1961–1990). Red and blue bars denote basins with rainfall below and above the long-term average, respectively. Note that the basins are ordered from north to south (left to right). Image extracted from Gruber *et al.* [1].

Freshwater discharge volumes into the Reef are typically closely related to rainfall during the wet season and can have a significant influence on coastal and inshore water quality. In 2022–23 season, the overall Reef catchment area had discharge just above the long-term median (1.4 times the long-term median). On a regional basis, discharge was either at or above the long-term median except for the Burnett–Mary region. Several regions had discharge well above the long-term median including the Cape York (2.1 times higher than long term median), Burdekin (2.1 times higher), and Mackay–Whitsunday (2.0 times higher) regions. The discharge in the Wet Tropics (1.2 times above) and Fitzroy (1.1 times above) regions were just above the long-term median while the Burnett–Mary was below the long-term median discharge (0.8 times the long-term median).

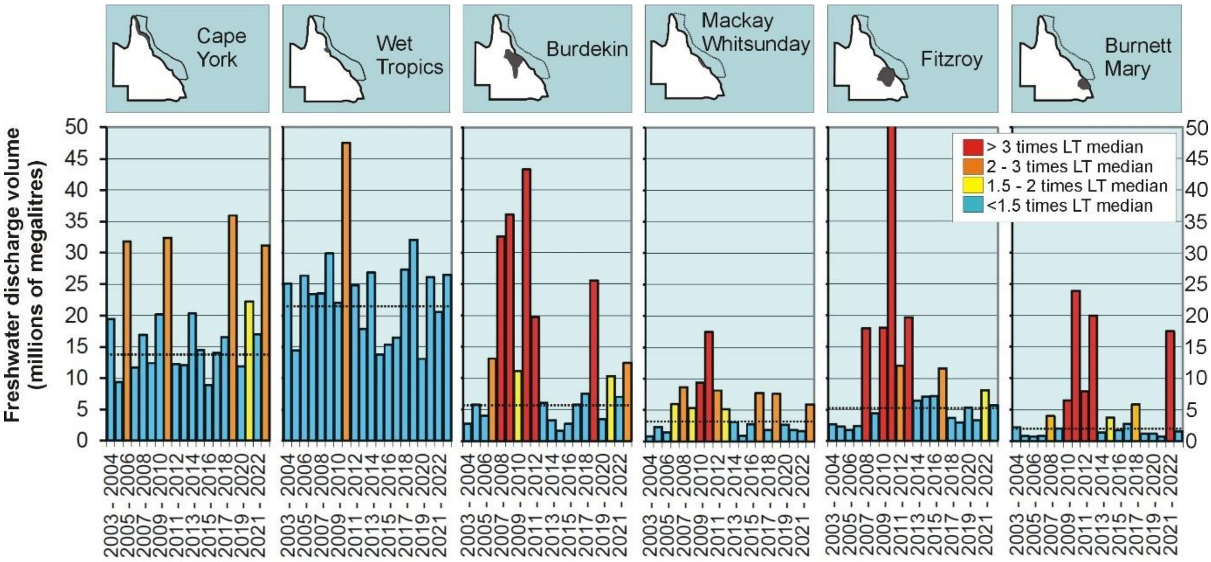

Figure 10. Corrected annual water year (1 October to 30 September) discharge from each region for 2003–04 to 2022–23. Image extracted from Gruber *et al*. [1]

Sea-surface temperature

Sea-surface temperatures over the 2022–23 summer were above long-term averages, but below accepted thresholds of 60 to100 degree heating days or four-degree heating weeks that are likely to lead to significant coral bleaching [3] (Figure 11). Daily within-canopy seawater temperature across the inshore Reef was slightly lower than in 2021–22. Since 2013, the frequency of weekly warm water deviations appears to have increased, relative to cooler occurrences. The 2022–23 average temperature was 0.4 degrees Celsius above the long-term (2003–2022), however there were regional differences and variability among habitat types [2].

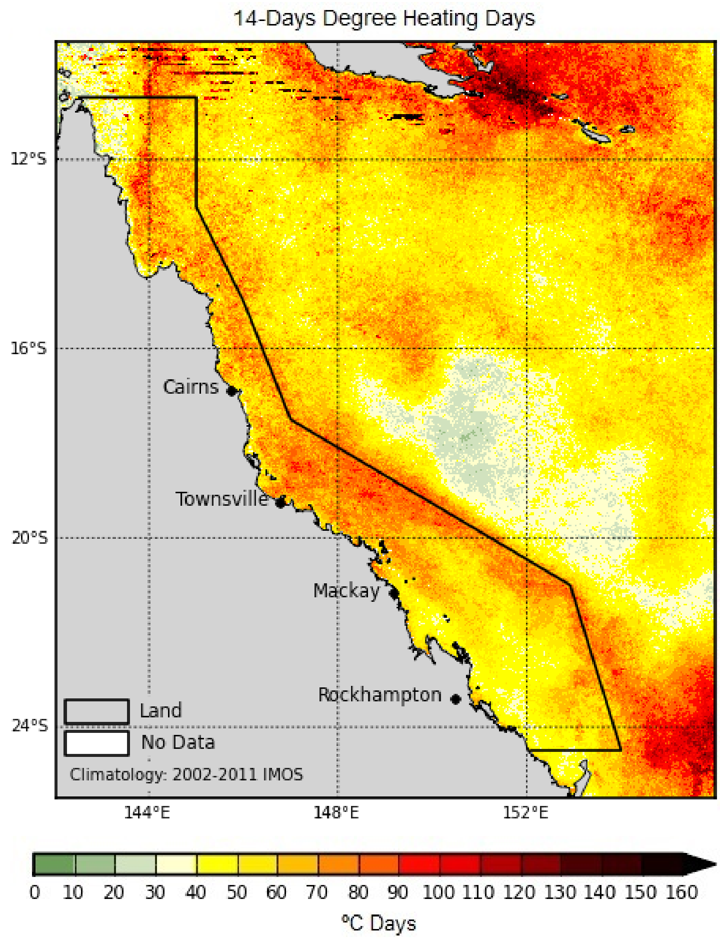

Figure 11. Sea-surface temperature (SST) presented as annual degree heating days estimates for the Reef. Annual degree heating day accumulation over the summer period (1 December to 31 March) for 4km^2 pixels based on temperatures exceeding the 14-day IMOS climatology mosaic. Data extracted from the Australian Bureau of Meteorology ReefTemp website.

Regional summaries

This section expands on the condition and trends of water quality, seagrass and coral at a regional level, primarily through the presentation of the condition index scores and the indicators that inform the indices. A brief summary of key environmental condition is also provided.

Cape York

In the 2022–23 monitoring season, *in-situ* water quality monitoring was conducted at 20 routine sites, sampled four to five times per year during ambient conditions. The Cape York region is subdivided into four sub-regions: the Pascoe, Stewart, Normanby, and Annan-Endeavour. Flood event monitoring was also conducted from December to March along the Normanby and Annan-Endeavour River transects. Seagrass was monitored in seven locations (Figure 12) in the late dry season. The MMP does not monitor coral reefs in the Cape York region.

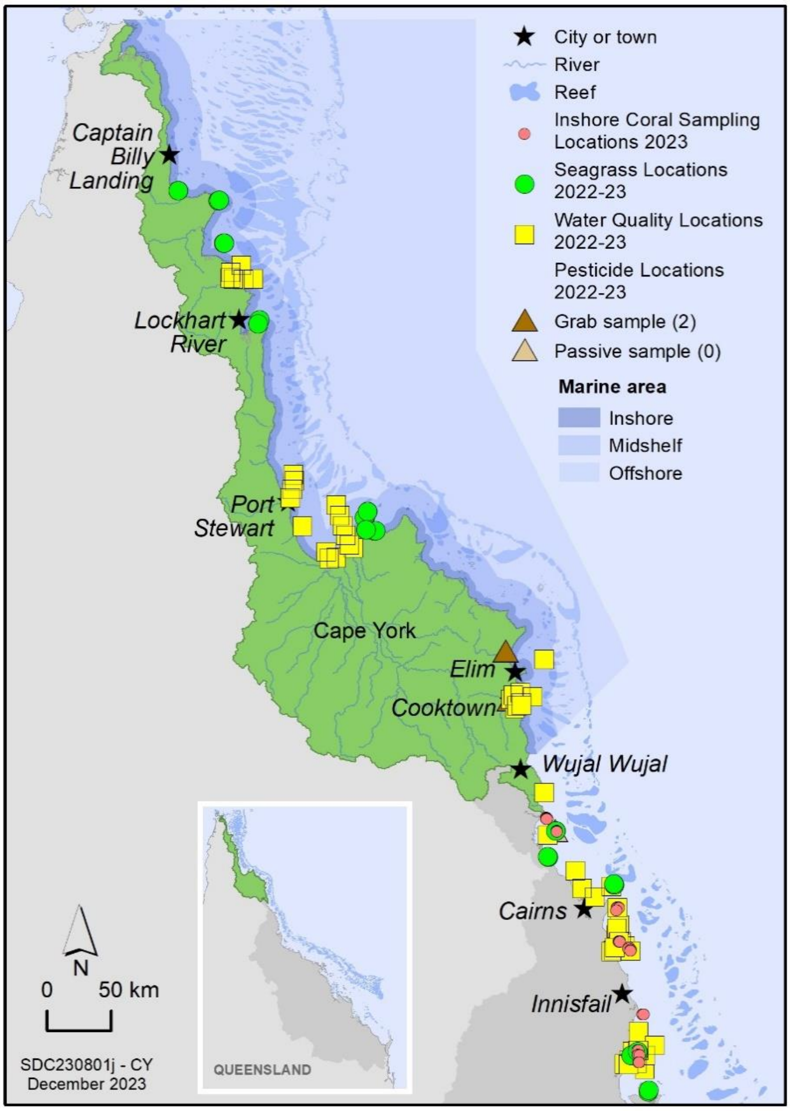

Figure 12. Water quality and seagrass sampling sites in the Cape York region shown with waterbody boundaries. Note coral monitoring is not conducted in Cape York as part of MMP.

Environmental conditions

Wet season rainfall and annual river discharge were above the long-term average for the region, between 1.5 to 2 times higher. In the Normanby River, freshwater discharge was slightly over three times the long-term median [1].

Water temperature within seagrass canopy was above long-term average for the third consecutive year and were 0.3 degrees Celsius above the decadal long-term average [2].

Water quality

The Annual Water Quality Index score for the Cape York region was 'good' for the 2022–23 monitoring year (Figure 13).

Key results:

- Chl-*a* concentration, total suspended solids (TSS), and particulate phosphorus (PP) met the water quality guideline values at most sites for all Cape York sub-regions.
- Nitrate/nitrite (NO_x) exceeded the guideline values at most sites and sub-regions.
- Secchi depth did not meet the minimum guideline values at most sites and sub-regions. However, monitoring occurred primarily during the wet season and mean averages are compared against annual guidelines.
- Annual Condition Water Quality Index scores for Pascoe and Anna-Endeavour sub-regions were 'good'. In the Pascoe, improvements in the score were primarily driven by reduction in concentration of particulates and improvements in clarity. While in the Annan-Endeavour, reduction in Chl-*a* concentration contributed to a 'very good' score for productivity.

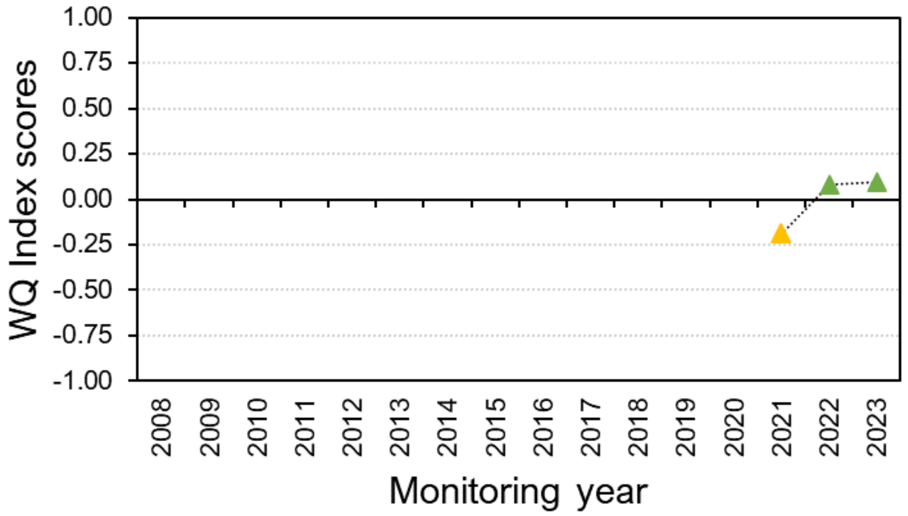

Figure 13. Temporal trends in the Annual Water Quality Index for the Cape York region from 2020–21 to 2022–23. Note that Water Quality monitoring started in the region in 2017, and only recently the Annual Index could be generated. Values are indexed scores scaled from -1.0 to 1.0 and graded: ■ = very good (1 to 0.5), ■ = good (0.5 to 0), ■ = moderate (< 0 to -1/3), ■ = poor (< -1/3 to -2/3), ■ = very poor (< -2/3 to -1). Note scores are unitless. Data source: Gruber *et al.* [1].

- Flood plumes and terrestrial runoff affected enclosed coastal, mid, and outer-reef areas of Cape York, and extended over 100 kilometres to the east beyond the outer reefs.
- It was estimated that 11 per cent of the Cape York region was exposed to a potential risk from degraded water quality. Approximately 14 per cent of the coral reef and 60 per cent of seagrass areas were exposed to a potential risk from degraded water quality.

Seagrass

During the 2022–23 monitoring year, the Seagrass Index score for the Cape York region declined slightly since the previous reporting period, with the overall grade remaining ‘moderate’ (Figure 14).

The Abundance indicator improved slightly between 2021–22 and 2022–23. The improvement in seagrass abundance was driven by increases at coastal intertidal and subtidal sites. Overall, the Resilience score deteriorated from moderate to poor. Reproductive structures continue to be rarely observed in Cape York in 2022–23 for the third consecutive year, which may hinder replenishment of the declining seed banks and weaken capacity to recover from seeds in the near future.

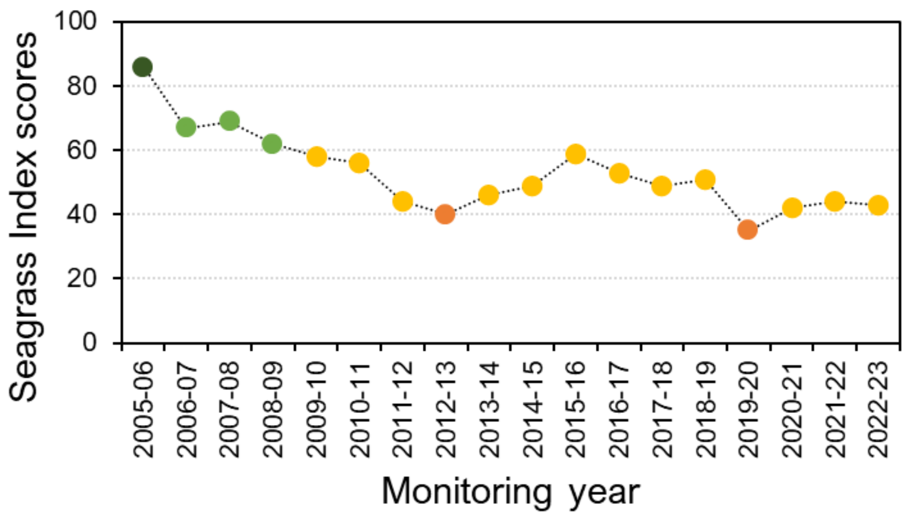

Figure 14. Seagrass Index scores for the Cape York region from 2005–06 to 2022–23. Black line with circles represents the index score and values are scaled from 0–100 and graded: ■ = very good (81–100), ■ = good (61–80), ■ = moderate (41–60), ■ = poor (21–40), ■ = very poor (0–20). Note, scores are unitless. Data source: McKenzie *et al* [2].

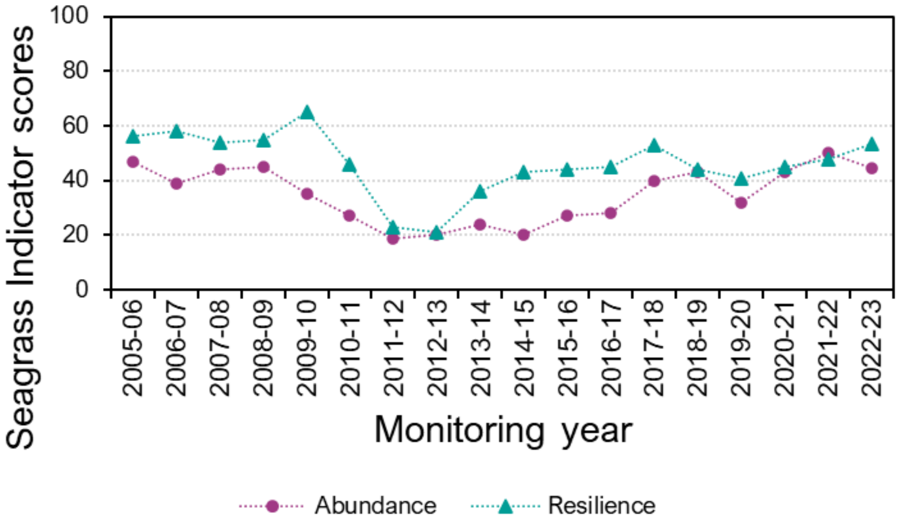

Figure 15. Seagrass Indicator scores of Abundance and Resilience for the Cape York region from 2005–06 to 2022–23. Scores values are scaled from 0–100 and graded: very good (81–100), good (61–80), moderate (41–60), poor (21–40), and very poor (0–20). Note, scores are unitless. Data source: McKenzie *et al* [2].

Wet Tropics

In the 2022–23 monitoring season, *in-situ* water quality monitoring was conducted at 17 routine sites, and sampled three to ten times per year during ambient conditions. Seagrass was monitored in six locations (Figure 16) in the late wet and late dry seasons, while corals were monitored at 12 sites in the dry season by the MMP and 2 sites by AIMS' Long-Term Monitoring Program (in the late wet season).

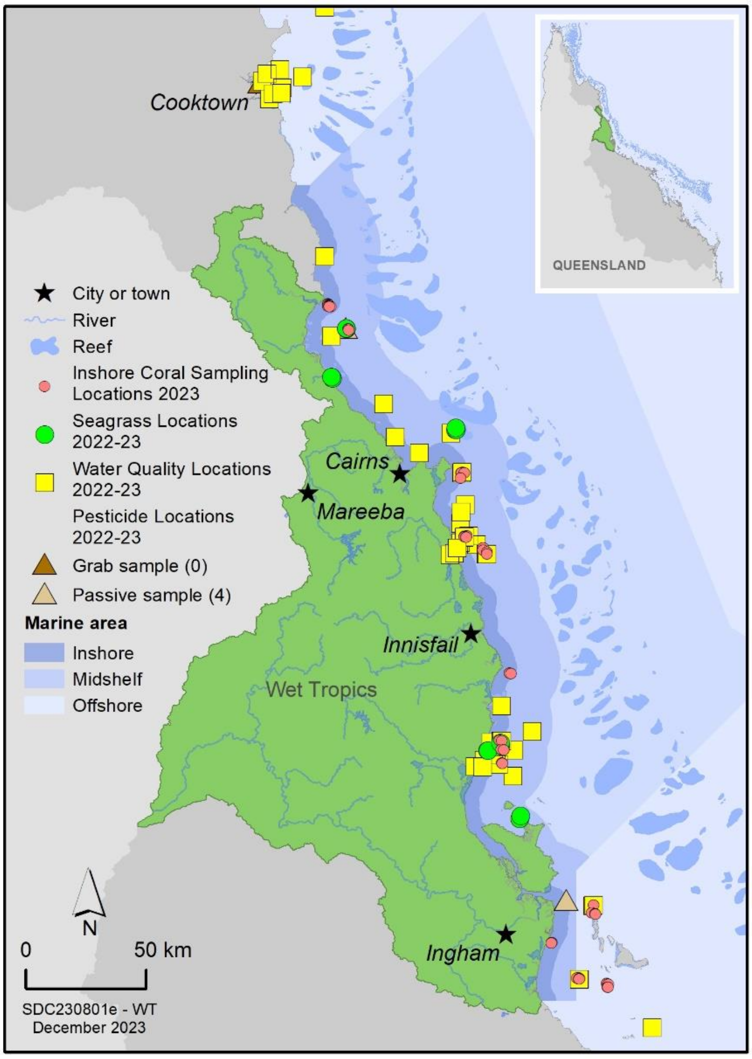

Figure 16. Map showing sampling sites in the Wet Tropics region. Note that water quality sites shown include flood event monitoring sites in addition to routine monitoring sites.

Environmental conditions

Discharge from the Daintree and Barron basins was 2.1 times the long-term median, while discharge from the Mossman, Russell–Mulgrave, Johnstone, Tully, Murray and Herbert basins was either close to the long-term median. Of the three sub-regions within the Wet Tropics, the Barron–Daintree Basin commonly contributes the lowest discharge and more consistent loads compared to the Johnstone–Russell–Mulgrave and Herbert–Tully sub-regions to the south. On average, annual rainfall was close to the long-term daily average across the Wet Tropics[1].

Sea-surface temperatures were above average but below the threshold known to cause coral bleaching [3]. Within-canopy water temperatures in the northern Wet Tropics were similar to the previous year and 0.5 degrees Celsius above average for the third consecutive year. In the southern sub-region, temperatures were similar to the long-term average [2].

Water quality

The Annual Water Quality Index score for the Wet Tropics region was 'moderate' for the 2022–23 monitoring year, but variations were detected among the sub-regions. The Barron–Daintree sub-region score was 'good', while the Johnstone–Russell–Mulgrave and Herbert–Tully sub-regions were scored 'moderate' (Figure 17). Detailed information on water quality results for each sub-region can be found in Gruber *et al.* [1]

Key results:

- Chl-*a* concentration, TSS, PP, and PO_4 met the water quality guideline values in all sub-regions.
- PN concentrations met water quality guideline values in the Barron–Daintree and Johnstone–Russell–Mulgrave, but not in the Herbert–Tully sub-region.
- NO_x exceeded the guideline values in all sub-regions but is improving in the Johnstone–Russell–Mulgrave and Herbert–Tully sub-regions.
- Secchi depth did not meet the minimum guideline values and an improving trend was only detected in the Johnstone–Russell–Mulgrave sub-region.
- Flood plumes and terrestrial runoff affected mainly enclosed coastal waters of the Wet Tropics.
- It was estimated that 11 per cent of the Wet Tropics region was exposed to a potential risk from degraded water quality. Approximately three per cent of the coral reef and 98 per cent of seagrass areas were exposed to a potential risk from degraded water quality.

The Long-term Water Quality Index trend has been improving across all sub-regions (Figure 17). The Long-term Water Quality Index in the Barron–Daintree and Johnstone–Russell–Mulgrave sub-regions was scored 'good'. In contrast, the Long-term Water Quality Index in the Herbert–Tully sub-region has improved from 'poor' to 'moderate' for the first time over the past seven monitoring seasons.

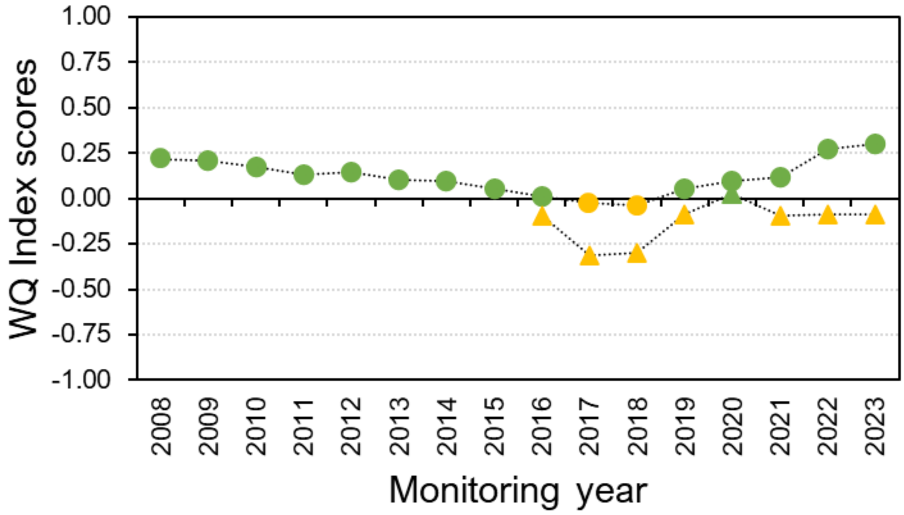

Figure 17. Temporal trends in the Long-term Water Quality Index and Annual Water Quality Index for the Wet Tropics region. Note that the annual Index is based on the post-2015 MMP sampling design and is sensitive to year-to-year variability, whereas the long-term Index is based on the pre-2015 review and it is insensitive to year-to-year variability. Values are indexed scores scaled from -1.0 to 1.0 and graded: ■ = very good (1 to 0.5), ■ = good (0.5 to 0), ■ = moderate (< 0 to -1/3), ■ = poor (< -1/3 to -2/3), ■ = very poor (< -2/3 to -1). Note scores are unitless. Data source: Gruber *et al.* [1].

Seagrass

During the 2022–23 monitoring year, the Seagrass Index score for the Wet Tropics region showed no change in the score, which remained 'moderate' (Figure 18). There was an increase in the Resilience indicator, and a decrease in the Abundance indicator. Northern and southern meadows were quantified and analysed separately as they diverge substantially in terms of seagrass meadow condition. While Resilience was rated 'moderate' in both northern and southern sites, Abundance was rated 'good' in northern sites and 'poor' in southern sites[2].

In the northern sites, seagrass Abundance deteriorated across the sub-region in 2022–23 relative to the previous period largely because of declines at some reef intertidal and subtidal sites. Exposure to reef water types WT1 and WT2 were slightly higher, which likely contributed to lower light levels, coupled with intertidal within-canopy temperatures above the long-term average in intertidal habitats for the third consecutive year. These conditions resulted in less favourable climatic conditions across the sub-region. However, Resilience increased in the north due to improvements in both coastal and reef intertidal habitats.

In the south, Abundance declined for the second consecutive year, which was mainly attributed to reductions in abundance in the coastal and reef subtidal habitats. In the south, Resilience slightly declined but was at the second highest level recorded to date in the southern area. This was due to slight decreases in the Resilience score at coastal intertidal sites where the meadow was below critical cover thresholds and comprised of only opportunistic species, which were not observed to be flowering.

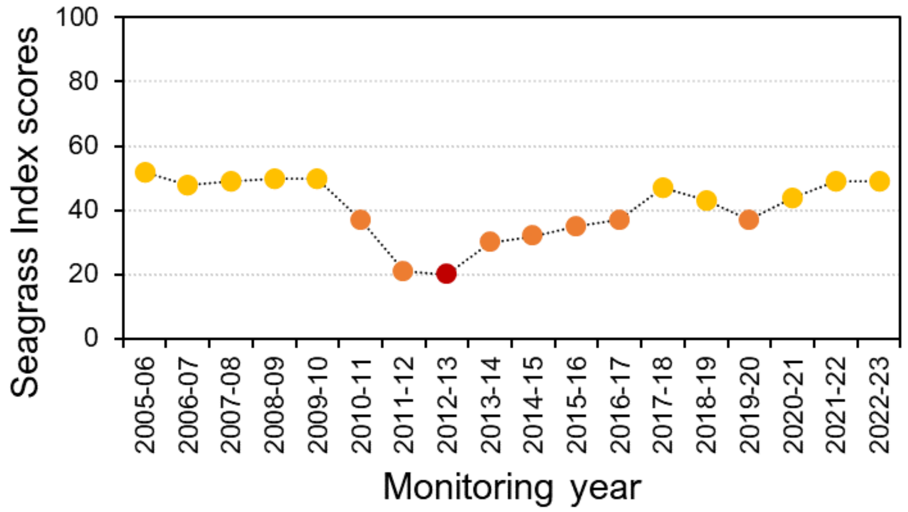

Figure 18. Seagrass Index scores for the Wet Tropics region from 2005–06 to 2022–23. Black line with circles represents the index score and values are scaled from 0–100 and graded: ■ = very good (81–100), ■ = good (61–80), ■ = moderate (41–60), ■ = poor (21–40), ■ = very poor (0–20). Note, scores are unitless. Data source: McKenzie *et al* [2].

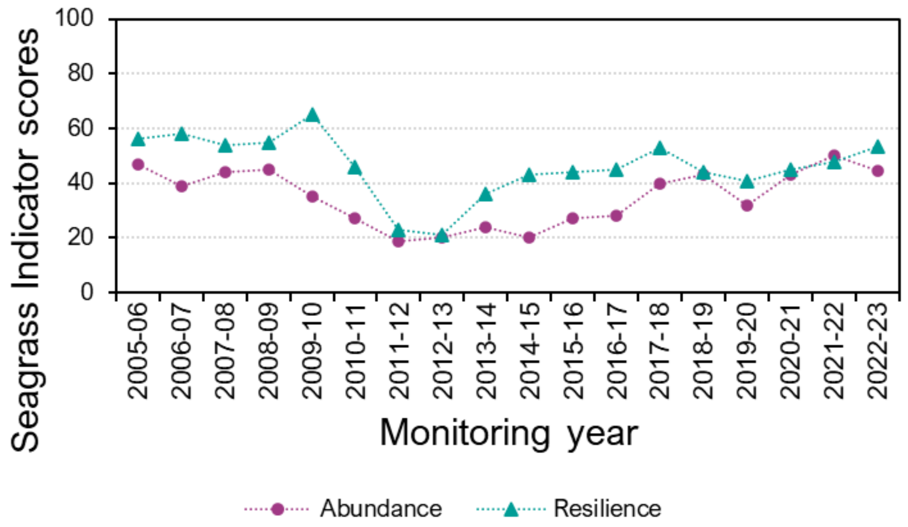

Figure 19. Temporal trends in the seagrass indicator scores of Abundance and Resilience for the Wet Tropics region from 2005–06 to 2022–23. Scores values are scaled from 0–100 and graded: very good (81–100), good (61–80), moderate (41–60), poor (21–40), and very poor (0–20). Note, scores are unitless. Data source: McKenzie *et al* [2].

Coral

Barron-Daintree

The coral community condition remained ‘moderate’ but has steadily improved since 2019 (Figure 20). Most indicators have shown signs of improvement since 2019, with the exception of Macroalgae. Coral cover across the region increased to over 50 per cent in the 2022–23 monitoring year and was scored ‘good’. The rate of coral cover increase was reflected in the 'good’ score for the Cover change indicator. Growth of *Acropora* in the region has driven the improvement in the Composition indicator from ‘poor’ to ‘moderate’. The cover of macroalgae remains high at Snapper North (2 m) and Snapper South (5 m), hindering improvements of the Macroalgae indicator which remains 'very poor' at these locations. The Juvenile indicator has remained in the 'poor' category due to declines in juvenile density at Low Isles countering increases at Snapper South (2 m).

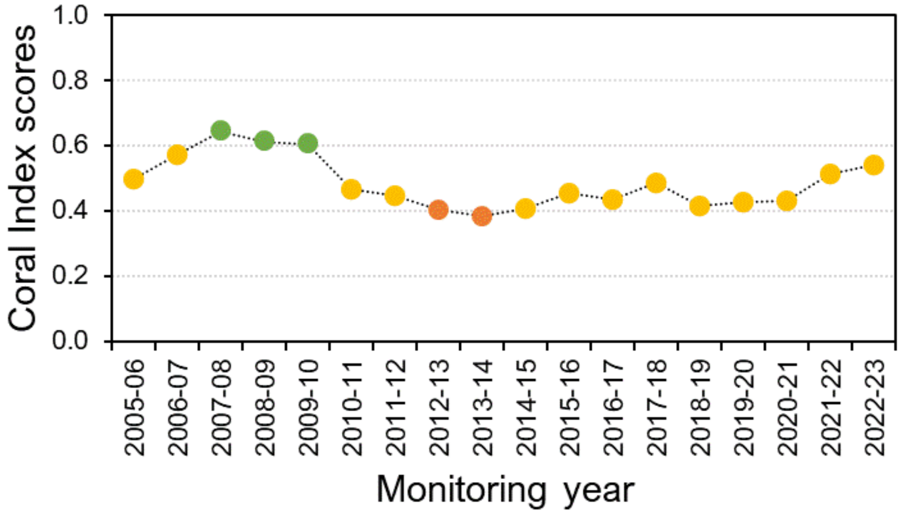

Figure 20. Temporal trend in Coral Index scores for the Barron-Daintree sub-region from 2005–06 to 2022–23. Values are indexed scores scaled from 0.0–1.0 and graded: ■ = very good (0.81–1.00), ■ = good (0.61–0.80), ■ = moderate (0.41–0.60), ■ = poor (0.21–0.40), ■ = very poor (0.00–0.20). Note, scores are unitless. Data source: Thompson *et al*. [3]

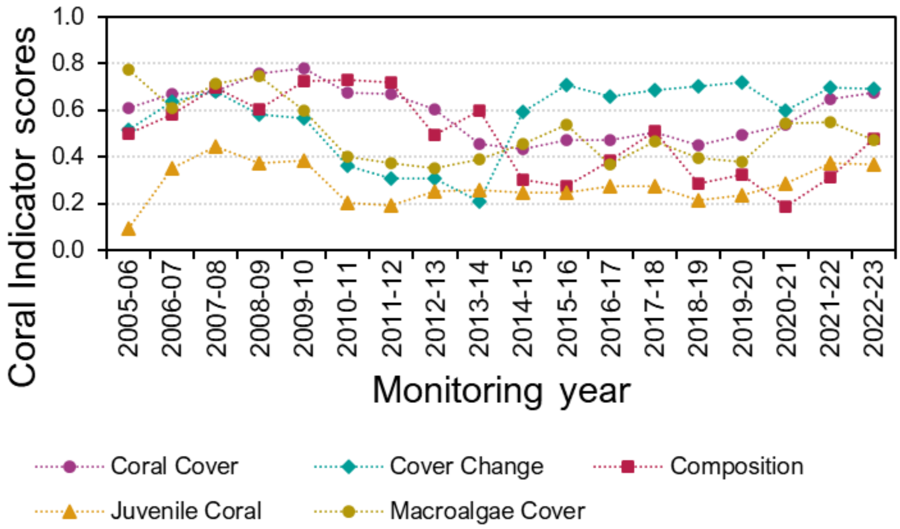

Figure 21. Temporal trends in coral indicator scores of Coral cover, Cover change, Composition, Juvenile coral, and Macroalgae for the Barron-Daintree sub-region from 2005–06 to 2022–23. Scores values are scaled from 0–1 and graded: very good (0.81–1.00), good (0.61–0.80), moderate (0.41–0.60), poor (0.21–0.40), and very poor (0.00–0.20). Note, scores are unitless. Data source: Thompson *et al* [3].

Johnstone-Russell-Mulgrave

The Coral Index score was categorised as 'moderate' for the second consecutive year (Figure 22). The slight decline in the 2022–23 monitoring season reflects declines in all indicators except for Juvenile coral. The most consistent declines contributing to the slightly lower score have been for the Macroalgae indicator and to a lesser extent the Cover change indicator. Presence of crown-of-thorns starfish remained at outbreak level at Franklands East.

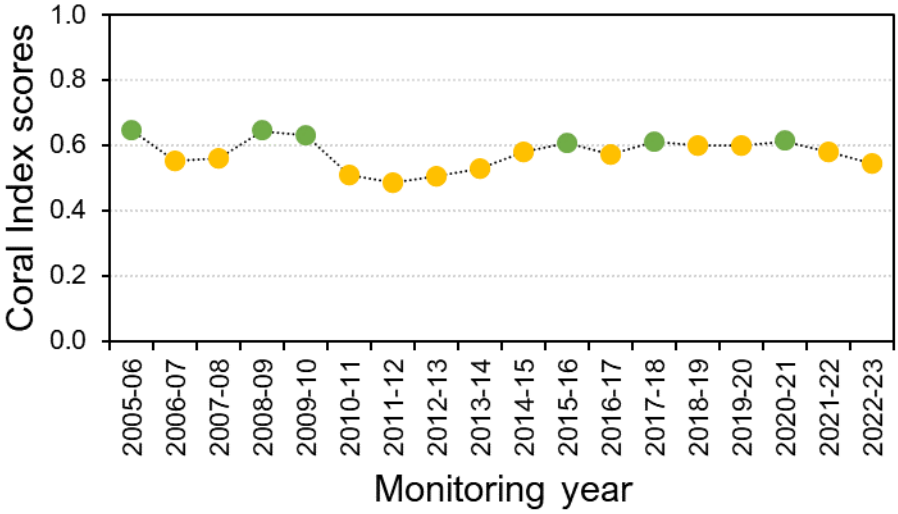

Figure 22. Temporal trend in Coral Index scores for the Johnstone-Russell-Mulgrave sub-region from 2005–06 to 2022–23. Values are indexed scores scaled from 0.0–1.0 and graded: ■ = very good (0.81–1.00), ■ = good (0.61–0.80), ■ = moderate (0.41–0.60), ■ = poor (0.21–0.40), ■ = very poor (0.00–0.20). Note, scores are unitless. Data source: Thompson *et al* [3].

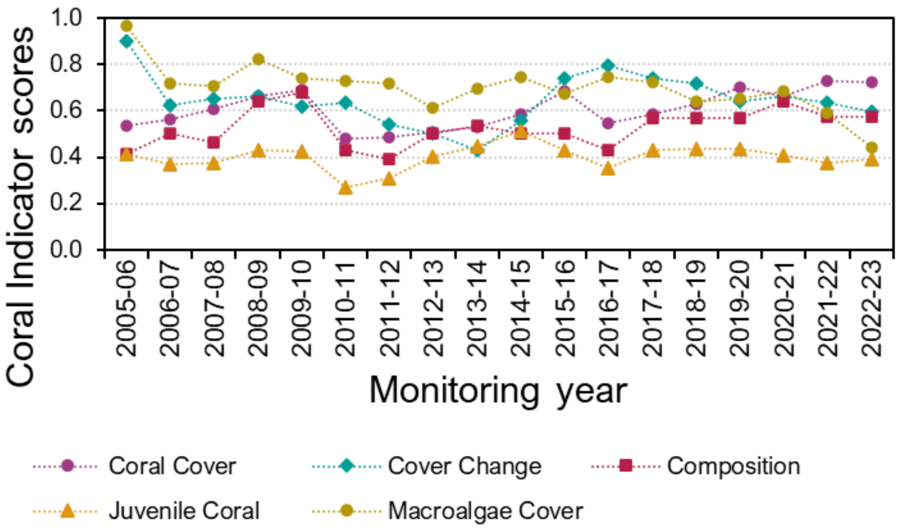

Figure 23. Temporal trends in the coral indicator scores of Coral cover, Cover change, Composition, Juvenile coral, and Macroalgae for the Johnstone-Russell-Mulgrave sub-region from 2005–06 to 2022–23. Scores values are scaled from 0–1 and graded: very good (0.81–1.00), good (0.61–0.80), moderate (0.41–0.60), poor (0.21–0.40), and very poor (0.00–0.20). Note, scores are unitless. Data source: Thompson *et al* [3].

Herbert-Tully

The Coral Index score has marginally declined but remained ‘moderate’ (Figure 24). Despite this decline, coral cover continues an upward trajectory. The Coral cover indicator score has been steadily increasing since 2011 but remained categorised as ‘moderate’.

The declining trend in Juvenile coral continued but remained in the 'good' range. The Juvenile coral indicator has been largely influenced by strong cohorts of *Turbinaria,* which recruited in the years following cyclone Yasi in 2011, which have now either died or grown out of the juvenile size classes. The scores for the Macroalgae indicator are highly variable within this region with persistent high cover of macroalgae in the shallows (2 m) at Dunk North and Bedarra where the score is 'very poor', whereas at Barnards the macroalgae cover is very low and the score is subsequently 'very good'.

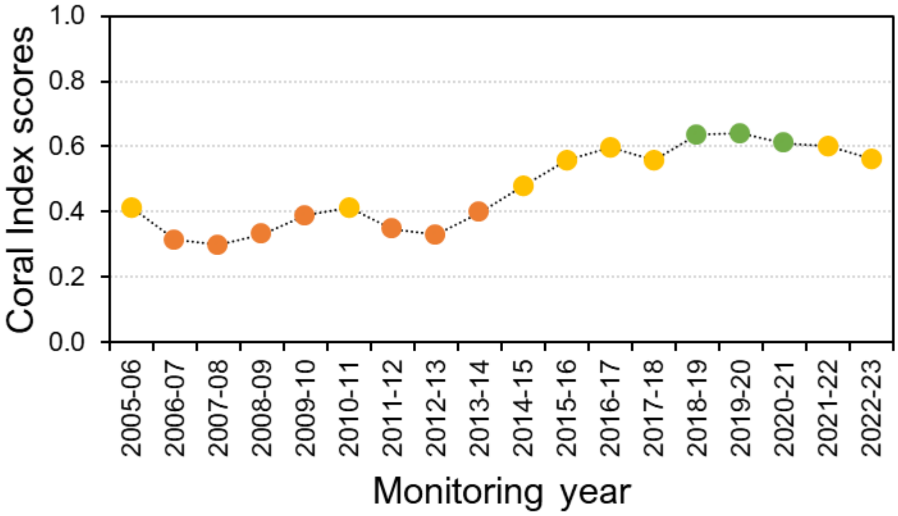

Figure 24. Temporal trend in Coral Index scores for the Herbert-Tully sub-region from 2005–06 to 2022–23. Values are indexed scores scaled from 0.0–1.0 and graded: ■ = very good (0.81–1.00), ■ = good (0.61–0.80), ■ = moderate (0.41–0.60), ■ = poor (0.21–0.40), ■ = very poor (0.00–0.20). Note, scores are unitless. Data source: Thompson *et al* [3].

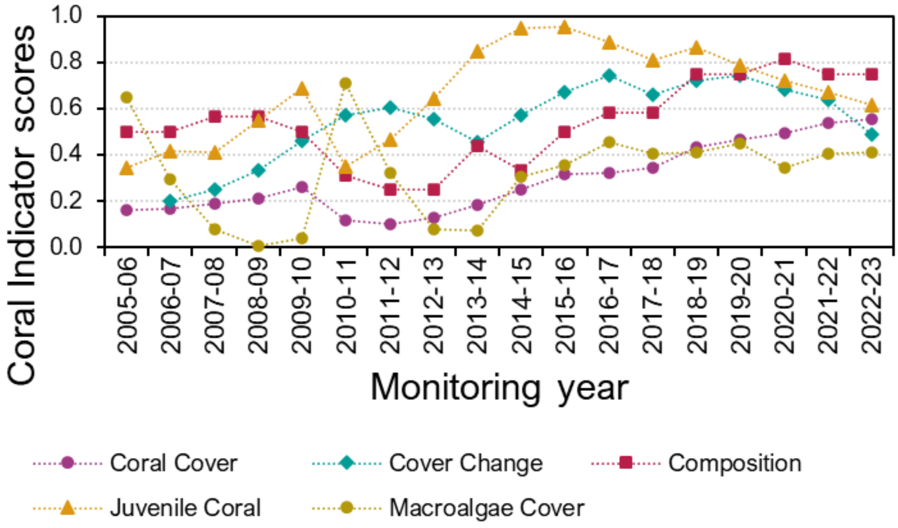

Figure 25. Temporal trends in the coral indicator scores of Coral cover, Cover change, Composition, Juvenile coral, and Macroalgae for the Herbert-Tully sub-region from 2005–06 to 2022–23. Scores values are scaled from 0–1 and graded: very good (0.81–1.00), good (0.61–0.80), moderate (0.41–0.60), poor (0.21–0.40), and very poor (0.00–0.20). Note, scores are unitless. Data source: Thompson *et al* [3].

Burdekin

In the 2022–23 monitoring season, *in-situ* water quality monitoring was conducted at six routine sites, sampled nine times per year during ambient conditions. Seagrass was monitored at six locations in the late wet and late dry seasons. Corals were monitored at six locations by the MMP, and at two locations by the AIMS' LTMP, all in the dry season (Figure 21).

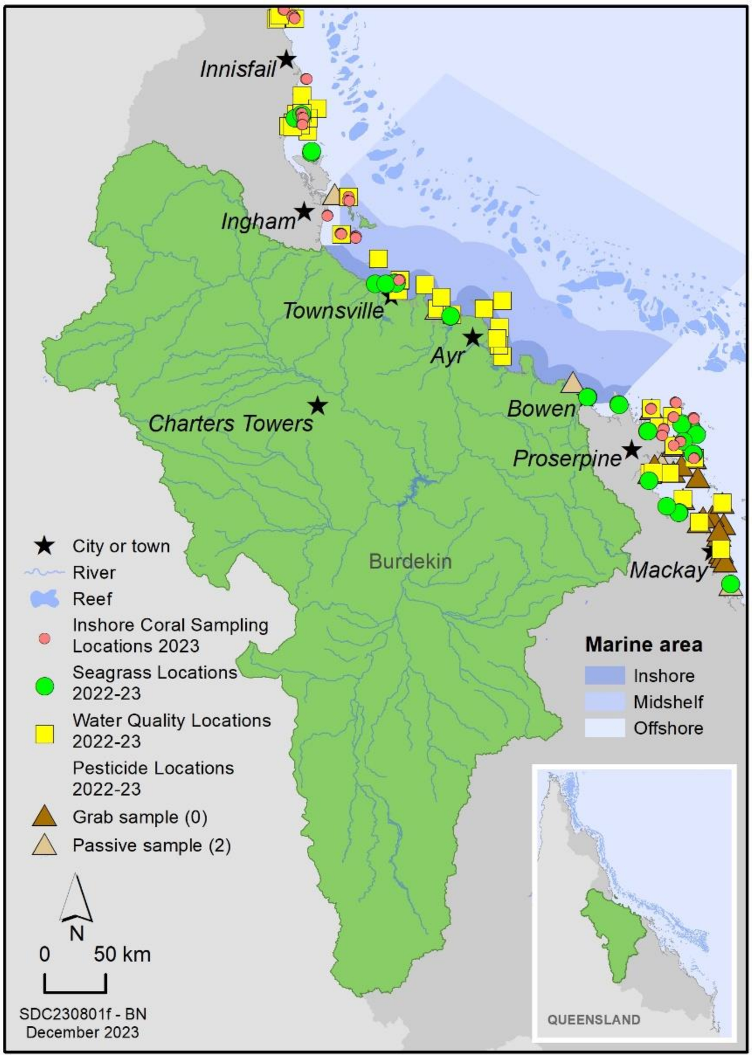

Figure 26. Map showing sampling locations in the Burdekin region. Note that water quality sites shown include flood event monitoring sites in addition to routine monitoring sites.

Environmental conditions

The combined discharge and loads calculated for the 2022–23 monitoring year from the Burdekin region were around 2.2 times the long-term median. The combined discharge and loads calculated for the 2022–23 water year from the Burdekin and Haughton Basins were in the lower range over the past decade. Wet season rainfall across the region was above the long-term average in most catchments [1].

Sea-surface temperatures were above long-term average but below levels that cause severe coral bleaching [3]. After the warmest period in 2021–22 since monitoring commenced, intertidal within-canopy temperatures decreased this year but remained above the long-term average[2].

Water quality

The Annual Water Quality Index for the Burdekin region scored 'moderate' for the 2022–23 monitoring year (Figure 27), which was similar to 2021–22.

Key results:

- Chl-*a* concentration, PP, PN, TSS, and PO_4 met the water quality guideline values and show trends of improvement since 2015.
- Clear seasonal differences were observed for some indicators such as NO_x, TSS, PN, and PP, where concentrations were higher during the wet than the dry season.
- NO_x exceeded the guideline values but is also showing an improving trend over the past few years.
- Secchi depth did not meet the minimum guideline values but has been stable over the past three monitoring seasons.
- Flood plumes and terrestrial runoff affected large proportions of enclosed coastal areas of Burdekin.
- It was estimated that 10 per cent of the Burdekin region was exposed to a potential risk from degraded water quality. Approximately 1 per cent of the coral reef and 90 per cent of seagrass areas were exposed to a potential risk from degraded water quality.

The Long-term Water Quality Index for the Burdekin region showed a trend of improvement over the last five years.

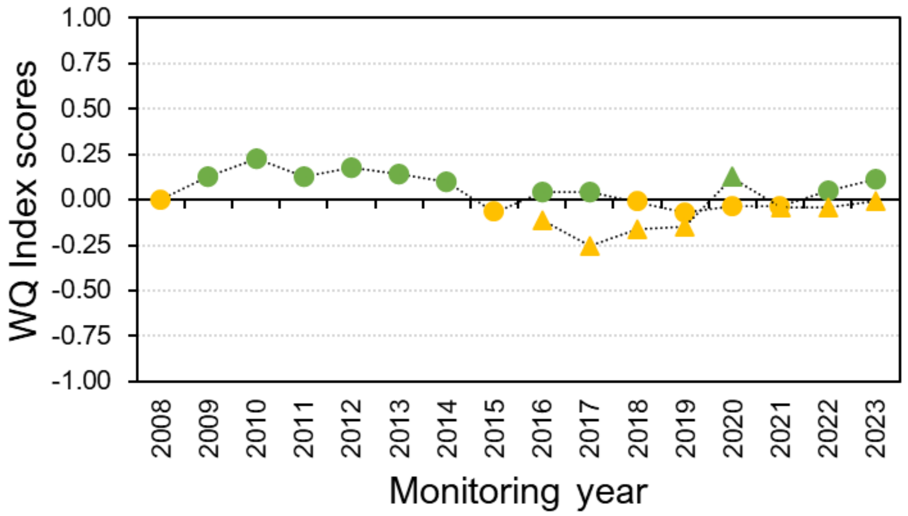

Figure 27. Temporal trends in the Annual and Long-term Water Quality Indices for the Burdekin region. Note that the annual Index is based on the post-2015 MMP sampling design and is sensitive to year-to-year variability, whereas the long-term Index is based on the pre-2015 review, and it is insensitive to year-to-year variability. Values are indexed scores scaled from -1.0 to 1.0 and graded: ■ = very good (1 to 0.5), ■ = good (0.5 to 0), ■ = moderate (< 0 to -1/3), ■ = poor (< -1/3 to -2/3), ■ = very poor (< -2/3 to -1). Note scores are unitless. Data source: Gruber *et al.* [1].

Seagrass

Overall seagrass condition deteriorated from the previous year, and condition remained 'moderate' for both indicators informing the Seagrass Index (Figure 28). However, both Abundance and Resilience indicators have declined from previous monitoring season.

Seagrass abundance marginally decreased relative to the previous period and remains lower than historical records. The low abundances observed at certain sites may be a legacy from the events of the 2018–19 wet season.

Seagrass resilience reduced marginally but remained 'moderate'. Patterns of resilience were inconsistent among habitat types. For example, coastal habitats declined in resilience score, while reef intertidal areas have improved and reef subtidal remained stable. Although seagrass abundance and composition exceeded thresholds in coastal intertidal habitats, reproductive structures were absent or low compared to historical levels.

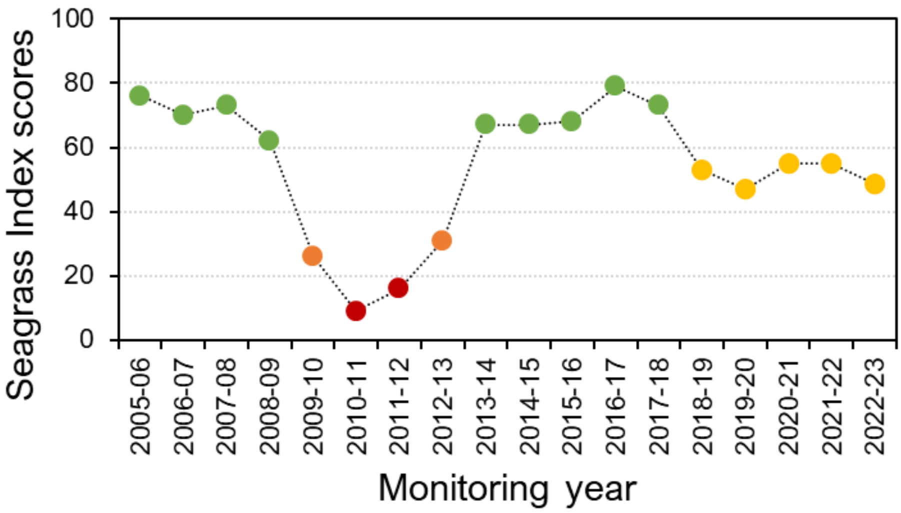

Figure 28. Seagrass Index scores for the Burdekin region from 2005–06 to 2022–23. Black line with circles represents the index score and values are scaled from 0–100 and graded: ■ = very good (81–100), ■ = good (61–80), ■ = moderate (41–60), ■ = poor (21–40), ■ = very poor (0–20). Note, scores are unitless. Data source: McKenzie *et al* [2].

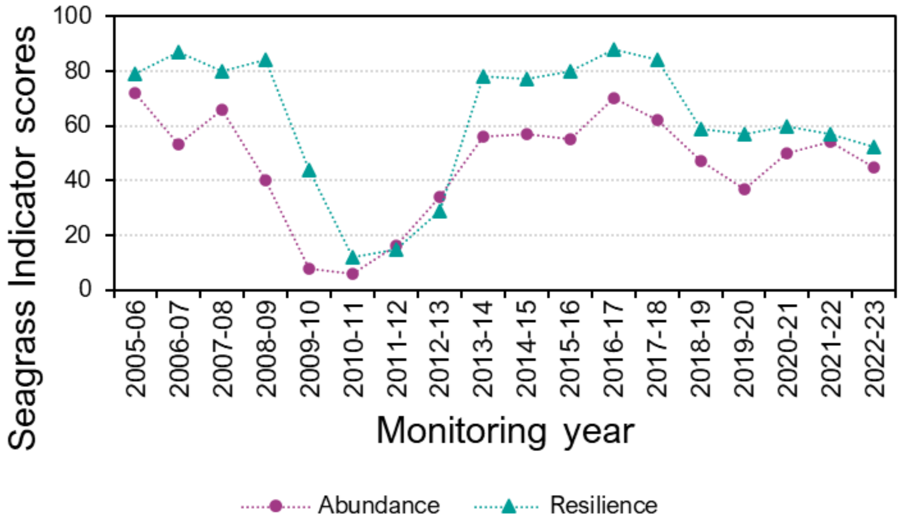

Figure 29. Temporal trends in the seagrass indicator scores of Abundance and Resilience for the Burdekin region from 2005–06 to 2022–23. Scores values are scaled from 0–100 and graded: very good (81–100), good (61–80), moderate (41–60), poor (21–40), and very poor (0–20). Note, scores are unitless. Data source: McKenzie *et al* [2].

Coral

The Coral Index remained in the ‘moderate’ condition range (Figure 30). There were no acute disturbances related to thermal stress in the region over the summer of 2022–23 however annual river discharge was above the long-term median for the region. The rate of increase in coral cover in 2022–2023 was low, suggesting there were chronic pressures influencing corals. However, even though the rate of increase was low, the Coral cover indicator increased moderately in 2023 and was attributed to the recovery of *Acropora, Montipora, Goniopora* and *Alveopora*, and Merulinidae. The Juvenile coral indicator was highly variable between reefs but remained categorised as ‘poor’. The Macroalgae indicator has continued to decline and remains ‘poor’.

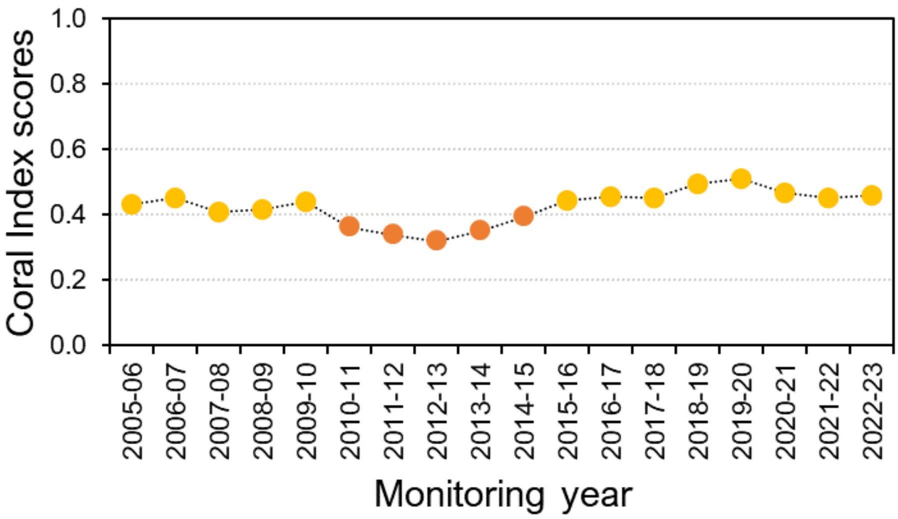

Figure 30. Temporal trend in Coral Index scores for the Burdekin region from 2005–06 to 2022–23. Values are indexed scores scaled from 0.0–1.0 and graded: ■ = very good (0.81–1.00). ■ = good (0.61–0.80), ■ = moderate (0.41–0.60), ■ = poor (0.21–0.40), ■ = very poor (0.00–0.20). Note, scores are unitless. Data source: Thompson *et al* [3].

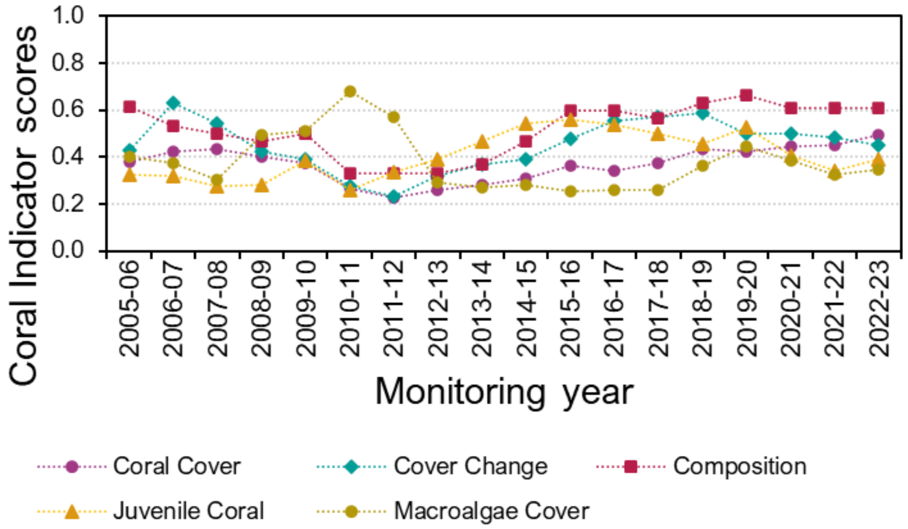

Figure 31. Temporal trends in the coral indicator scores of Coral cover, Cover change, Composition, Juvenile coral, and Macroalgae for the Burdekin region from 2005–06 to 2022–23. Scores values are scaled from 0–1 and graded: very good (0.81–1.00), good (0.61–0.80), moderate (0.41–0.60), poor (0.21–0.40), and very poor (0.00–0.20). Note, scores are unitless. Data source: Thompson *et al* [3].

Mackay–Whitsunday

In the 2022–23 monitoring season, *in-situ* water quality was monitored at five routine sites under ambient conditions five times a year. Seagrass condition was monitored at 12 locations up to twice a year, once in the late dry season and once in the late wet season. Coral communities were assessed at seven sites at two and five metres in the dry season by the MMP, and a further two sites by the AIMS' LTMP in the wet season (Figure 32).

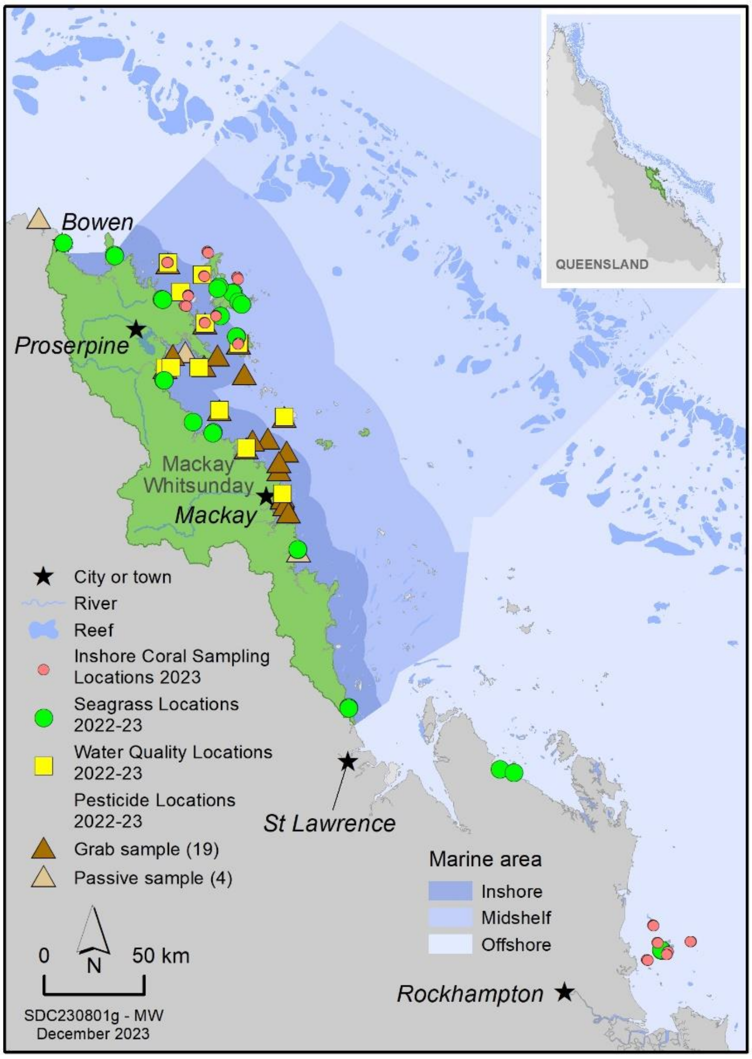

Figure 32. Map showing sampling sites in the Mackay–Whitsunday region. Note that water quality sites shown include flood event monitoring sites in addition to routine monitoring sites.

Environmental conditions

The 2022–23 season was the first year since 2019 that river discharges exceeded the region's long-term median. The combined discharge calculated for the 2022–23 monitoring year from the Proserpine, O'Connell, Pioneer and Plane basins was 1.7 times the long-term median. River discharge was 2.2 times the long-term average in the Proserpine and O'Connell basins, causing significant flooding, and was just above the long-term median in the Pioneer and Plane basin. Wet season rainfall across the Mackay–Whitsunday region was around the long-term average [1].

Sea-surface temperatures over summer in early 2023 were below those likely to cause severe coral bleaching [3]. Intertidal within-canopy temperatures were slightly cooler than the previous period and at the long-term average [2].

Water quality

The Annual Water Quality Index for the Mackay–Whitsunday region scored 'moderate' for the 2022–23 monitoring year (Figure 33).

Key results:

- Concentrations of five water quality variables (NO_x, PO_4, PP, TSS, and Secchi depth) did not meet guideline values.
- Concentrations of PN and Chl-*a* met guideline values.
- All water quality variables showed a trend of improvement since 2015.
- It was estimated that 11 per cent of the Mackay-Whitsunday region was exposed to a potential risk from degraded water quality. Approximately four per cent of the coral reef and 84 per cent of seagrass areas were exposed to a potential risk from degraded water quality.

The Long-term Water Quality Index has shown continued signs of improvement over the last four years and was scored 'moderate'.

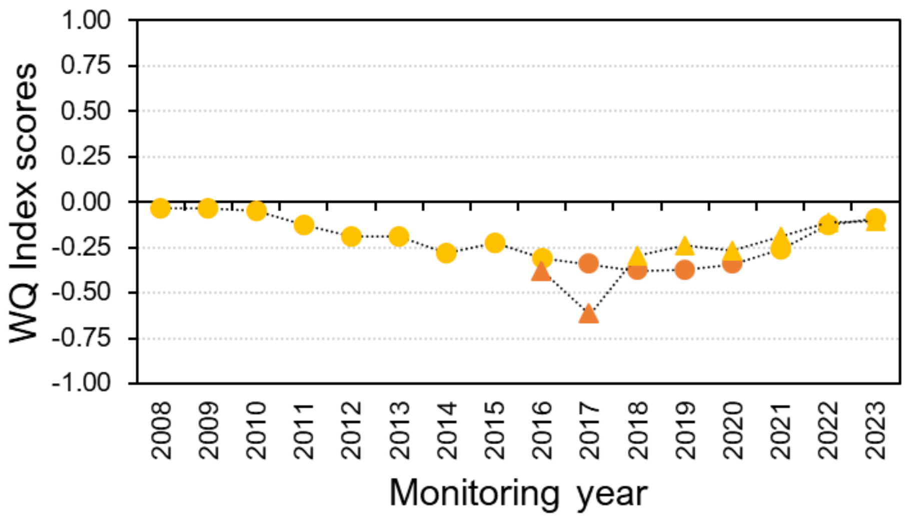

Figure 33. Temporal trends in the Annual and Long-term Water Quality Indices for the Mackay–Whitsunday region. Note that the annual Index is based on the post-2015 MMP sampling design and is sensitive to year-to-year variability, whereas the long-term Index is based on the pre-2015 review, and it is insensitive to year-to-year variability. Values are indexed scores scaled from -1.0 to 1.0 and graded: ■ = very good (1 to 0.5), ■ = good (0.5 to 0), ■ = moderate (< 0 to -1/3), ■ = poor (< -1/3 to -2/3), ■ = very poor (< -2/3 to -1). Note scores are unitless. Data source: Gruber *et al.* [1].

Seagrass

Inshore seagrass meadows across the Mackay–Whitsunday region continued to improve in overall condition in 2022–23 and remained 'moderate'. There were improvements in both indicators. Abundance scores improved from 'poor' to 'moderate', while the Resilience indicator increased and was scored 'moderate' (Figure 34).

The seagrass Abundance score increased after two consecutive years of decline, driven by increases in estuarine intertidal and coastal and reef subtidal habitats.

The overall Resilience score for the Mackay–Whitsunday region was ‘moderate’ increasing to its highest level in six years. Trends were highly variable among habitats. There were large improvements in Resilience at the estuarine intertidal habitat where foundational species became more prevalent, and a high number of reproductive structures were observed.

These results appear to be the first indication that seagrass habitats in the region may be recovering from past disturbances despite recent floods and significant runoff from the Proserpine and O’Connell Rivers.

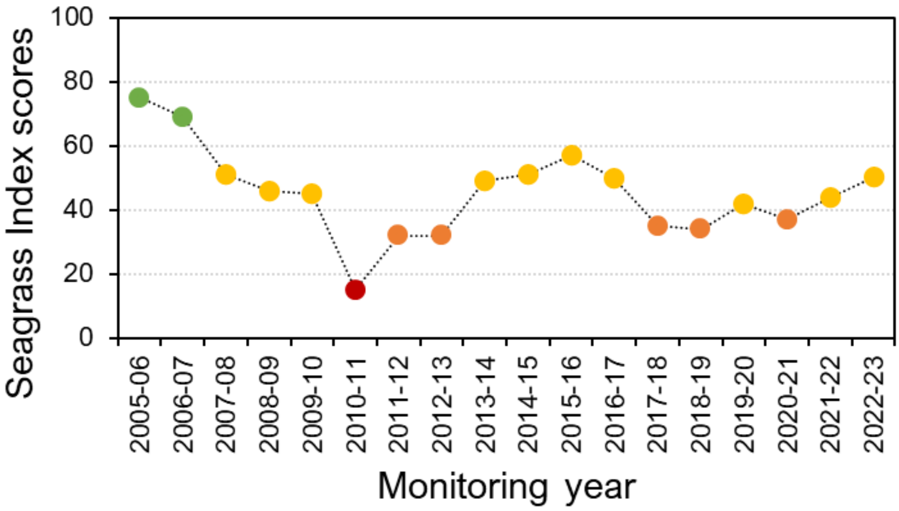

Figure 34. Seagrass Index scores for the Mackay–Whitsunday region from 2005–06 to 2022–23. Black line with circles represents the index score and values are scaled from 0–100 and graded: ■ = very good (81–100), ■ = good (61–80), ■ = moderate (41–60), ■ = poor (21–40), ■ = very poor (0–20). Note, scores are unitless. Data source: McKenzie *et al*.

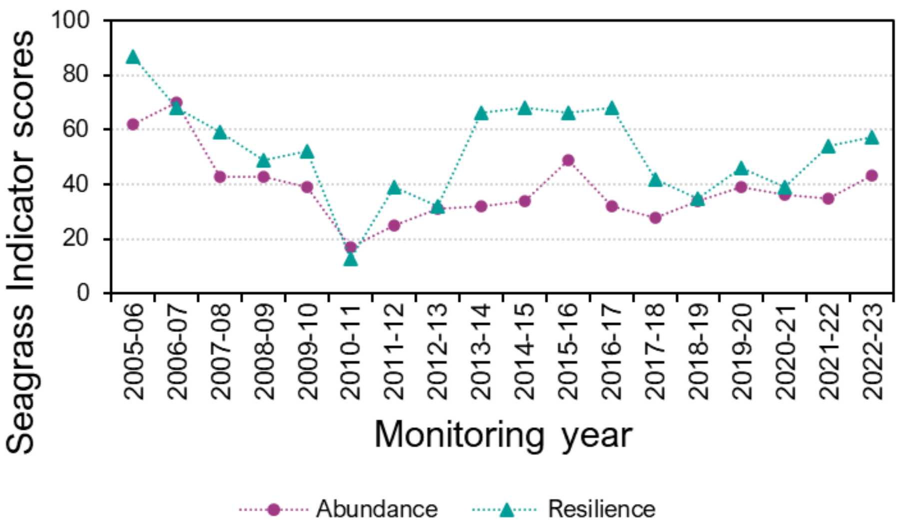

Figure 35. Temporal trends in the Seagrass Indicator scores of Abundance and Resilience for the Mackay–Whitsunday region from 2005–06 to 2022–23. Scores values are scaled from 0–100 and graded: very good (81–100), good (61–80), moderate (41–60), poor (21–40), and very poor (0–20). Note, scores are unitless. Data source: McKenzie *et al* [2].

Coral

The Coral Index score remained 'poor', as the region continues to slowly recover after cyclone Debbie in 2017 (Figure 36). The Juvenile coral indicator score continues to improve with increasing abundance of juvenile corals but remained within the 'moderate' range. High densities of juvenile corals were observed at Hayman and Daydream islands where scores were in the 'good' to 'very good' range. At Hayman the genus *Acropora* is strongly represented among juvenile corals while at Daydream a more diverse assemblage of juvenile corals has recruited.

The combined cover of hard and soft corals has gradually increased since the impacts of cyclone Debbie with recovery at 2 metre sites more consistent than at 5 metres, however the Coral cover indicator remains in the 'poor' or 'very poor' range at most reefs. The trend in coral cover is reflected in the Cover change indicator, which has remained in the 'poor' range for most years following cyclone Debbie and has not significantly improved in the 2022–23 season.

The Macroalgae indicator was scored 'poor' although was highly variable within the region with minimum values (zero) at several reefs. It is noteworthy that the score at Daydream at 5 metres improved considerably, contributing to improvement in the Coral Index score.

Similar to seagrass meadows, there were no signs of flood impact among the reef communities. Disease levels remain below the long-term median level and unchanged from the previous year.

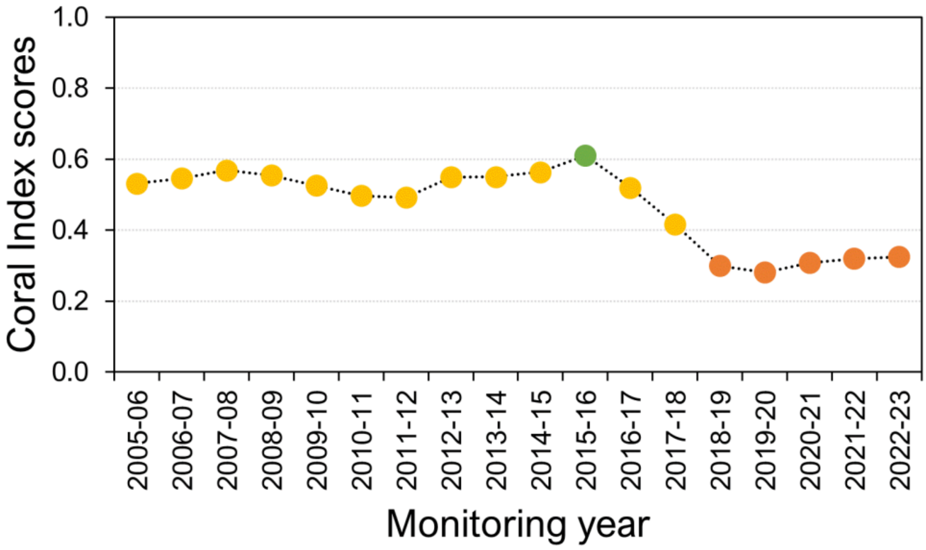

Figure 36. Temporal trend in Coral Index scores for the Mackay–Whitsunday region from 2005–06 to 2022–23. Values are indexed scores scaled from 0–1 and graded: ■ = very good (0.81–1.00), ■ = good (0.61–0.80), ■ = moderate (0.41–0.60), ■ = poor (0.21–0.40), ■ = very poor (0.00–0.20). Note, scores are unitless. Data source: Thompson *et al* [3].

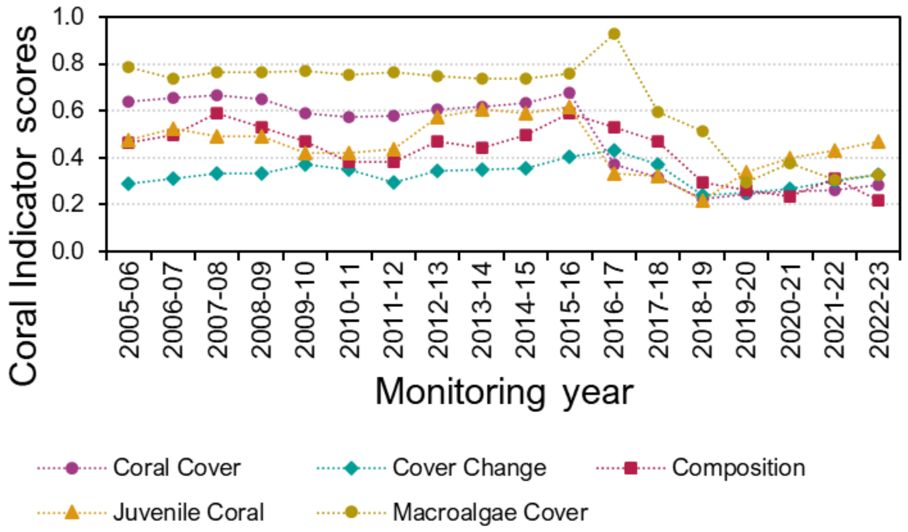

Figure 37. Temporal trends in the coral indicator scores of Coral cover, Cover change, Composition, Juvenile coral, and Macroalgae for the Mackay–Whitsunday region from 2005–06 to 2022–23. Scores values are scaled from 0–1 and graded: very good (0.81–1.00), good (0.61–0.80), moderate (0.41–0.60), poor (0.21–0.40), and very poor (0.00–0.20). Note, scores are unitless. Data source: Thompson *et al* [3].

Fitzroy

In the 2022–23 monitoring season, *in-situ* water quality was monitored in six routine sites under ambient conditions ten times a year. Please note that the MMP monitored water quality in the region from 2005 to 2014. Since 2020, water quality monitoring has been conducted by the Fitzroy Basin Marine Monitoring Program following a consistent design with the MMP. This water quality program is funded in partnership by the Australian Government's Reef Trust Partnership, the Great Barrier Reef Foundation, and AIMS.

Seagrass condition was monitored in four locations in the late dry season. Coral communities were assessed in five sites in the dry season (Figure 38).

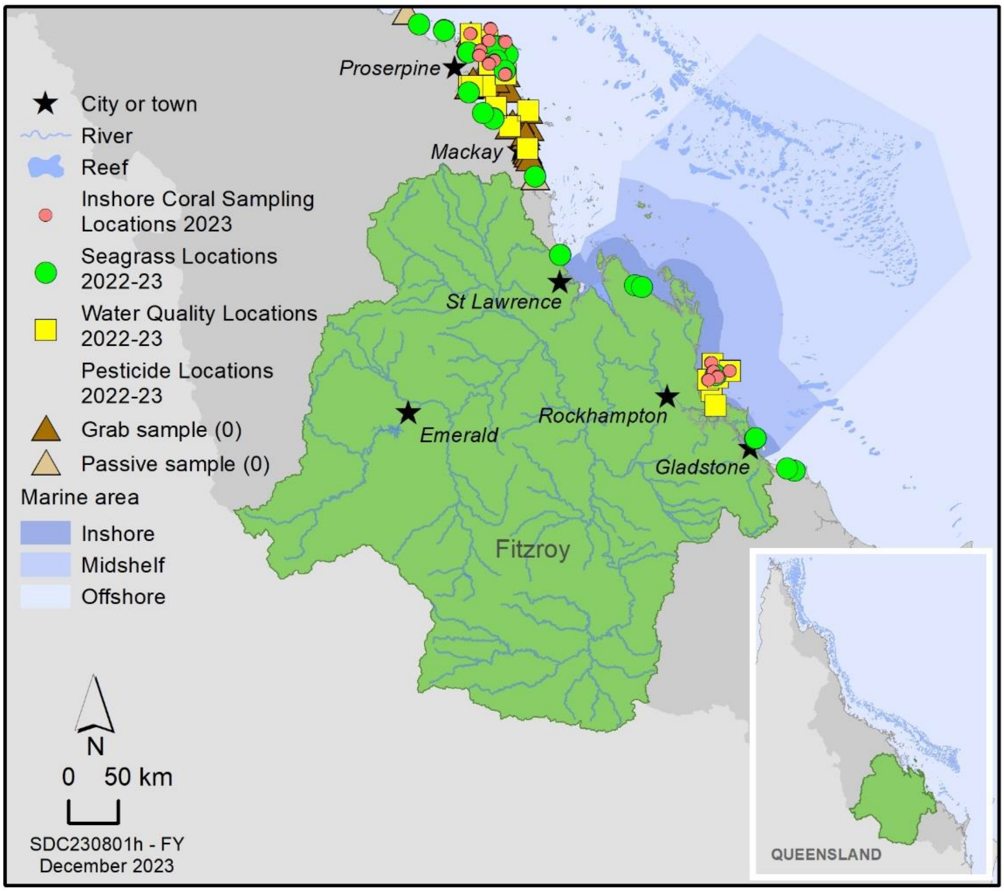

Figure 38. Map showing sampling sites in the Fitzroy region. Note that water quality locations are monitored by the Fitzroy Basin Marine Monitoring Program.

Environmental conditions

In the 2022–23 monitoring year, river discharge from the Fitzroy River and Water Park Creek were slightly above long-term median. Rainfall was below average for both river basins. All other basins had river discharge slightly above the long-term median, except the Boyne basin which was considerably below the long-term median [1].

Average annual sea-surface temperatures were slightly cooler than the previous period, and did not reach levels known to cause coral bleaching [3]. Water temperature within seagrass canopy was also below the long-term average for the 10th consecutive year [2].

Water quality

The Annual Water Quality Index for the Fitzroy region scored ‘good’ for the 2022–23 monitoring year (Figure 39).

Key results:

- Concentrations of Chl-*a* met guideline values at most monitoring sites in the region.
- Concentrations of NO_x and Secchi depth did not meet guideline values at most monitoring sites.
- Concentrations of PO_4, PN, PP, and TSS did not meet guideline values at half the monitoring sites in the region.
- It was estimated that seven per cent of the Fitzroy region was exposed to a potential risk from degraded water quality. Approximately three per cent of the coral reef and 65 per cent of seagrass areas were exposed to a potential risk from degraded water quality.

The Long-term Water Quality Index has shown continued signs of improvement over the last three years and is similar to scores from 2015 when MMP monitoring ended.

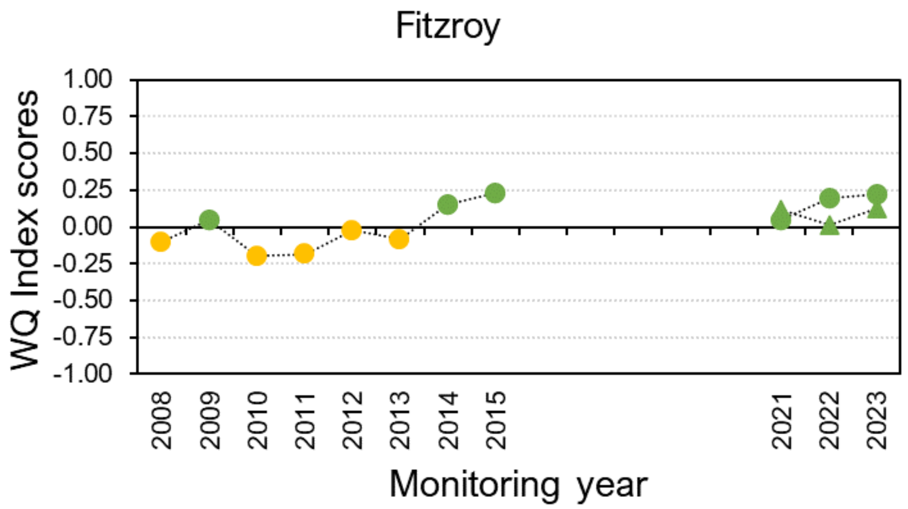

Figure 39. Temporal trends in the Annual and Long-term Water Quality (WQ) Indices for the Fitzroy region. Note, that the annual Index is based on the post-2015 MMP sampling design and is sensitive to year-to-year variability, whereas the long-term Index is based on the pre-2015 review, and it is insensitive to year-to-year variability. WQ monitoring was paused between 2015 and 2020. Values are indexed scores scaled from -1.0 to 1.0 and graded: ■ = very good (1 to 0.5), ■ = good (0.5 to 0), ■ = moderate (< 0 to -1/3), ■ = poor (< -1/3 to -2/3), ■ = very poor (< -2/3 to -1). Note, scores are unitless. Data source: Gruber *et al.* [1].

Seagrass

The Seagrass Index score for the Fitzroy region deteriorated but remained ‘poor’ for the 2022–23 monitoring year. Abundance recovered from ‘very poor’ to ‘poor’ but Resilience continued to decline and remained ‘poor’ (Figure 40).

Seagrass Abundance score marginally improved from the previous period, but this was driven by only one site (estuarine intertidal). Average Abundance scores for all other sites continued to slightly decline, however, the overall score was unimpacted as the median abundances used to calculate individual scores were unchanged. Abundances remain very low at over half the sites in the region, particularly the reef intertidal sites.

The Resilience indicator score decreased to the second lowest level recorded. However, the trend varies depending on the habitat and site. For estuarine and coastal habitats, one replicate site showed an improvement while the other declined. Increased resilience was noted in sites that were dominated by foundational species, with their abundance exceeding the threshold for resistance, and reproductive structures present. In reef intertidal habitat, Resilience score fell to the lowest level in three years.

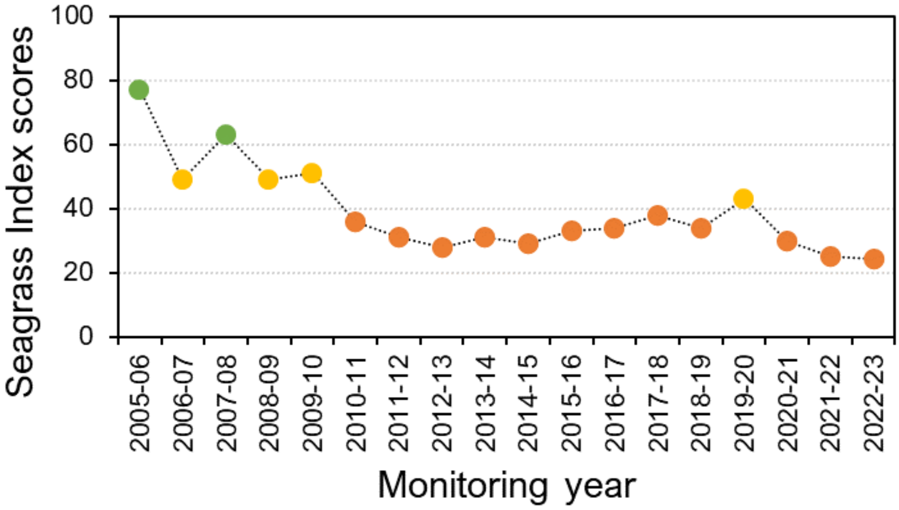

Figure 40. Seagrass Index scores for the Fitzroy region from 2005–06 to 2022–23. Black line with circles represents the index score and values are scaled from 0–100 and graded: ■ = very good (81–100), ■ = good (61–80), ■ = moderate (41–60), ■ = poor (21–40), ■ = very poor (0–20). Note, scores are unitless. Data source: McKenzie *et al* [2].

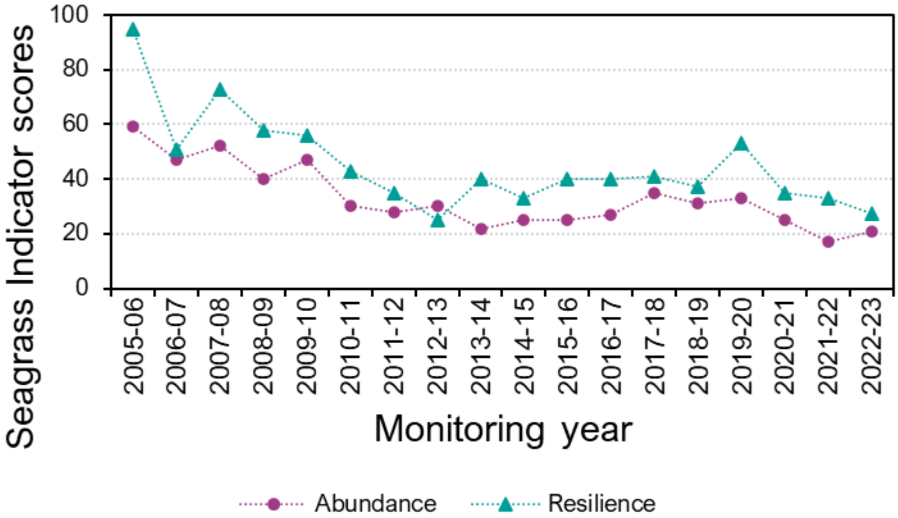

Figure 41. Temporal trends in the seagrass indicator scores of Abundance and Resilience for the Fitzroy region from 2005–06 to 2022–23. Scores values are scaled from 0–100 and graded: very good (81–100), good (61–80), moderate (41–60), poor (21–40), and very poor (0–20). Note, scores are unitless. Data source: McKenzie *et al* [2].

Coral

The Coral Index score in the Fitzroy region remained 'poor' with no improvement following a period of recovery from 2014 to 2020 (Figure 42).

Since 2020, scores for Juvenile coral and Macroalgae at 5 metres depth have declined. Conversely, the Coral cover score has slowly improved since 2020 but remains within the 'moderate' range, however this improvement was not consistent among reefs. Cover change was at the upper boundary of the 'poor' range indicating slower than expected recovery of hard coral cover in recent years. The Macroalgae indicator score has remained 'very poor' and in 2023 the proportion macroalgae cover within the algal communitiy increased at most reefs.

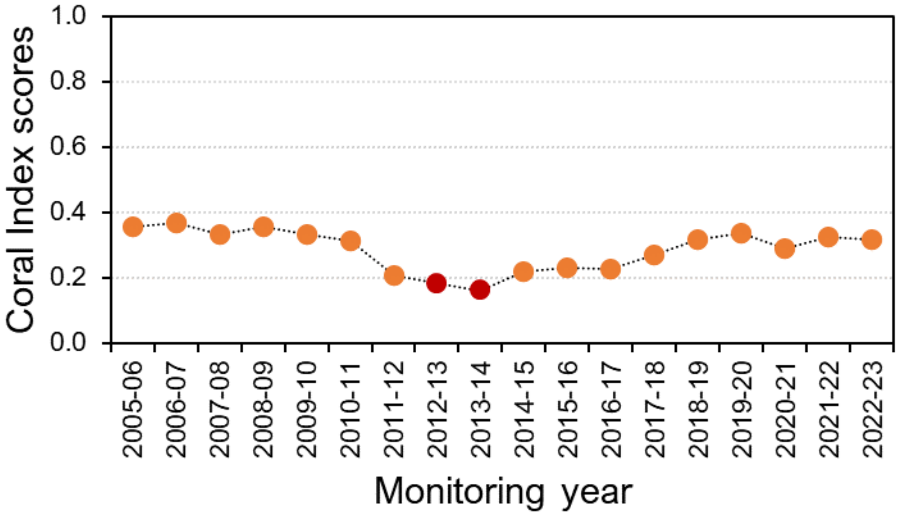

Figure 42. Temporal trend in Coral Index scores for the Fitzroy region from 2005–06 to 2022–23. Values are indexed scores scaled from 0–1 and graded: ■ = very good (0.81–1.00), ■ = good (0.61–0.80), ■ = moderate (0.41–0.60), ■ = poor (0.21–0.40), ■ = very poor (0.00–0.20). Note, scores are unitless. Data source: Thompson *et al* [3].

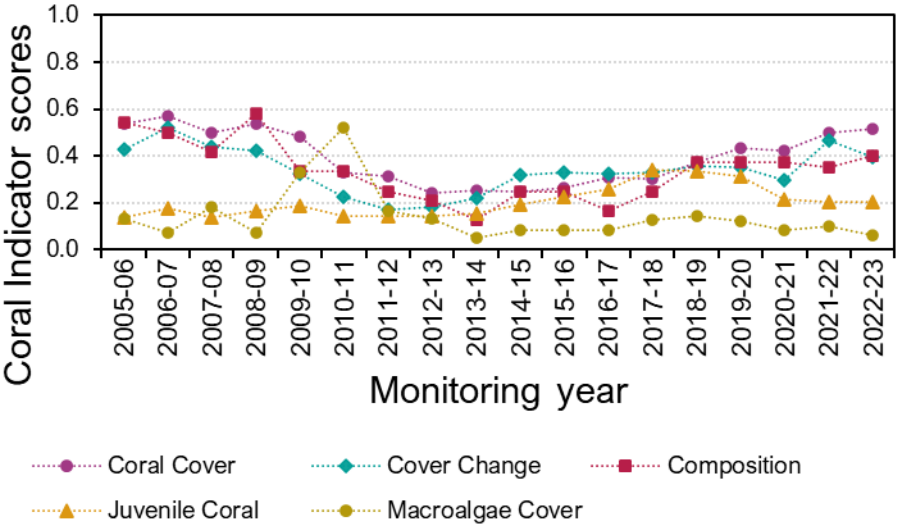

Figure 43. Temporal trends in the coral indicator scores of Coral cover, Cover change, Composition, Juvenile coral, and Macroalgae for the Fitzroy region from 2005–06 to 2022–23. Scores values are scaled from 0–1 and graded: very good

(0.81–1.00), good (0.61–0.80), moderate (0.41–0.60), poor (0.21–0.40), and very poor (0.00–0.20). Note, scores are unitless. Data source: Thompson *et al* [3].

Burnett–Mary

In the 2022–23 monitoring season, seagrass condition was monitored in three locations in the late dry and wet seasons. The MMP does not monitor *in-situ* water quality nor coral reefs condition in the Burnett–Mary region (Figure 44).

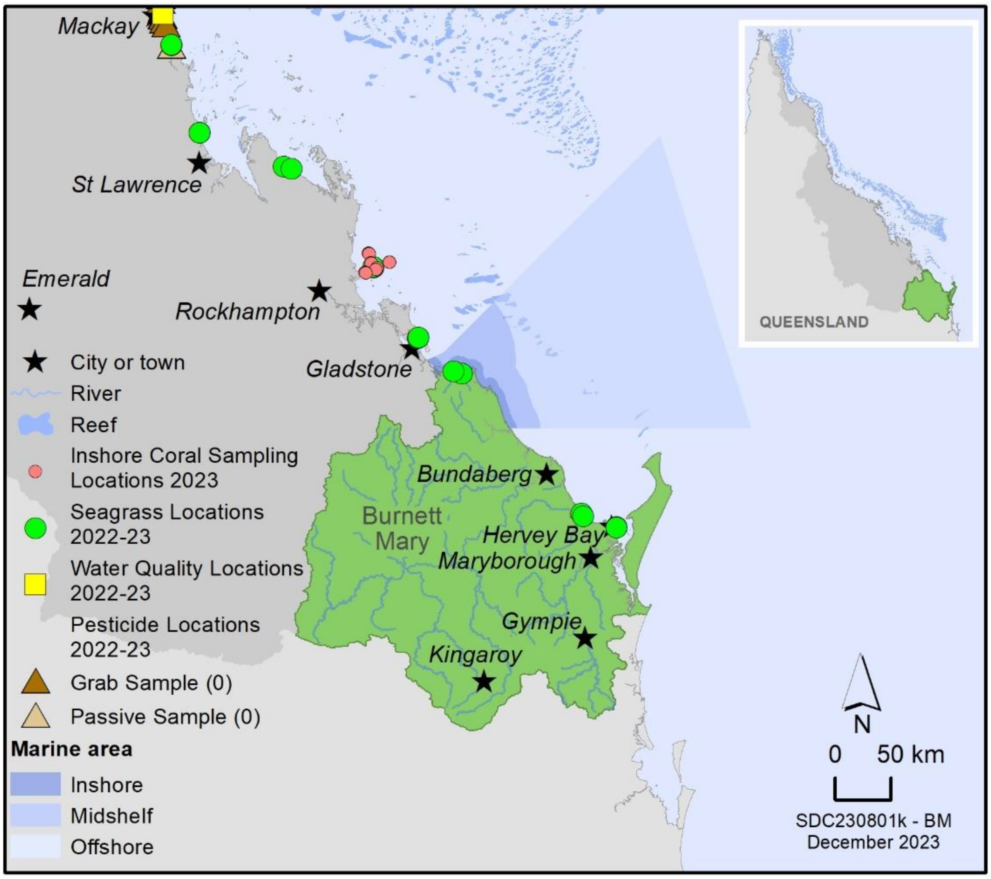

Figure 44. Map showing sampling sites in the Burnett–Mary region.

Environmental conditions

Although the 2022–23 monitoring period in the Burnett–Mary region was relatively mild with environmental pressures similar to or below the long-term averages, the legacy of extreme weather events in 2021–22 continued to influence region.

Rainfall and river discharge were similar to or below long-term conditions across the region, however, the Burrum basin discharge was 2 times above the long-term median. Within canopy daily light and water temperature were below the long-term term average, and daytime tidal exposure was also below average.

Water Quality

While *in-situ* monitoring is not conducted in the region by the MMP, remote sensing products are generated for the Burnett-Mary and reported in the MMP Water Quality Annual Report [1]. It was estimated that two per cent of the Burnett-Mary region was exposed to a potential risk from degraded water quality. Approximately two per cent of the coral reef and 58 per cent of seagrass areas were exposed to a potential risk from degraded water quality.

Seagrass

Inshore seagrass meadows across the region declined in overall condition in 2022–23, with the Seagrass Index score decreasing to a 'very poor' grade for the first time in 16 years. Abundance and Resilience indicators declined as well (Figure 45).

The seagrass Abundance score remained 'very poor' for the second consecutive year. The decline is a continuing trend that has been occurring for the region since 2015–16. In 2022-23, abundances in coastal habitats were the lowest since the MMP was established, while in estuarine habitats they were the lowest in the last decade. Spatial extent in estuarine habitat also declined to the lowest level since 2008.

Resilience declined and remained 'poor' overall, and marked the fourth time in the past decade that the score has fallen below 'moderate'. Despite this, meadows throughout the region have a higher capacity to recover as seed banks persist, although replenishment ability has been reduced, making the meadows susceptible to future significant disturbances.

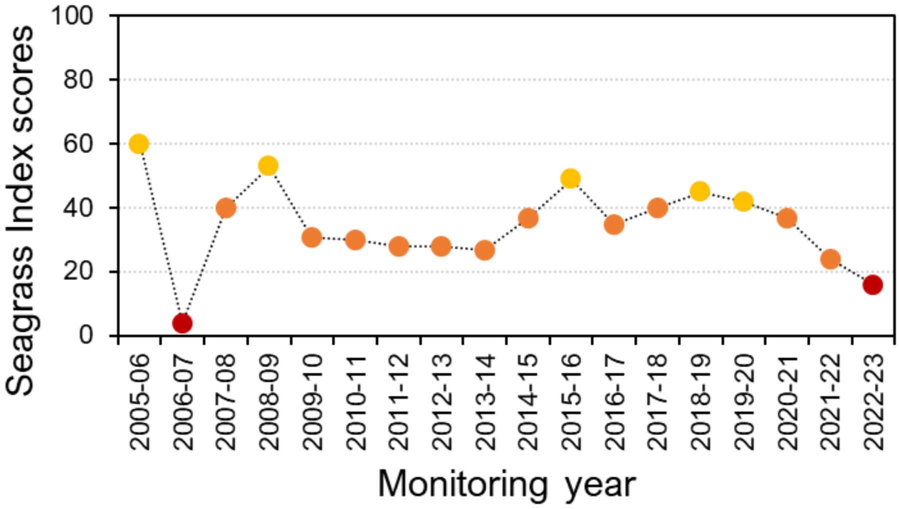

Figure 45. Seagrass Index scores for the Burnett–Mary region from 2005–06 to 2022–23. Black line with circles represents the index score and values are scaled from 0–100 and graded: ■ = very good (81–100), ■ = good (61–80), ■ = moderate (41–60), ■ = poor (21–40), ■ = very poor (0–20). Blue and pink lines represent the indicators that inform the Seagrass Condition Index score. Note, scores are unitless. Data source: McKenzie *et al* [2].

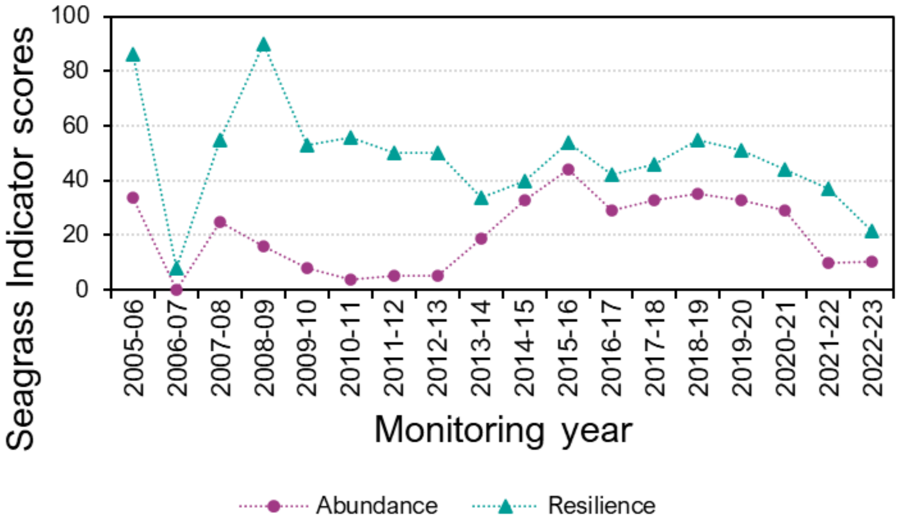

Figure 46. Temporal trends in the seagrass indicator scores of Abundance and Resilience for the Burnett–Mary region from 2005–06 to 2022–23. Scores values are scaled from 0–100 and graded: very good (81–100), good (61–80), moderate (41–60), poor (21–40), and very poor (0–20). Note, scores are unitless. Data source: McKenzie *et al* [2].

Pesticide monitoring

Pesticides were monitored throughout the wet season including specific monitoring in flood conditions in the Cape York and Mackay-Whitsunday regions. Results are reported as estimated pesticide concentration in nanograms per litre (ng per L). The dominant pesticide found in all monitoring sites during the wet season was diuron, particularly in passive samplers. It should be noted that results yielding from single point-in-time grab samples and passive samplers represent different sampling strategies and, consequently, different information. Grab samples represent a point-in-time concentration estimate (acute exposure) whereas passive samplers represent a time-integrated average water concentration over the deployment period (chronic exposure). Therefore, the two methods are representing different but complementary results.

Passive samplers

The highest concentration of pesticides detected were diuron, atrazine and hexazinone, which are herbicides often used in sugarcane production and other cropping such as horticulture and grains [14]. Other pesticides such as the insecticide imidacloprid were also detected in areas where sugar cane crops are common. Diuron was ubiquitously present in the marine environment, detected in most passive samplers, except in the passive sampler deployed in the Whitsunday-Channel in early November 2022. Lowest concentrations of diuron were detected in Low Isles, Euri Creek, and Whitsunday Channel, whereas highest concentrations were found in Dunk Island, Flat Top Island, and Sarina Inlet. Hexazinone and atrazine also contributed a significant proportion of pesticides detected. Atrazine typically contributed a higher relative proportion at sites in the Wet Tropics, Burdekin, and Mackay–Whitsunday regions, whereas hexazinone contributed a higher proportion at sites in Mackay–Whitsunday (see Kaserzon *et al.*[6]). Total pesticide concentrations at sites ranged from 0.183 ng per L at High Island deployed in November 2022 to 153 ng per L for Flat Top Island in January 2023.

Since diuron was the dominant pesticide detected using passive samplers, it is important to illustrate the ranges in the maximum concentration of diuron within different regions. Maximum diuron concentrations ranged from 13.6–22.5 ng per L, 4 ng per L, and 22–64 ng per L in the Wet Tropics, Burdekin, and Mackay–Whitsunday regions, respectively.

The Pesticide Risk Metric (PRM) results showed that while many pesticides were detected below guidelines values, which protects > 99 per cent of species, in combination these pesticides can create an increased risk to species present over the deployment period. It is noteworthy that pesticide data were only available for a few pesticides (not for the whole suite of 22 pesticides, which are used to calculate the PRM), and so the risk is potentially underestimated and not accurately represented. Nevertheless, these results present the best estimate of pesticide risk in the monitoring areas (Figure 47).

Grab samples

The most frequently detected pesticide measured in grab samples across all sites was tebuthiuron, followed by atrazine, diuron and hexazinone, corroborating the results from passive samplers (see Kaserzon *et al.* [6]). A total of nine grab samples returned total pesticide concentrations below the detection limits for the whole suite of 25 pesticides. For example, grab samples collected from Dunk Island in January 2023, High Island in December 2022 and April 2023, Low Isles in November, December, January and February, and Repulse Bay in December 2022 returned a mixture of pesticides all below detection limits. Total pesticide concentrations at sites where at least one pesticide was detected above the detection limit ranged from 0.6 ng per L at Euri Creek collected on 6 December 2022 to 1448 ng per L at Sarina Inlet on 12 January 2023.

The PRM calculated for the grab samples returned 'low' to 'moderate' risk at sites in the Mackay–Whitsunday region (Figure 48), which are typical for the region.

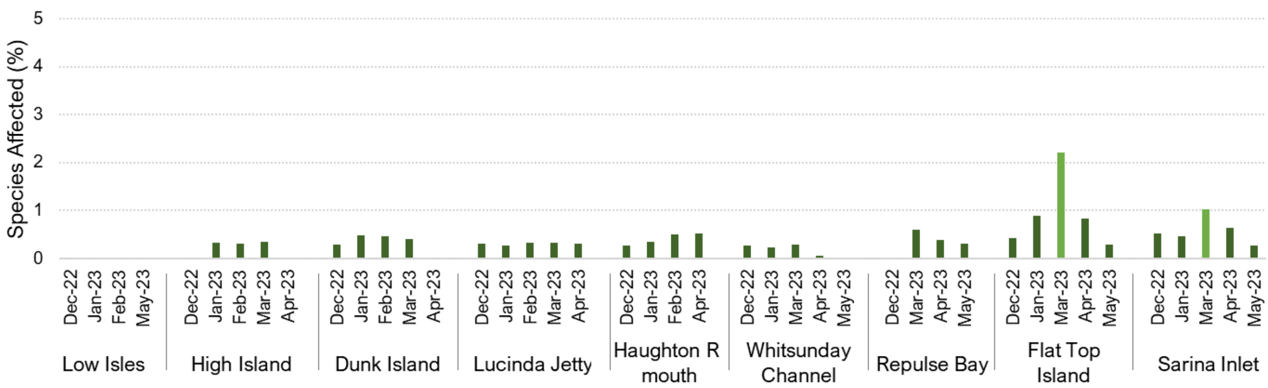

Figure 47. Percentage of species affected by pesticide mixture calculated using the Pesticide Risk Metric at each fixed monitoring site using passive samplers over the 2022– 23 wet season. Risk grades: ■ = very low (≤1 per cent) and ■ = low (> 1 and ≤ 5 per cent). Note, Euri Creek is not represented in the graph.

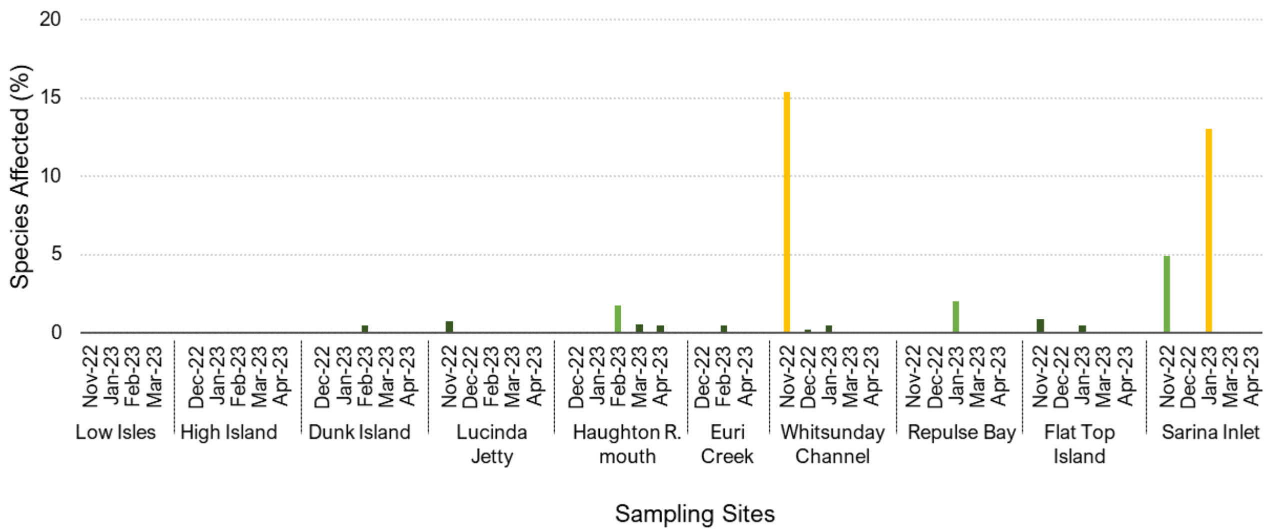

Figure 48. Percentage of species affected by pesticides mixture calculated using the Pesticide Risk Metric at each fixed monitoring site using grab samples over the 2022– 23 wet season. Risk grades: ■ = very low (≤1 per cent), ■ = low (> 1 and 5 per cent), and ■ = moderate (>5 to 10 per cent).

Flood monitoring

In 2022–23 wet season, the MMP conducted flood monitoring in Cape York and the Mackay–Whitsunday regions. A summary of both events can be found below.

Cape York

Targeted flood sampling conducted on 14 and 25 January 2023 coincided with the first major flood event of the year, starting from 28 December 2022 and maintaining flood levels throughout the month of January. Satellite images around the time of sampling show the flood plume flowing northeast towards Corbett Reef on 14 January, with the majority of sediment discharged from the Kennedy River. On 24 January, southeasterly winds forced the flood plume to the northwest, travelling along the coast past Cliff Isles and beyond the Stewart River transect to the north (Figure 49).

After a short decline, discharge from the Normanby River increased again in mid-February, remaining at flood levels until mid-March. Satellite images of Princess Charlotte Bay on 10 March show turbid floodwater inundating Cliff Isles and Corbett Reef to the north and extending approximately 100 km to the east beyond the outer reefs.

During this event, water quality indicators such as NOx increased by 10-fold. Dissolved organic carbon (DOC), PN, and PP have doubled compared to ambient concentrations. Elevated nutrient concentrations were generally detected in coastal sites, gradually declining at mid-shelf and offshore regions. TSS and Chl-*a* concentrations were also elevated in coastal waters.

Figure 49. Satellite image of Kennedy and Normanby River during flooding on 24 January (left) and 10 March 2023 (right). During the late January flood event floodwater can be seen travelling north up the coast beyond the Stewart transect (left). In March, floodwater inundated Corbett Reef and Clack Reef and flowed east beyond the outer reef (right). Source: NASA MODIS Aqua & Terra. Extracted from Gruber *et al* [1].

Mackay–Whitsunday

High discharge occurred in the Proserpine and O'Connell Basins in January 2023. Despite considerable rainfall in the Mackay area and surrounds, the high volume of rainfall did not result in large flows in the Pioneer River. The event peaked on 16 January 2023 and targeted flood sampling was conducted on 21 and 22 January.

As the sampling was conducted 5–6 days after the flood peak, as earlier sampling was prevented by weather, the plume was well-dispersed throughout the offshore waters of the Mackay–Whitsunday region (Figure 50). In general, the TSS, PN, and Chl-*a* concentrations are consistent to plume sampling from other regions, although, it appears that NO_x, DIP, and PP are typically higher at comparable salinity values when compared to plumes from the Wet Tropics and Burdekin regions.

Figure 50. Flood plume line in the Whitsundays following the floods in the Mackay–Whitsunday region in January 2023 (©TropWater, James Cook University)

Samples for pesticide analysis were also collected in the Mackay–Whitsunday flood sampling campaign in January 2023. Several pesticides were detected in the plume waters. The most detected pesticides were 2,4-D, atrazine, diuron, imidacloprid, metolachlor, tebuthiuron, and hexazinone, which were detected in the majority (>90 per cent) of samples. The concentrations of all pesticides were well below Guideline Values likely due to dilution post-flooding. However, the Pesticide Risk Metric [11] showed that, at the moment of sampling, the proportion (per cent) of species exposed to a potential risk from this pesticide mixture was low or very low in the region, with the exception of sample JCF223 located in Repulse Bay (Figure 51). Metric values above five per cent represent a 'moderate' exposure to pesticide.

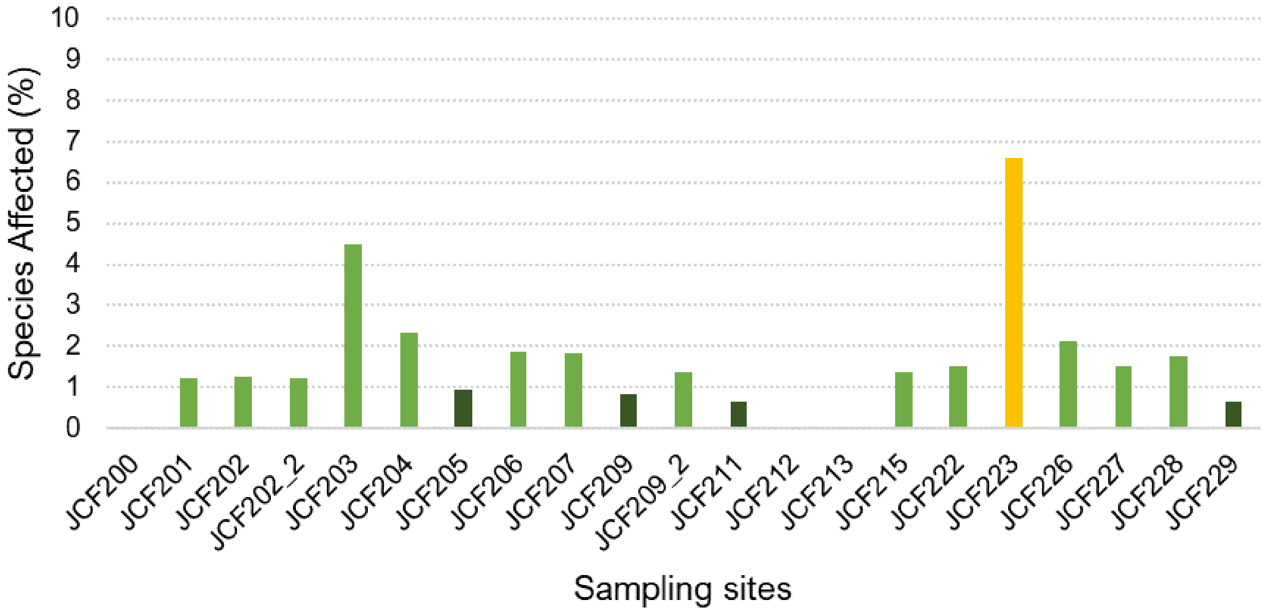

Figure 51. Daily Pesticide Risk Metric calculated for grab samples collected during the Mackay–Whitsunday reactive flood sampling event. Note that not all pesticides are represented in the calculation, as only polar pesticides have been analysed. Therefore, the metric represents a potential underestimation of potential risk. Risk grades: ■ = very low (≤1 per cent), ■ = low (> 1 and 5 per cent), and ■ = moderate (>5 to 10 per cent).

Discussion

The 2022–23 monitoring season was characterised by a continuing trend of water quality improvement across the inshore Reef, but seagrass and coral condition and trend varied between regions. Seagrass meadows and coral reefs from the northern regions continue to fare better than their southern counterparts, which are still recovering from the legacy impacts of bleaching, cyclone Debbie, heat stress, and major floods.

Water Quality Indices continued to show trends of stability or improvement in water quality indicators, with no trends of deterioration found. Water quality indicators including Chl-*a*, TSS, and particulate nutrients generally met local guideline values (GVs) across the inshore region, despite overall rainfall and discharge above the long-term median. These improvements were reflected in the Annual Water Quality Index, which scored all regions as either ‘good’ or ‘moderate’ in the 2022–23 monitoring season. NO_x did not meet guideline values in almost all regions (the exception being the Annan-Endeavour catchment in Cape York), yet it continues to show a trend of improvement since 2015. If this trend continues, concentrations in some regions could approach GVs in the next few years. It can take a long time (up to decades) for water quality to respond to land management practice change. While positive results in water quality indicators of nutrients and total suspended solids are great news for the inshore Reef, these results should be interpreted with caution as further work is needed to determine whether these results are due to extended oceanographic and climatic drivers or can be linked back to catchment land use practices [1].

The ecological benefits of enhanced water quality reported over the last three to five years, depending on the region, are yet to be realised within communities in the inshore Reef. For example, for inshore coral reef communities, chronic stress due to legacy effects of poor water quality is manifesting as decreased resilience in some regions. In 2022 –23, poor water quality is linked to persistence of macroalgal cover in some monitoring sites and is hindering recovery of coral populations, by either suppressing juvenile recruitment or reducing the health of adult colonies leading to slower growth or mortality [3]. Similarly, the Seagrass Index declined to the lowest and second lowest levels on record in the Fitzroy and Burnett–Mary regions, respectively. Resilience declined in both regions while Abundance either marginally increased or remained very poor, absent. In fact, Abundance had been declining at some sites since early 2018. In 2022–23, environmental pressures in the southern regions were relatively benign, with rainfall and river discharges below average, and slightly cooler temperatures. These would have been more conducive to seagrass growth. However, light availability was either around or below average. With the severe loss of all or some of the meadows, destabilisation of the sediments may contribute to challengers for seagrass to establish and begin recovery. These trends highlight that there is an interplay between local-scale processes, and region wide pressures influencing seagrass condition.

The water quality results presented here suggest that elevated nutrients and total suspended solids levels, which are often considered important factors driving decline of health and resilience of seagrass and coral habitats, are consistently improving across the inshore Reef. If improvements in water quality parameters such as nutrients and sediments continue, it is expected that positive changes in the condition of seagrass meadows and coral communities, particularly metrics of resilience, should improve. However, any improvement in water quality that reduces pollutants in land-based runoff entering the Reef can be negated by other simultaneous pressures, such as increases in sea-surface temperature caused by heatwave conditions. Additionally, the ‘recovery window’ between disturbances is expected to shrink because of the intensification of global anthropogenic impacts, resulting in less inter-disturbance time for ecosystems to recover from acute disturbances.

Catchment, coastal and inshore areas can be exposed to high concentrations of pesticides, especially to certain PSII herbicides such as diuron and atrazine, during rainfall and river discharge events. The pesticide profiles indicated that the Mackay–Whitsunday region, which has approximately 50 per cent of the regional catchment area associated with agricultural activities, predominantly sugarcane and beef cattle grazing[15], remains a priority catchment in terms of management of pesticide loads to the Reef[16]. In particular, the highest maximum concentration of pesticides was detected in 2022–23 wet season was at Sarina Inlet, south of Mackay, which has significant areas of inshore seagrass and coral reefs. Experimental studies demonstrated that the effects of mixtures of pesticides are generally additive [17] and that low concentrations of individual pesticides (below a toxicity threshold) add to the overall effect of the mixture [13]. While most pesticides did not exceed the guideline values that protect 99 per cent of species, the calculation of the Pesticide Risk Metric showed, in combination, these pesticides have the potential to cause deleterious effects to marine habitats and species [18]. Whilst the frequency and intensity of concentration pulses associated with high flow river events are reduced with distance from river mouths, chronic exposure to pesticides in inshore areas may still impact biota at the receiving habitats. The long-term impacts of chronic exposure of pesticides to seagrasses and corals are poorly known due to compounding effects of other pressures, such as repeated events of thermal stress.

Continued monitoring is crucial for linking environmental conditions to responses of inshore ecosystems to chronic and acute pressures. The long-term data collected through the MMP provides a unique opportunity to understand how declines in water quality affects the inshore ecosystems, but also track potential improvements made through the implementation of the Reef 2050 WQIP, and how improvements can influence the condition and resilience of the inshore Reef.

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