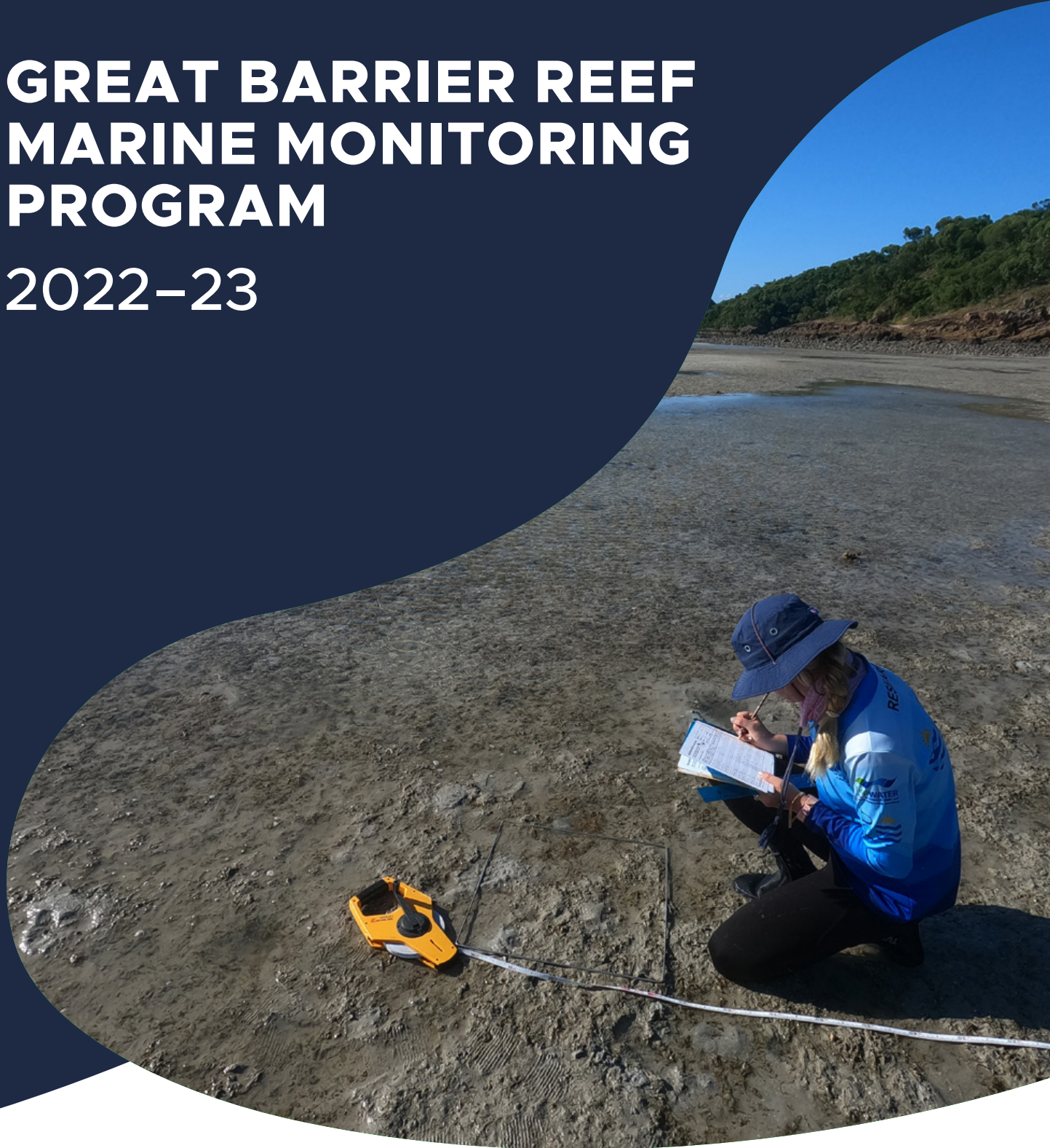


GREAT BARRIER REEF MARINE MONITORING PROGRAM 2022–23



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This publication should be cited as:
Great Barrier Reef Marine Park Authority. 2024. Great Barrier Reef Marine Monitoring Program Summary Booklet 2022–23, Great Barrier Reef Marine Park Authority, Townsville

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2022–23 summary

Environmental conditions over 2022-23 monitoring season were reasonably benign across the inshore Reef.

Cyclones

No cyclones crossed the east coast of Queensland. However, several weak tropical lows resulted in high rainfall and river discharge events in some locations such as Cape York and Mackay-Whitsunday regions.

River discharge

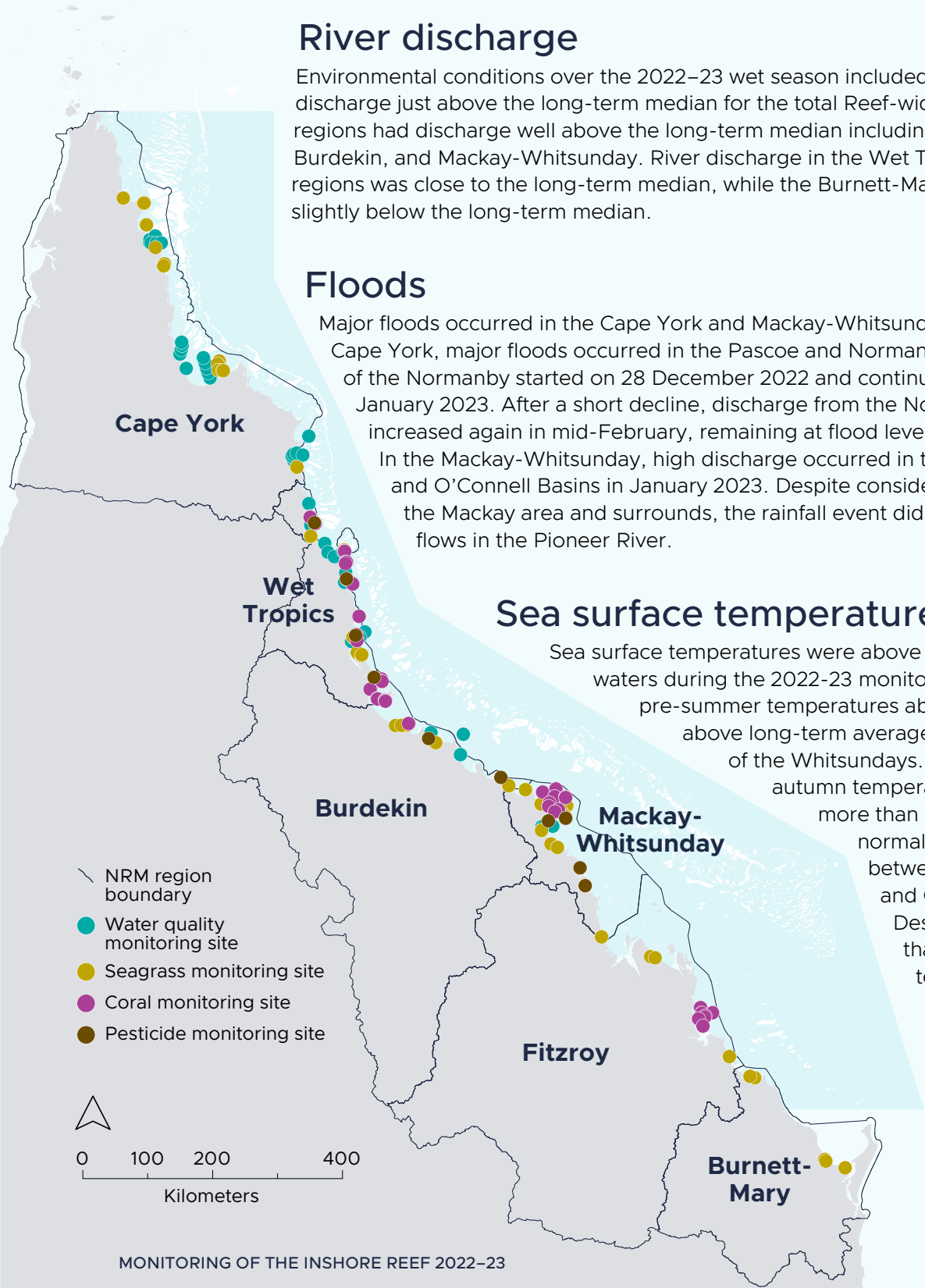
Environmental conditions over the 2022–23 wet season included rainfall and river discharge just above the long-term median for the total Reef-wide discharge. Three regions had discharge well above the long-term median including the Cape York, Burdekin, and Mackay-Whitsunday. River discharge in the Wet Tropics and Fitzroy regions was close to the long-term median, while the Burnett-Mary region was slightly below the long-term median.

Floods

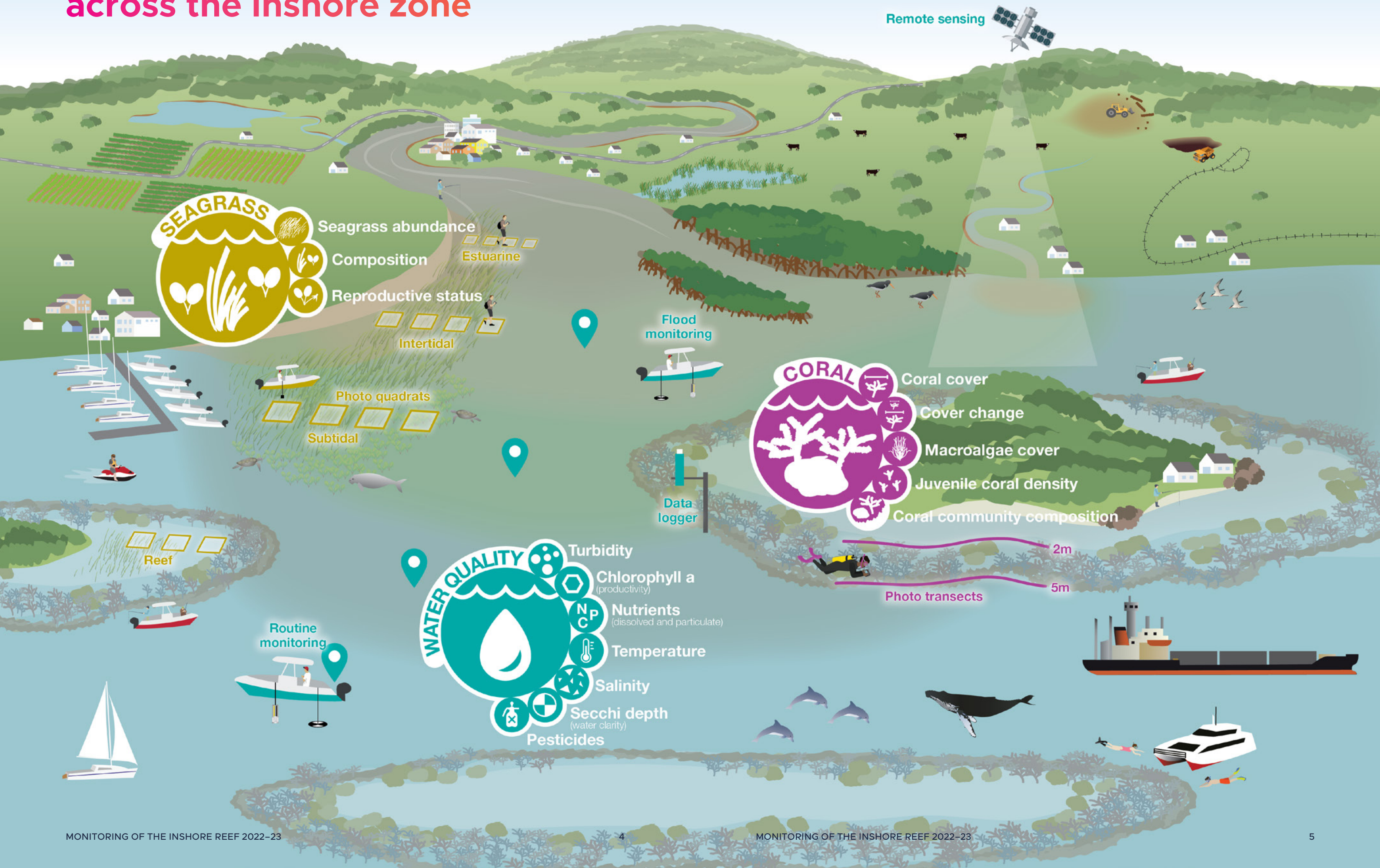
Major floods occurred in the Cape York and Mackay-Whitsunday regions. In Cape York, major floods occurred in the Pascoe and Normanby Rivers. Floods of the Normanby started on 28 December 2022 and continued throughout January 2023. After a short decline, discharge from the Normanby River increased again in mid-February, remaining at flood levels until mid-March. In the 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 rainfall event did not result in large flows in the Pioneer River.

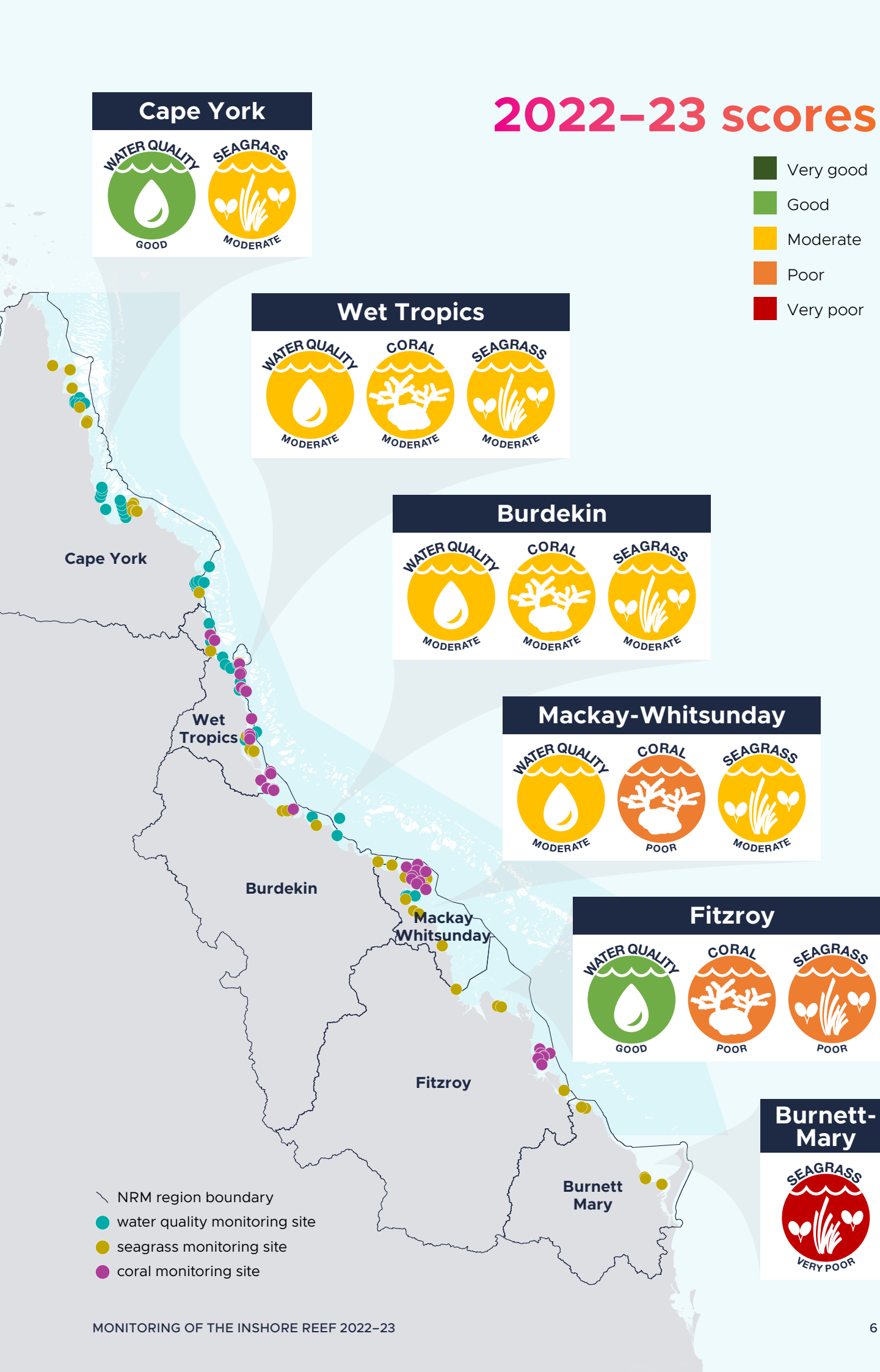
Sea surface temperatures

Sea surface temperatures were above average in inshore waters during the 2022-23 monitoring season, with pre-summer temperatures above 2 degrees above long-term average in waters north of the Whitsundays. Late summer and autumn temperatures reached more than 3 degrees above normal in some areas between Townsville and Cape Tribulation. Despite these higher-than-average temperatures, accumulated heat stress was below levels likely to cause coral bleaching.



Year-round monitoring occurs across the inshore zone





Water quality

In 2022-23, the Long-term Water Quality (WQ) Index showed trends of improvement in water quality in all regions where this score can be generated. In addition, the Annual Condition WQ Index scored either 'good' or 'moderate' in all regions.

Trend analysis has shown that since 2015, all water quality indicators have **improved** or been **stable** in all regions with the exception of particulate nitrogen in the Tully region, which has shown a trend of deterioration. Nitrate/nitrite has shown a trend of improvement in most focus regions, although concentrations are generally well above guideline values (GVs). This is a promising finding for nitrate/nitrite, and if current trends continue, concentrations may approach GV in the next few years. Long-term trends indicated that overall water quality has improved across the inshore Reef after years of deterioration.



Coral

Inshore coral communities at the whole of Reef-scale have remained in 'poor' condition since 2019. The prevalence of macroalgae is the most influential factor in the ongoing 'poor' assessment of coral communities at many reefs. Scores for the Macroalgae indicator have steadily declined in recent years and were lower than previously observed in 2023. The prevalence of macroalgae on inshore reefs shows a clear relationship to poor water quality, being higher on reefs exposed to higher concentrations of Chl α , which is a proxy for nutrient availability, and total suspended solids in their surrounding waters.

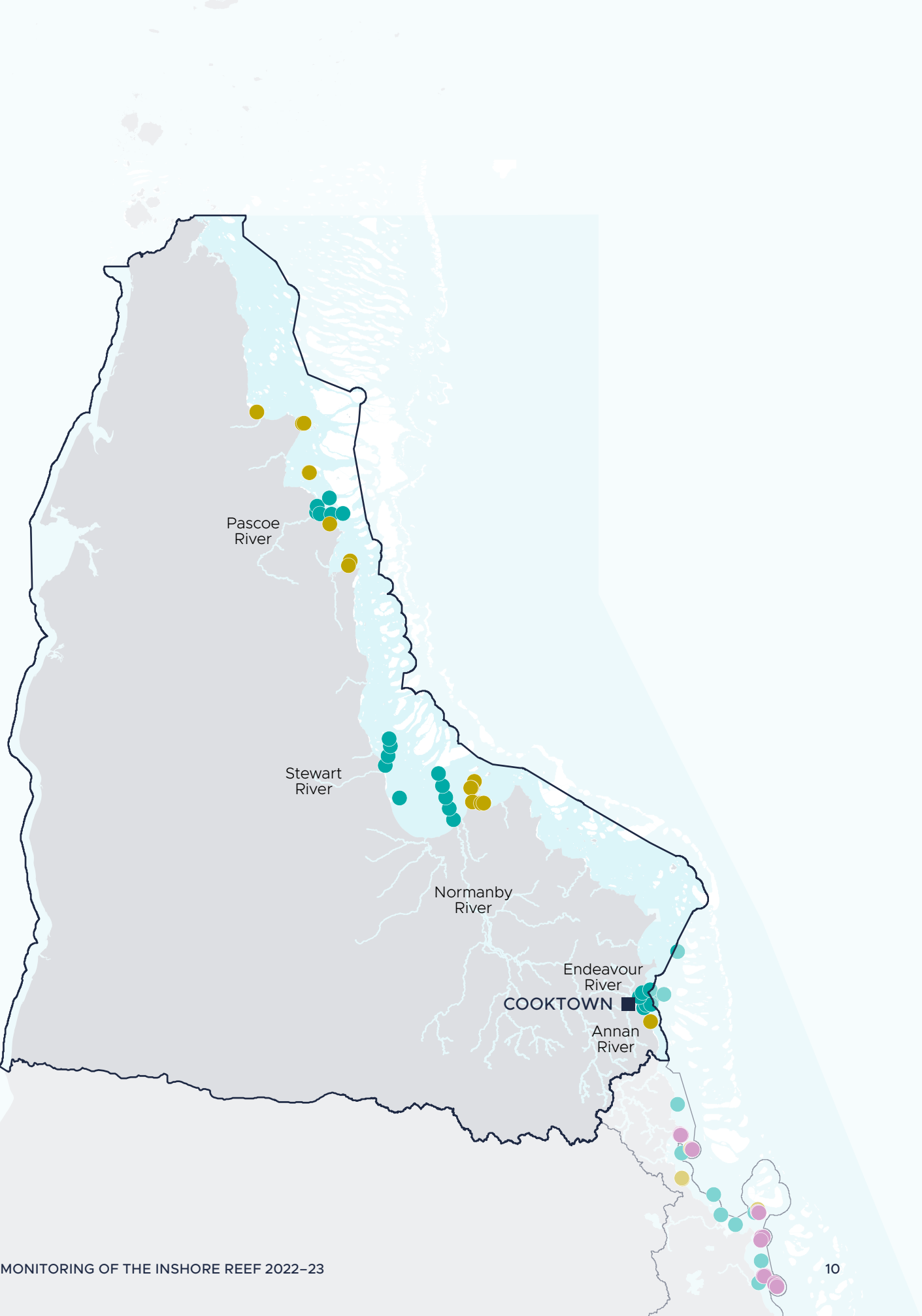


Seagrass

The condition of inshore seagrass meadows across the Reef marginally declined in 2022-23, and the Seagrass Index remained 'moderate'. However, there were marked regional differences. Seagrass condition in the northern regions (Cape York, Wet Tropics, Burdekin and Mackay-Whitsunday) remained 'moderate', whereas condition in the two southernmost regions continued to decline with Fitzroy remaining 'poor', and the Burnett-Mary deteriorating to 'very poor' for the first time in 16 years. Overall improvements in abundances were offset by losses in resilience, which reached its lowest point in a decade.



Cape York region



The Annual WQ Index for the Cape York region was ‘good’.

Discharge from rivers in the Cape York region was between 1.5 and 1.9 times above the long-term median discharge, except for the Normanby, which had discharge 3.1 times the long-term median. The flood plume from the Normanby River extended across Princess Charlotte Bay throughout most of January, February and March, reaching up to 100 km to the east, well beyond the outer reefs and north beyond the Stewart River.

Indicators such as Chlorophyll a (Chl a), Total Suspended Solids (TSS), and Particulate Phosphorus (PP) met guideline values (GVs) at most sites, while inorganic nitrogen as NO_x and Secchi depth did not.



The Seagrass Index for the Cape York region was ‘moderate’.

Seagrass condition was assessed only in the late dry in Cape York, which precedes the summer when the highest temperatures occurred. Seagrass meadow condition across the region in 2022–23 was marginally lower than in 2021–22 but remained ‘moderate’. Seagrass abundance increased from the previous period overall, however the resilience score deteriorated from ‘moderate’ to ‘poor’. Reproductive structures continued to be rarely observed in Cape York for the third consecutive year, which may hinder replenishment of the declining seed banks and weaken the capacity to recover from seeds in the near future.



Wet tropics region



The Annual WQ Index for the Wet Tropics region was 'moderate'.

River discharge in the Wet Tropics region was close to the long-term median in most catchments. NO_x and Secchi depth did not meet water quality GVs for any sub-region in the Wet Tropics. Phosphate (PO₄), PP, TSS, and Chl-*a* met GVs for all sub-regions. Particulate Nitrogen (PN) met GVs for two of the three sub-regions.

Over the period from 2015–2023, NO_x and Chl-*a* showed a trend of improvement in two of the three sub-regions in the Wet Tropics. Most other indicators showed a trend of stability. PN was the only indicator that showed a trend of deterioration in the Tully region. WQ Index scores have shown a trend of improvement over the past two to five years in most regions of the Wet Tropics.



The Seagrass Index for the Wet Tropics region was 'moderate'. However, sub-regional differences were observed.

Seagrass condition in the northern meadows increased from 'moderate' to 'good', while conditions in the southern region deteriorated and remained 'poor'. Improvements in the northern meadows were primarily driven by increases in the resilience score, which improved across all habitats. In the southern regions, both abundance and resilience indicators declined. Abundance has declined for the second consecutive year. While resilience declined in the south, it was still the second highest level on record. Recovery of seagrass meadows post 2011 has been challenging, particularly in the south, due to unstable substrates, chronic poor water quality compared to the north driving high turbidity and light limitation, and limited recruitment capacity.



At the regional level, the Coral Index scores have remained relatively stable at 'moderate' since 2016 with scores for all indicators consistently in the 'moderate' or 'good' range.

In all sub-regions the Coral Index was 'moderate' in 2023. While there were no severe disturbances over the 2022-23 monitoring year, the trend in scores varied among sub-regions as coral communities responded to, or recovered from, localised pressures. For example, the Coral Index score has continued to improve in the Barron Daintree sub-region as coral communities recovered from the impacts of coral bleaching in 2017 and localised damage caused by cyclone Owen and flood waters in 2019. In contrast, the Coral Index has declined since 2020 in the Herbert-Tully sub-region. Here, although Coral cover has improved and all indicators remain in the 'moderate' or 'good' range, scores for Juvenile corals and Cover change have moderated.

In the Johnstone Russell-Mulgrave sub-region crown-of-thorns starfish have been the primary cause of coral cover loss. The Coral Index has fluctuated between 'moderate' and 'good' condition since 2016 despite the ongoing presence of crown-of-thorns. In 2023, Coral cover remained similar to the level reached in 2022, the highest recorded since 2005.



Burdekin region



The Annual WQ Index for the Burdekin region was 'moderate'.

River discharge in the Burdekin region was around 2.2 times the long-term median, following two years of near-median discharge. NO_x and Secchi depth did not meet water quality GVs in the Burdekin region whereas PO₄, PN, PP, TSS, and Chl-*a* met GVs.

Over the period from 2015 to 2023, NO_x and PO₄ showed a trend of improvement in the Burdekin region. All other indicators remained stable (no net improvement or deterioration). No indicators showed a trend of deterioration. Water Quality Index scores declined from 2010 to 2018 followed by a period of stability. The last two years have shown an improving trend driven by improvements in PN and Chl-*a*.



The condition of seagrass meadows across the Burdekin region deteriorated overall but remained 'moderate'. Seagrass abundance marginally decreased relative to the previous period and remains lower than historical records. Seagrass resilience slightly decreased in 2022–23 and remained 'moderate' despite seed banks being abundant in the region.



The Coral Index score remained 'moderate', but had declined slightly from a peak reached in 2020.

The primary pressure to have influenced coral communities since 2020 surveys was a marine heatwave in early 2022. Although coral bleaching was associated with the 2022 marine heatwave, the impacts were not severe with Coral cover scores continuing to improve. In 2023, the regional Coral cover score was the highest observed since the beginning of the program in 2005.

Most influential in the recent decline in the Coral Index have been declines in the Juvenile coral and Macroalgae scores both of which remained 'poor'. Low numbers of juvenile corals can negatively affect the recovery of coral communities. Scores for Macroalgae remained 'poor' or 'very poor' at all but the two most offshore reefs monitored, a result that implies pressures associated with poor water quality were continuing to influence coral communities inshore of the Palm Islands.

Burdekin River as the main source of sediments to the Reef

Export of fine sediments to the Reef is dominated by the region's two largest rivers, the Burdekin and Fitzroy, with the Burdekin River the largest individual contributor. The Burdekin region has an estimated contribution of nearly 45 per cent of the total loads exported from all Reef catchments. Fine sediments are the fraction most likely to reach the Reef lagoon and the dominant proportion in monitored sediment loads in the MMP. Influx of fine sediments from large flood events can have long-lasting impacts on ecosystems. Immediately after flood events and a few months afterwards, fine sediments remain resuspended in the water column and decrease availability of light reaching the seafloor, primarily impacting the condition of shallow inshore coral and seagrass communities, and organisms that rely on these habitats.

In the Burdekin, concentrations of Total Suspended Solids (TSS), which include fine sediments, have fluctuated above and below the guideline values (GVs) since monitoring began in 2005. Over the period 2015–2023, the mean concentration of TSS has remained stable, with no significant improvement or decline overall, despite an oscillation over this 8-year period. TSS concentrations in 2022–23 were below the local water quality GVs. The continued improvement in TSS concentration in the marine environment is crucial for the health and resilience of coral reefs and seagrass meadows in the Burdekin, particularly with the added pressure of heat stress that impacted the region in recent years.

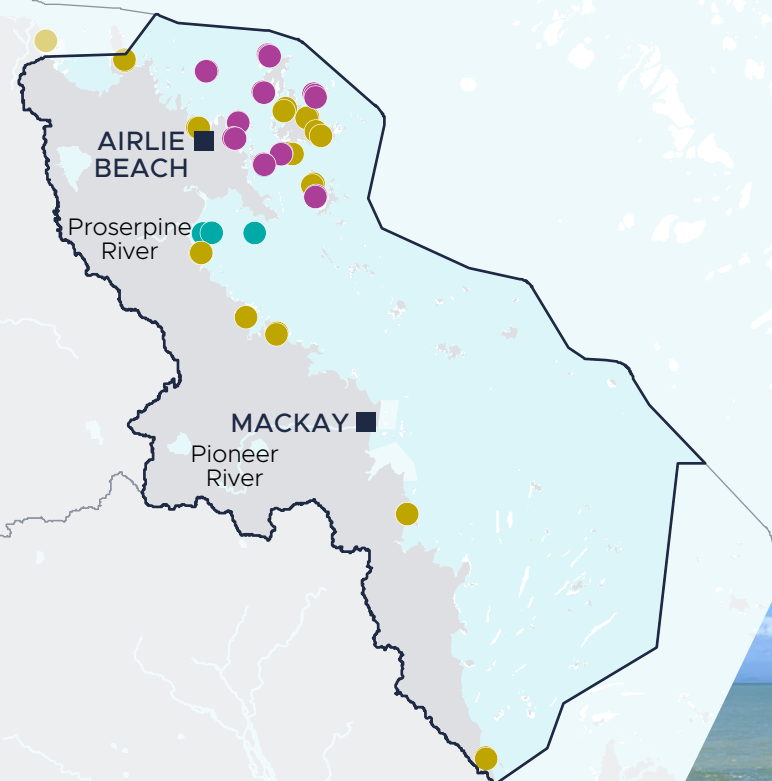
Mackay-Whitsunday region



The Annual WQ Index for the Mackay-Whitsunday region was 'moderate'.

River discharge in the Mackay-Whitsunday region was 1.7 times the long-term median, following three years of below-median discharge. NO_x, PO₄, PP, TSS, and Secchi depth did not meet water quality GVs in the Mackay-Whitsunday region whereas PN and Chl-*a* met GVs.

Over the period from 2015 to 2023, all indicators showed a trend of improvement in the Mackay-Whitsunday region. WQ Index scores showed a long-term trend of deterioration from 2007 to 2018. The trend then stabilised and has started to improve over the last four years, driven by improvements in PN, PP, water clarity, and Chl-*a*.



The Seagrass Index for the Mackay-Whitsunday region was 'moderate'.

Seagrass condition in the Mackay-Whitsunday has fluctuated between 'poor' and 'moderate' since 2011-12 which appears to be due to a range of environmental pressures. The seagrass abundance score increased in 2022-23, driven by increases in estuarine intertidal and coastal and reef subtidal habitats. The overall resilience score for the Mackay-Whitsunday region was 'moderate' in 2022-23, increasing to its highest level in six years. This appears the first indication that seagrass habitats in the region may be recovering from past disturbances. This is also likely due to alleviation of localised pressures and possibly chronic changes not easily identifiable in all sites and habitats.



The Coral Index for the Mackay-Whitsunday region remained 'poor'.

Most reefs in this region were severely impacted by cyclone Debbie in 2017 with early recovery of coral communities following one of two alternate paths. Where high cover of macroalgae became established the density of juvenile corals and rate of hard coral cover recovery have been low. In contrast, where the cover of macroalgae remained low there are higher densities of juvenile corals and hard coral cover has tended to increase more rapidly. Prior to Cyclone Debbie in 2017, 'very poor' scores for macroalgae were only recorded at two of the nine reefs currently monitored, in 2023 five reefs have 'very poor' Macroalgae scores at one, or both, of the site depths.

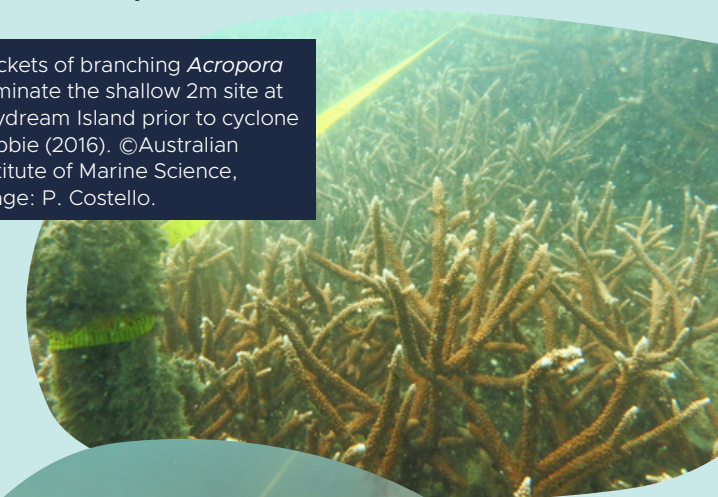
High levels of macroalgae associated with poor water quality

In all regions some of monitored reefs have persistently high levels of macroalgae. This is a concern as macroalgae compete with corals for space. This competition limits the resilience of coral communities by either suppressing the early life-history phases of corals, meaning fewer juveniles corals, or reducing the health of larger colonies leading to slower growth, or death. When macroalgae are in high abundance this can lead to feedback loops that promote their dominance over corals and result in long-term maintenance of macroalgae rather than coral-dominated communities.

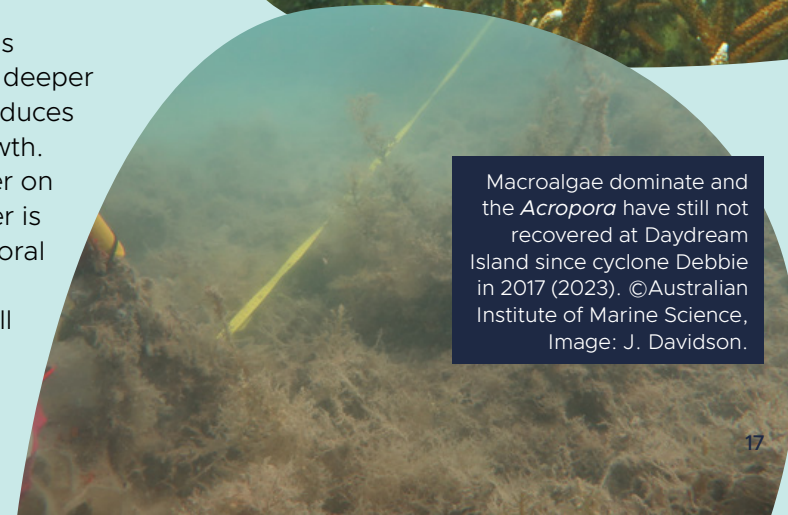
The prevalence of macroalgae on inshore reefs is correlated with water quality, with more macroalgae on reefs with higher concentrations of nutrients and suspended sediments. This relationship is strongest at 2 m depths particularly in the Burdekin region. At the deeper 5 m depths, reduced water quality also reduces light penetration, limiting macroalgal growth. While corals can, and do, attain high cover on some reefs in these conditions, once cover is reduced by a disturbance event such as coral bleaching or cyclones, poor water quality increases the chances that macroalgae will limit their recovery.

When the MMP began monitoring in 2005 six of the 30 reefs monitored at 2 m depth had higher cover of Macroalgae than Corals. In 2023, the number of algal-dominated-reef has increased to 12, of which three have been in a macroalgae dominated state since large floods in 2011 killed corals on some reefs in Keppel Bay, and three since cyclone Debbie severely impacted reefs in the Whitsundays in 2017.

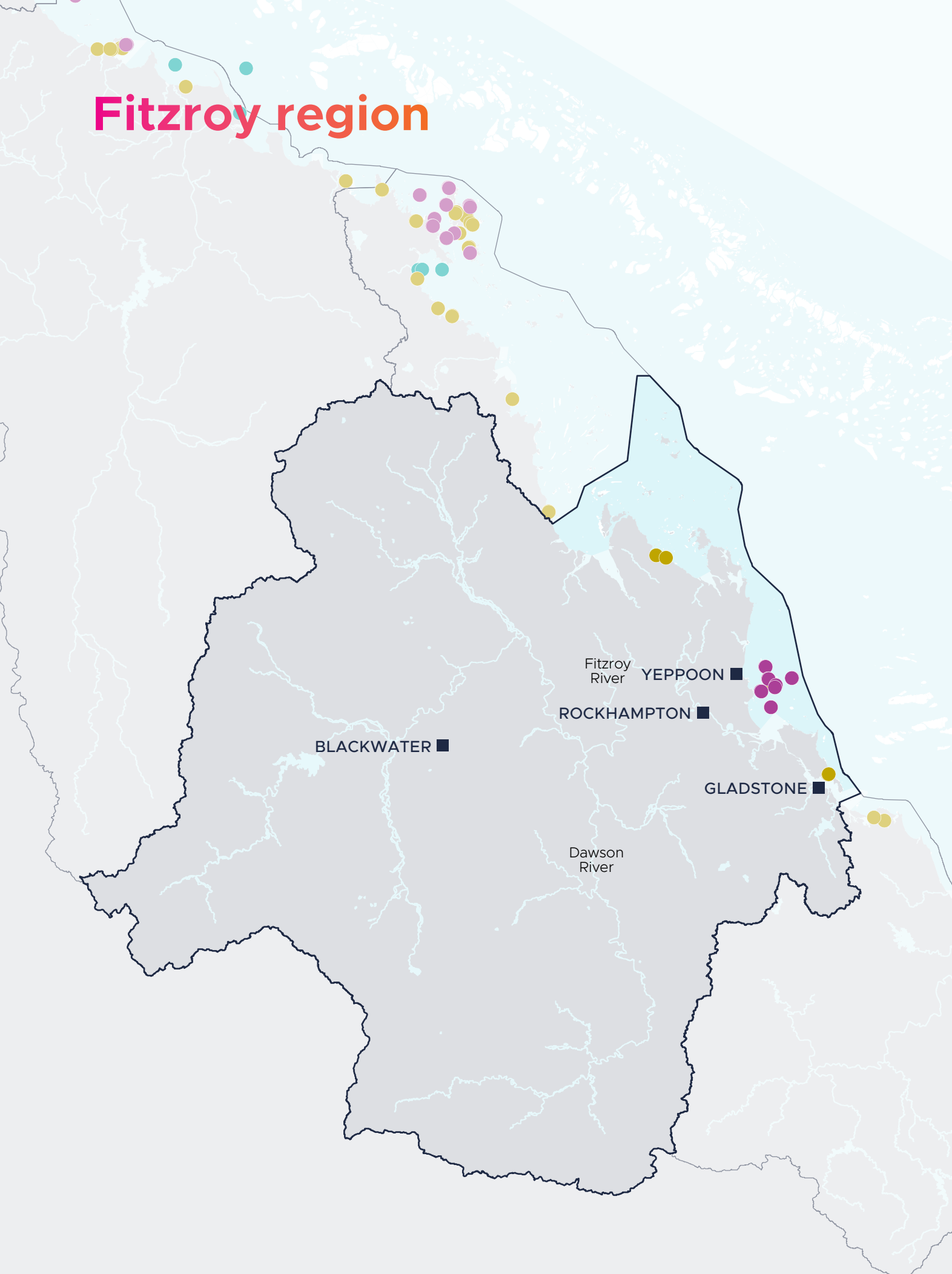
Thickets of branching *Acropora* dominate the shallow 2m site at Daydream Island prior to cyclone Debbie (2016). ©Australian Institute of Marine Science, Image: P. Costello.



Macroalgae dominate and the *Acropora* have still not recovered at Daydream Island since cyclone Debbie in 2017 (2023). ©Australian Institute of Marine Science, Image: J. Davidson.



Fitzroy region



The Annual Water Quality Index for the Fitzroy region was 'good'.

River discharge in the Fitzroy region was near the long-term median, following five years of near- or below-median discharge.

Concentrations of NO_x and Secchi depth did not meet GVs at most monitoring sites. Concentrations of PO_4 , PN, PP, and TSS did not meet GVs at half the monitoring sites in the region. Concentrations of Chl- α were below (meeting) GVs at most monitoring sites in the region (except Peak West).

WQ Index scores showed a small (i.e., changing by a single grade) improvement in water quality over the period 2008 to 2015, which was driven by improvements in PN, PP, and Chl- α indicators. Over the period 2020-2023, a trend of improvement has been seen, although continuing monitoring is needed to confirm these findings.



The Seagrass Index for the Fitzroy region was 'poor'.

Seagrass continued to deteriorate in the 2022-23 monitoring period. For the third year in a row, inshore seagrass meadows in the region have experienced a decline, despite gradual improvement from 2012-13 to 2019-20 after years of climate-related impacts. Seagrass abundance score marginally improved from the previous period, but this was driven by only one site (estuarine intertidal). The latest findings on resilience show a decrease to the second lowest level recorded.

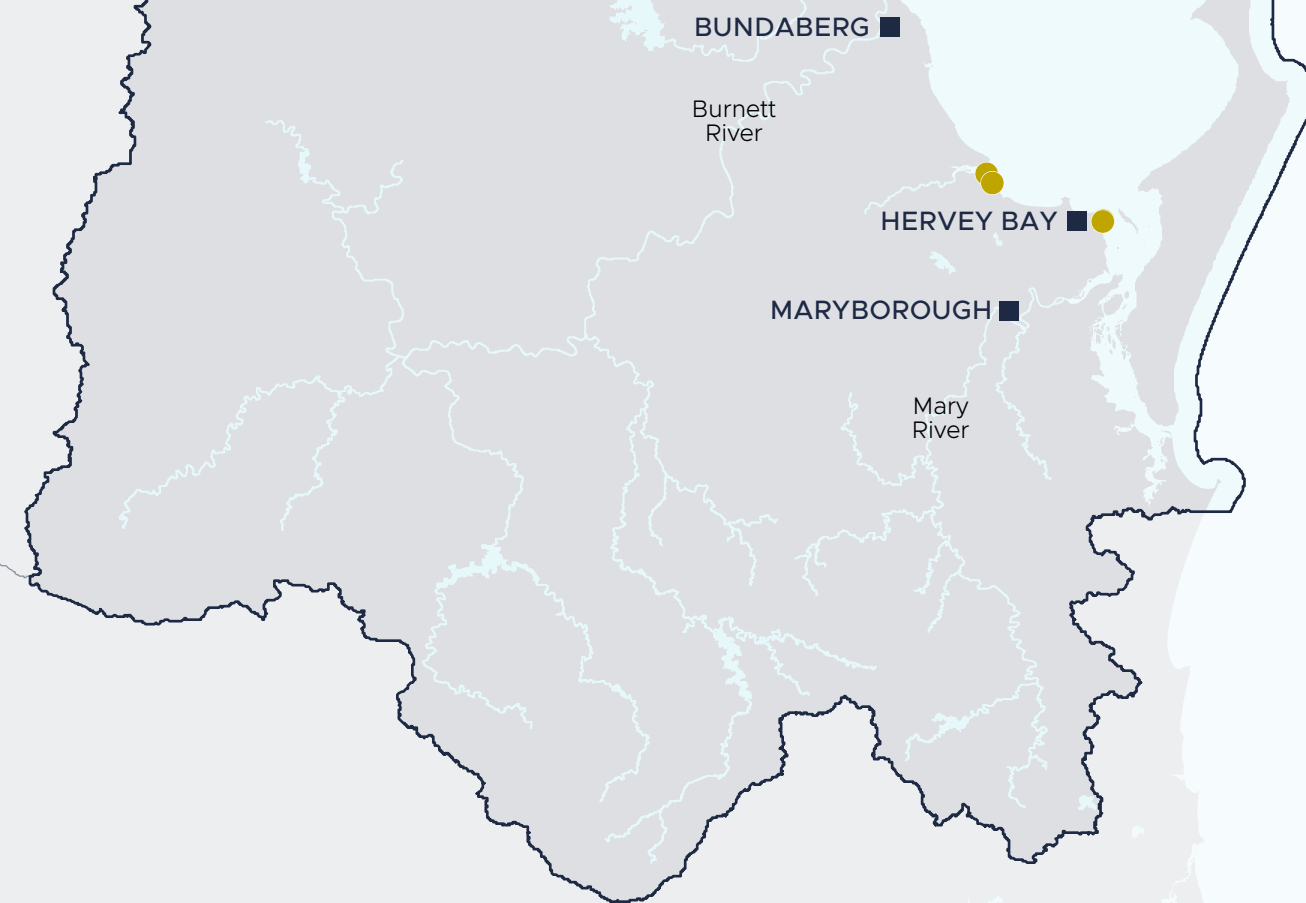


The Coral Index has varied around the middle of the 'poor' range since 2020, following a gradual recovery from the 'very poor' condition observed in 2014.

While regional coral cover has continued to increase in recent years, the rate of this increase has been slow. Continuing to limit Coral Index scores have been high cover of macroalgae and low densities of juvenile corals at most reefs. The Macroalgae indicator in this region has remained 'very poor' except for brief improvement in 2011 when macroalgae cover was temporarily reduced following severe flooding of the Fitzroy River.

The current state of reefs varies markedly across the region. Coral cover was highest at Barren Island, the reef furthest from the coast. In contrast, macroalgae were prevalent at most other reefs. At Middle Island there has been a shift from 70 per cent cover of *Acropora* in 2005 to 50 per cent cover of macroalgae in 2023.

Burnett–Mary region



The Seagrass Index for the Burnett–Mary region was 'very poor'.

Inshore seagrass meadows across the Burnett–Mary NRM 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. The seagrass abundance score remained very poor for the second consecutive year. The decline is a continuing trend that has been occurring for the NRM region since 2015–16. It is the fourth time this decade that the score has declined below moderate. This marks 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.

Novel thermal risk modelling to help with the management of seagrass meadows

Seagrass meadows are at risk from decline caused by thermal stress, particularly intertidal and subtidal meadows. Meadows in these areas of the tidal zone form critical habitats in the Reef, but are at greatest risk of exposure to temperature extremes because they are exposed to air temperatures at low tide and very high temperatures in shallow pools. However, using current models and spatial environmental information, it is difficult to estimate the level and extent of thermal stress within shallow inshore seagrass habitats. Recently, a new research project conducted as part of the MMP is collecting *in situ* temperature information from shallow inshore seagrass habitats to develop a realistic model to predict and estimate the level and extent of thermal stress in the shallow meadows of the inshore Reef.





Inshore marine pesticide monitoring

In 2022-23, presence of herbicides was monitored at 10 fixed monitoring sites along the inshore region between November 2022 and May 2023. The sampling approach included monthly deployments of Empore Disk passive samplers as well as collection of grab samples when each passive sampler was collected for the analysis of pesticide concentration, primarily herbicides. Pesticides were detected across all sites.

The most frequently detected pesticides in both passive samplers and grab samples were atrazine, diuron, hexazinone and tebuthiuron. Total herbicide concentrations were highest at sites in the Mackay-Whitsunday region (Sarina Inlet, Flat Top Island, Repulse Bay, and Whitsunday Channel), which correspond to high rainfall in those areas. Although pesticides were ubiquitously found in the marine environments, concentrations do not exceed the protection guideline values of 99 per cent of species at most sites. However, while individually pesticides concentration often did not exceed the guideline values, the Pesticide Risk Metric (PRM) showed that exceedances (PRM > 1 per cent) occurred during flood events, particularly in the Mackay-Whitsunday region where pesticide risk is often higher than in other regions. These results indicate that the inshore region is at risk due to chronic and acute exposure of pesticide.

