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Southern Inshore Zone: Coral Indicators for the 2024–2025 monitoring period

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A report prepared for the Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership

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Cover photo: Henderson Island reef slope showing extensive *Acropora* hard coral in July 2025. Image: Cassandra Thompson

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1 EXECUTIVE SUMMARY

This report presents the results of monitoring undertaken in 2025 for the coral component of the Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership's Southern Inshore Monitoring Program, *funded by Dalrymple Bay Coal Terminal Pty Ltd and Dalrymple Bay Infrastructure*. Coral communities were monitored by the Australian Institute of Marine Science under a 50/50 co-investment arrangement. These results form the basis of the coral indicator scores for the Southern Inshore Zone that inform the marine inshore results for the Mackay-Whitsunday-Isaac 2024/2025 monitoring period.

In July 2025 the Australian Institute of Marine Science (AIMS) resurveyed benthic communities at permanent coral monitoring locations at five reefs in the Southern Inshore Zone of the Great Barrier Reef (GBR). The overall report card grade for community condition in 2025 remained at D ('poor'), based on a Coral Index score of 0.26 (Figure 1).

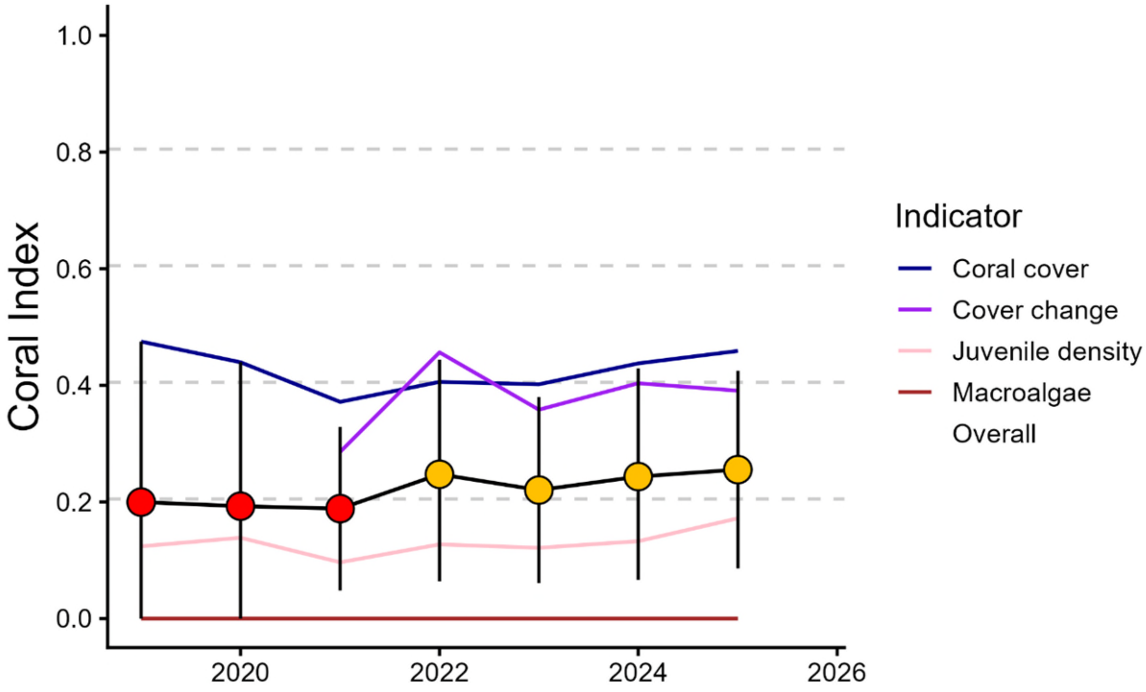

Figure 1 Coral Index and indicator scores. The Cover change indicator could not be assessed in 2019 or 2020 and so regional Coral Index scores in those years are not directly comparable to later years. Score categories are: >0.8 'very good' (A), > 0.60 ≤ 0.80 'good' (B), > 0.40 ≤ 0.60 'satisfactory' (C), > 0.20 ≤ 0.40 'poor' (D), 0 ≤ 0.20 'very poor' (E).

The Coral Index scores are based on the assessment of four indicators of coral condition:

- **Coral cover** - the proportion of the substrate occupied by living corals,
- **Macroalgae** - the proportion of the benthic algae cover comprised of large fleshy species,
- **Juvenile density** - the density of juvenile hard corals, and
- **Cover change** -the rate at which hard coral cover increased.

The very slight improvement in the Coral Index from 0.24 in 2024 reflects minor gains in the Coral cover and Juvenile density indicator scores, though both retain their grade of 'satisfactory' and 'very poor' respectively (Figure 1). The score for the Cover change indicator continues to hover just below the boundary between 'poor' and 'satisfactory' classifications as the overall rate of increase in hard coral cover remains below expected levels. The ongoing dominance of macroalgae at most reefs continues to keep the Macroalgae indicator score zero with a 'very poor' grade. The very high levels of macroalgae likely contribute to lack of coral community resilience indicated by the low scores for Cover change and Juvenile density indicators (Figure 1).

Over the 2024-2025 period there were no incidences of widespread disturbance to the region. While water temperatures in early 2025 briefly exceeded the long-term threshold for heat-stress they were well below the levels experienced in the marine heat waves of 2020 and 2024 and did not lead to widespread bleaching over the 2024-2025 summer. There was no direct impact of river discharge on the coral communities and there were no cyclones that would have damaged corals in this region.

2 BACKGROUND

Inshore coral reefs of the Great Barrier Reef are impacted by multiple pressures including large scale disturbances such as cyclones and coral bleaching through to more localised issues such as elevated levels of nutrients or suspended sediments that may result from activities in the coastal zone and adjacent catchments (Waterhouse *et al*. 2024). Successful management of coral communities requires the ability to identify where and when the resilience of communities is compromised and then identify and remediate causative pressures.

The Healthy Rivers to Reef Partnership (HR2RP) was created in October 2014 with the objective of using a collaborative, community-led, approach to inform long-term management of the region's waterways and marine environments. In October 2015, the pilot report card was released which provided a snapshot of waterway health in the region.

The HR2RP identified a knowledge gap in the Southern Inshore Zone of the report card and, following an initial scoping study in October 2017 by Sea Research (2018) and funding received from Dalrymple Bay Coal Terminal Pty Ltd and Dalrymple Bay Infrastructure, co-invested with the Australian Institute of Marine Science (AIMS) to establish a long-term monitoring project of corals in the area. The design spans a gradient in water quality from the coast out to the Percy Island group some 80 km offshore.

The sampling methods used are consistent with those used more broadly by AIMS under the Marine Monitoring Program (MMP). The MMP has strongly invested in the development of indicator metrics that focus on coral community resilience as a tool for synthesising coral monitoring. The Coral Index, which is based on a series of indicators, is central to reporting of coral community condition across regional and state-level report cards. There are considerable efficiencies in terms of indicator development, quality control, and reporting in following the standards for sampling and analysis developed by the MMP.

This report presents the seventh annual survey of five permanent coral monitoring locations in the Southern Inshore Zone reported by the Mackay-Whitsunday-Isaac HR2RP Report Card. The purpose of this report is to provide a description of reef communities observed in 2025 that expands on the necessarily succinct summary of overall condition presented by the Mackay-Whitsunday-Isaac Report Card.

3 METHODS

3.1 Sampling Design

Coral communities are monitored along permanently marked transects. The selection of sites and construction of transects occurred in January and May of 2019, as reported in detail in Davidson *et al.* (2019).

In brief, suitable sites were identified at five fringing reefs located along the gradient in water quality from the very turbid waters close to the coast through to the clearest waters some 80km offshore (Figure 2).

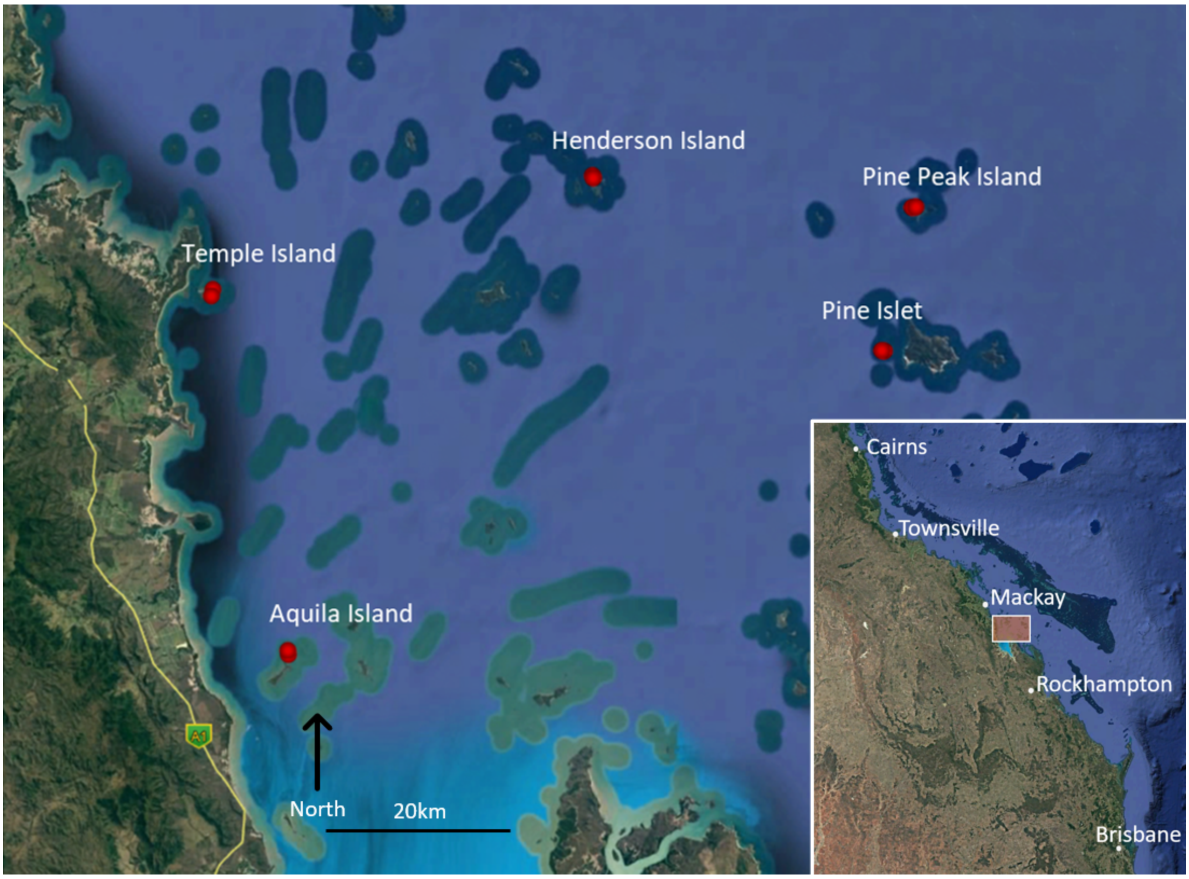

Figure 2 Map showing islands selected of coral monitoring in the Southern Inshore Zone. Insert shows location of monitoring area in relation to the Queensland coastline.

At each reef, two replicate sites separated by at least 150 m were selected haphazardly from the surface with the only limitations being that they were positioned on areas of substrate suitable for corals. Within each site, five transects of 20 metre length were constructed to follow the depth contour of the site. Each transect was separated from the previous by a gap of 5 m and marked with a steel fence post 'star-picket' at the start and a section of 10 mm steel rod at both the 10 m and end marks.

In recognition of the importance of depth as a determinant of coral community composition (e.g., Thompson *et al.* 2014), transects were replicated at both 2 m and 5 m depths below lowest astronomic tide datum (LAT) at Pine Peak Island and Pine Islets as predicted by Navionics electronic charts at the time of site construction. Sites at Henderson Island were setup in 2018 by a third party and parts of some transects at site 1 were set 1-3 m deeper than the intended 5 m datum. In 2022 the last rod at Transect 3 of the 5 m depth at Site 1 was relocated to better follow the depth contour. In 2024 the same was done for the last rod at Transect 5. In addition to keeping transects at a consistent depth these slight amendments improve dive logistics based on the use of DCIEM dive tables as per Australian Scientific Dive Standards. This is an important consideration given the accessibility of these sites.

At Temple Island and Aquila Island the reef slope transitions to sand at 1-1.5 m below LAT and as such transects were set at 1 m below LAT only. Additional details including the GPS waypoints marking the start of each site and depth combination along with compass directions along each transect are provided in Table A 7.

Reefs were monitored on visits in July 2025 (Table 1).

Table 1 Dates of coral monitoring.

Island	2019	2020	2021	2022	2023	2024	2025
Pine Peak Island	27th January	26th May	6th March	5th June	23rd June	12th June	17th July
Pine Islets	28th January	27th May	6-7th March	4th June	22nd-23rd June	11-12th June	17-18th July
Henderson Island	29th January	25th -26th May	7th March	4th June	22nd June	12th June + 13th July	18th July
Temple Island	27th May	27th-28th May	3rd June	3rd June	24th June	12th July	15th July
Aquila Island	27th May	12th July	3rd June	6th July	24th June	12th July	15th July

3.2 Sampling Methods

3.2.1 Photo Point Intercept Transects

Benthic cover was estimated using photo point intercept transects (PPIT, Jonker *et al.* 2020). Along the upslope side of each transect line, digital images of the substrate were taken at ~40 cm elevation at 50cm intervals. Benthic organisms beneath five evenly spaced points on each image were identified to the finest taxonomic resolution possible, typically genus level for corals and larger algae. In addition, the state of bleaching observed at each coral point was recorded as one of three levels: fully bleached, partially bleached, and non-bleached. A total of 32 images were analysed from each transect. Identifications for each point were entered directly into a data entry front-end to an Oracle® database, developed by AIMS. This system allows the recall of stored transect images. For data quality assurance all identified points were checked by a second observer.

3.2.2 Juvenile Coral Surveys

The number of juvenile coral colonies were counted *in situ* along the permanently marked transects. Corals in the size classes: 0-2 cm and >2-5 cm found within a strip 34 cm wide (data slate length) positioned on the upslope side of the transect line were identified to genus level and recorded. Importantly, this method aimed to record only those small colonies assessed as juveniles, i.e., having resulted from the settlement and subsequent survival and growth of coral larvae, and so did not include small coral colonies considered to have resulted from the fragmentation or partial mortality of larger colonies.

3.2.3 Scuba Search Transects

Scuba search transects documented the incidence of disease and other agents of coral mortality and stress observed at the time of survey. This method followed closely the Standard Operation Procedure Number 9 of the AIMS Long-Term Monitoring Program (Miller *et al.* 2020) and serves to help identify probable causes of any declines in coral community condition.

For each 20 m transect a search was conducted within a 2 m wide belt transect centred on the marked transect line and the incidence of: coral disease, coral bleaching, coral predation by *Drupella* or crown-of-thorns starfish, overgrowth by sponges, smothering by sediments, or physical damage to colonies was recorded.

3.3 Coral Community Indicators

The indicators and methods used to derive report card scores for coral communities are a subset of those used for the Reef Report Card (Thompson *et al.* 2022), the development of which are described in detail in Thompson *et al*. (2020). The indicators, Coral cover, Macroalgae and Juvenile density have been used since the start of this program. The Cover change indicator requires repeated observations that span a period during which the coral communities were not subjected to an acute pressure, such as a marine heatwave or tropical cyclone. As most reefs were impacted by coral bleaching in 2020, with flow on effects evident in 2021, this indicator was first implemented in 2022. Back calculated scores for Cover change in 2021 are supplied, although values from 2021 should be treated with caution as they relate only to changes at Aquila Island, Temple Island, and Pine Islets 2 m. AIMS does not support the inclusion of the Community composition indicator in this region based on analysis by Thompson *et al.* (2022) that demonstrates this indicator primarily varies in response to changes in coral cover, which is captured by the Coral cover indicator. In addition, the low cover of corals at several reefs suggests the composition of communities observed to date may not represent an aspirational condition on which to set a baseline.

This section provides an overview of the rationale for the selection of the four indicators used to assess coral community condition and how they are scored. A full description of these indicators can be found in Thompson *et al.* (2020).

3.3.1 Coral cover

The most tangible and desirable indication of a healthy coral community is an abundance of coral. The coral cover indicator scored reefs based on the proportional area of substrate covered by both 'Hard' (order Scleractinia) and 'Soft' (subclass Octocorallia) corals.

$Coral\ cover_{ij} = hard\ coral\ cover_{ij} + soft\ coral\ cover_{ij}$ where i = reef and j = time.

While high coral cover provides a good indication that environmental conditions are supportive of the growth and survival of corals, low cover does not necessarily indicate the opposite. Coral communities are naturally dynamic, being impacted by acute disturbance events such as cyclones (Harmelin-Vivian 1994; Osborne *et al.* 2011), temperature anomalies (Berkelmans *et al.* 2004) and, in coastal areas, flooding (van Woesik 1991; Jones and Berkelmans 2014). The Juvenile and Macroalgae indicators were included as they represent the potential for coral communities to recover from disturbances.

3.3.2 Macroalgae

Macroalgae may suppress the recovery of coral communities through a variety of mechanisms ranging from direct competition with surviving colonies through to physical and chemical suppression of the recruitment process (McCook *et al.* 2001; Hughes *et al.* 2007; Foster *et al.* 2008; Hauri *et al.* 2010, Clements *et al.* 2020). To ensure that the assessment of macroalgae cover was independent of the cover of corals, and that differences in available space for algal colonisation were considered, the indicator for macroalgae was defined as the proportion of the total algae cover that is made up of large fleshy species, collectively macroalgae.

$Macroalgae\ proportion_{ij}$ = $Macroalgae\ cover_{ij}$ /$Total\ algae\ cover_{ij}$ where i = reef and j = time.

3.3.3 Juvenile density

The density of juvenile corals is an indicator of the successful completion of early life history stages of corals from gametogenesis through fertilisation, larval survival, settlement to the substrate and then early post settlement survival, all of which may be impacted by poor water quality (reviewed by Fabricius 2005; van Dam *et al.* 2011; Erftemeijer *et al.* 2012). The juvenile indicator was derived from counts of juvenile hard corals along belt transects and converted to a density per area of potentially colonisable hard substrate, estimated as the proportion of benthos identified as algae along the co-located point intercept transects.

$Juvenile\ density_{ij} = J_{ij}\ /\ A_{ij}$

Where J= count of juvenile colonies < 5cm in diameter, A = area of transect occupied by algae (m^2), i = reef and j = time.

Selection of thresholds for the scoring of this metric was based on the analysis of recovery outcomes for MMP and AIMS' Long-Term Monitoring Program (LTMP) reefs up to 2014 (Thompson *et al*. 2020). From these time series a binomial model was fitted to juvenile densities observed at times when coral cover was below 10% and categorised based on recovery rate as being either below or above the predicted lower estimate of hard coral cover increase as estimated by the Cover change indicator described below. This analysis identified a threshold of 4.6 juveniles per m^2 beyond which the probability that coral cover would subsequently increase at predicted rates outweighed the probability of lower than predicted rates of recovery. Consequently, a juvenile density of 4.6 m^{-2} was considered to be the threshold at which the indicator score improves from 'poor' to 'satisfactory'. The upper threshold density, at which the probability was > 80% for coral cover to recover at predicted rates, was calculated at 13 m^{-2}, at or above this density scores reach a maximum value of 1.

3.3.4 Cover change

While high coral cover can justifiably be considered a positive indicator of community condition, the reverse is not necessarily true. Low cover may occur following acute disturbance and, hence, may not be a direct reflection of the community's resilience to underlying environmental conditions. For this reason, in addition to considering the actual level of coral cover, we assess the rate at which hard coral cover increases as a measure of recovery potential. The assessment of rates of cover increase is possible as rates of change in hard coral cover on inshore reefs have been modelled (Thompson *et al.*

2020), allowing estimations of expected increases in cover for communities of varying composition to be compared against observed changes.

A Bayesian framework was used to permit propagation of uncertainty through predictions of expected hard coral cover increase from separate models applied to fast growing corals of the family Acroporidae, and the combined cover of all other hard corals. Note that the example presented below for Acroporidae (*Acr*), has the same form as that applied for Other Corals (*OthC*) if these terms are exchanged where they appear in the equations:

$$\ln(Acr_{it}) \sim \mathcal{N}(\mu_{it}, \sigma^2)$$

$$\mu_{it} = vAcr_i + \ln(Acr_{it-1}) + \left(-\frac{vAcr_i}{\ln(estK_i)}\right) * \ln\left(Acr_{it-1} + OthC_{it-1} + Sc_{it-1}\right)$$

$$vAcr_i = \alpha + \sum_{j=0}^{J} \beta_j Reef_i$$

$$\alpha \sim \mathcal{N}(0, 10^6)$$

$$\beta_j \sim \mathcal{N}(0, \sigma^2_{Reef})$$

$$\sigma^2, \sigma^2_{Reef} = \mathcal{U}(0{,}100)$$

$$rAcr = v\overline{A}cr_i$$

Where, $Acr_{it}, OthC_{it}$ and Sc_{it} are the cover of Acroporidae coral, other hard coral and soft coral respectively at a given reef at time (t). $eskK$ is the community size at equilibrium (100-proportion of area comprised of unconsolidated substrates) and $rAcr$ is the rate of increase (growth rate) in cover of Acroporidae. Varying effects of Reef (β_j) is also incorporated to account for spatial autocorrelation. Model coefficients associated with the intercept, and Reef (α_i and β_j) all had weakly informative Gaussian priors (the latter two with model standard deviation). The overall rate of coral growth parameters ($rAcr$ or alternatively $rOthC$) constituted the mean of the individual posterior rates of increase ($vAcr_i$ or alternatively $vOthC_i$).

3.3.5 Scoring of Indicators

To facilitate the reporting of coral community condition, the observed values for each indicator were converted to scores on a common scale of 0 to 1. For each indicator, observed levels were scaled against thresholds used by the MMP. These thresholds were set based on expert opinion and knowledge gained from the time-series of coral community condition collected by the MMP and LTMP. Upper bounds were set that represent values of indicators that were considered to represent communities in as good a condition as could be expected in the local environment (Figure 3 uses coral cover as an example). Conversely, lower bounds were set to represent minimal resilience (Table 2). While observations may exceed these limits, any such values will be capped at the minimum or maximum score (0 or 1 respectively). For the macroalgae indicator upper and lower bounds were set individually for each reef and depth to account for natural variation in macroalgal abundance across the steep gradient in water quality that exists in the inshore Great Barrier Reef. Selection of the reef-level thresholds were based on predictions of macroalgae proportion based on gradient boosted models (Ridgeway 2007). The models predict macroalgae proportion based on mean chlorophyll *a* and non-algal particulate (turbidity) concentrations for each reef derived from MODIS Aqua data sourced from the Bureau of Meteorology[1].

Table 2 Indicator score thresholds.

Indicator	Location	Upper bound (score=1)	Lower bound (score=0)
Coral cover	All	75%	0%
Macroalgae	Pine Peak Island 2 m	0.2%	3.4%
	Pine Peak Island 5 m	0%	6.3%
	Pine Islets 2 m	0.2%	5.4%
	Pine Islets 5 m	0%	6.4%
	Henderson Island 2 m	0.2%	3.9%
	Henderson Island 5 m	0%	6.7%
	Temple Island 1 m	0.3%	23%
	Aquila Island 1 m	0.3%	23%
Juvenile density	All	13 m^{-2}	0 m^{-2}
Cover change	All	2* upper 95% CI	Hard Coral cover declined

[1] *Marine water quality indices produced by the Australian Bureau of Meteorology as a contribution to eReefs – a collaboration between the Great Barrier Reef Foundation, Australian Government, Bureau of Meteorology, Commonwealth Scientific and Industrial Research Organisation, Australian Institute of Marine Science and the Queensland Government. Data are acquired from NASA spacecraft by the Bureau, Australian Institute of Marine Science, and the Commonwealth Scientific and Industrial Research Organisation.*

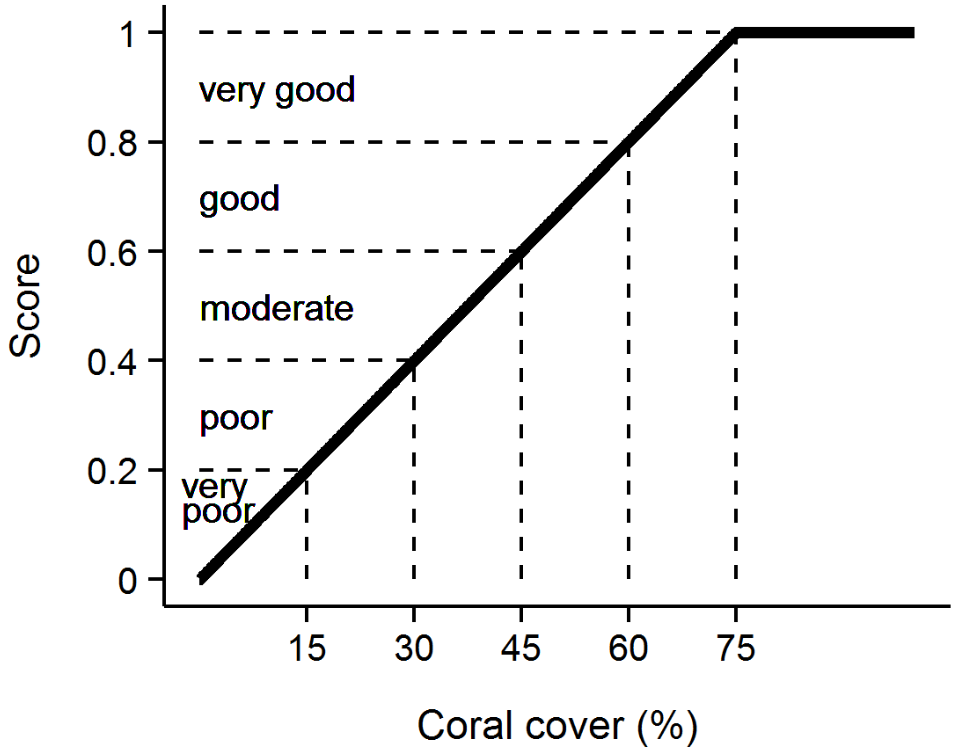

Figure 3 An example of a scoring diagram, here for the Coral Cover metric. Numeric scores and associated condition classifications based on observed coral cover are presented (see also Table 2).

3.3.6 Aggregation of Indicator Scores

The scaling of all scores to the common range of 0 to 1 allows the aggregation of scores across indicators at a hierarchy of spatial scales. At any given spatial scale, the mean of the individual indicator scores provides the Coral Index score. Within this report, indicator and index scores are presented at the scale of individual indicators at each reef and depth, and for the Southern Inshore Zone. Grades and associated condition classifications for coral communities were derived from the index scores, according to the conversions described in Table 3.

Table 3 Indicator scores, condition descriptions and report card grade conversions. Scores are rounded to the nearest single decimal place.

Score	Condition description	Grade
> 0.8	very good	A
> 0.6 ≤ 0.8	good	B
> 0.4 ≤ 0.6	satisfactory	C
> 0.2 ≤ 0.4	poor	D
0 ≤ 0.2	very poor	E

3.3.7 Data Analysis

A panel of plots provide temporal trends in the Coral Index and the indicators on which the index is based.

For each of the indicators that inform the Coral Index, temporal trends and their 95% confidence intervals were derived from linear mixed effects models. Models for each indicator included a fixed effect for year and random effect for each reef and depth combination. Observed trends for individual reef and depth combinations (averaged over sites) are provided as grey lines. Annual Coral Index scores are the arithmetic mean of the three indicator scores; associated confidence intervals are derived from bootstrapped distributions of reef and depth level scores.

Genus level cover data for the current year are included in Appendix Table A 1, Table A 2, Table A 3, Table A 4, and Table A 5. In 2022 AIMS adopted an updated taxonomic classification scheme for hard corals based primarily on molecular studies that altered the accepted taxonomy of several coral species. The taxonomy adopted aligned with the World Register of Marine Species. This change means that it is not appropriate to compare values for genus richness of hard coral cover or juvenile hard corals with those presented in reports prior to 2022.

A more detailed summary of raw data for benthic cover and juvenile density at each reef and depth combination is presented as bar plots in Appendix Figure A 2. These additional plots breakdown cover and density of corals to the taxonomic level of Family. Due to the overall abundance of the family Acroporidae, this is split further into genus groups *Acropora* and *Montipora*. Photos representative of coral communities at each reef and depth in 2025 are at Appendix Figure A 3 (a-f) and Figure A 4 (a-b).

3.3.8 Key Pressures

Coral communities are susceptible to a range of pressures. Identifying these pressures and the associated drivers is essential in determining the likely cause of impacts to coral community condition. For inshore reefs of the GBR common disturbances to coral communities include physical damage caused by tropical cyclones (Osborne *et al.* 2011; De'ath *et al.* 2012), exposure to low salinity waters during flood events (van Woesik 1991; Jones and Berkelmans 2014), predation by corallivorous crown-of-thorn starfish (Pratchett *et al.* 2017), and anomalously high summer temperatures resulting in coral bleaching (Berkelmans *et al.* 2004; Sweatman *et al.* 2007), most recently summarised by Thompson *et al.* 2024. It is only once the influences of acute pressures have been accounted for that the potential impacts of chronic pressures such as elevated turbidity and nutrient levels can be inferred.

3.3.9 Thermal Stress

Thermal stress, resulting in coral bleaching, is an increasing threat to coral communities in a warming world (Schleussner *et al.* 2016). In 2019 temperature loggers (Vemco Minilog-II-T) were deployed to star pickets marking site 1, transect 1 at each of Pine Peak Island (2 m and 5 m), Henderson Island (2 m and 5 m), and Aquila Island (1 m). These loggers were retrieved annually. In 2024 the temperature loggers were upgraded to the RBR*solo*3T. As this time-series develops, an accurate temperature climatology for each location will be developed enabling the estimation of site-specific temperature stress metrics. In the interim, the mean temperature during the hottest month of the year from time-series of temperatures recorded by the MMP at reefs in the Whitsunday Islands has been adopted as a visual reference for temperatures recorded in the Southern Inshore Zone.

Satellite-based estimates of thermal stress resulting in coral bleaching were accessed to allow spatial and inter-annual comparisons of thermal stress across the Mackay Whitsunday Isaac reporting region. Thermal anomalies expressed as Degree Heating Weeks (DHW) were sourced from NOAA coral reef watch . Thresholds at which severe coral bleaching is likely are DHW values greater than eight (Lui *et al*. 2014). Realised severity of bleaching will depend on the pattern of warming and differences in the tolerances of coral species.

3.3.10 Runoff

Median discharge for the water-years 1990-1991 through to 2019-2020 are compared to the current year. Discharge data were sourced from the Queensland Government water monitoring portal. Correction factors to account for un-gauged portions of the catchment were applied to gauged discharge. These data were supplied by Dr Stephen Lewis from TropWater at James Cook University and represent those reported by the Great Barrier Reef Marine Monitoring Program.

3.3.11 Cyclones

Significant impacts to coral reefs in the GBR have been attributed to cyclone and storm damage (Osborne *et al.* 2011; De'ath *et al.* 2012). Due to the physical nature of damage associated with cyclones, impacts are readily identifiable by surveys the following winter. In addition, cyclones are well publicised and highly unlikely to go unnoticed. Verification of the potential impacts of past cyclones was assessed based on viewing seasonal cyclone tracks published online by the Australian Bureau of Meteorology.

3.3.12 Environmental Settings of Reefs.

Turbidity and nutrient levels are critical components of the aquatic environment and are fundamental determinants of benthic community composition and condition. For the reporting of coral community condition in inshore areas, nutrient availability determines the level of macroalgae cover that can be expected, influencing the thresholds set for scoring macroalgae on a site-specific basis (Thompson *et al.* 2020). In addition, the composition of sediments, as a proxy for the hydrodynamic setting of a site, is a useful covariate to consider in terms of coral community dynamics (Wolanski *et al.* 2005). For a detailed appraisal of both nutrient and sediment regimes in the local environment of the Southern Inshore Zone, see our baseline report, Davidson *et al.* (2019).

4 RESULTS

4.1 Pressures

4.1.1 Thermal Stress

When surveys were conducted in July 2025 only a few coral colonies at Pine Peak Island and Pine Islets showed signs of bleaching. Over the 2024-25 period *in situ* temperature records show temperatures at the monitored sites peaked between 25th - 27th January 2025, with the highest temperature at Aquila Island (30.3^{O}C) marginally lower than those recorded in the marine heat wave in 2024 (Figure 4). While temperatures at all three sites exceeded the baseline (28.5^{O}C), a figure derived from long-term temperature records of reefs in the nearby Whitsunday Islands, these exceedances were relatively modest and short lived compared to those observed in either 2020 or 2024 when widespread bleaching occurred (Figure 4).

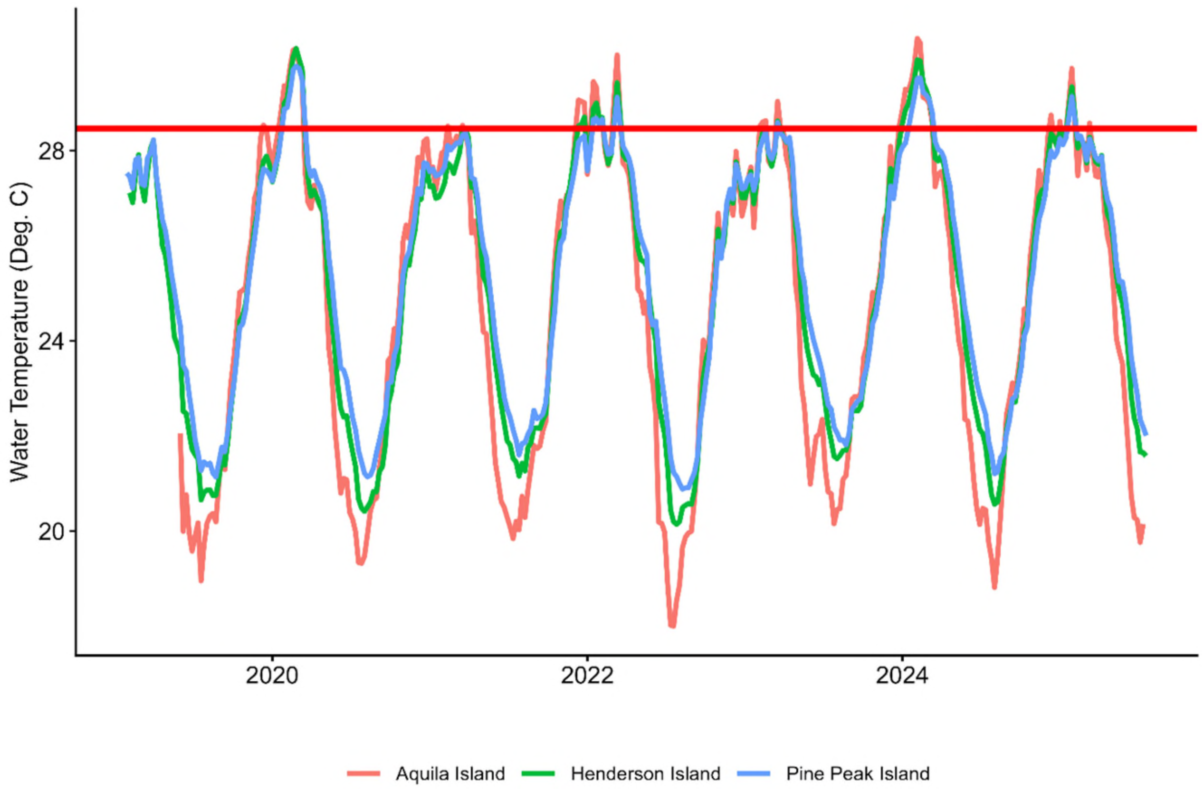

Figure 4 Temperature profiles recorded by in-situ loggers. The horizontal reference line was derived from the mean of the means of the hottest month each year observed over timeseries of in situ temperature data available from reefs in Whitsunday Islands. This baseline excluded years in which bleaching was observed.

This observation was supported by estimates of Degree Heating Weeks (DHW) that showed the levels of heat stress likely to cause coral bleaching were well below those observed in 2020 or 2024 that coincided with widespread bleaching (Figure 5).

As an explanatory note, DHW estimates represent the sum of weekly mean temperatures that exceed the mean temperature of the hottest month in a location's climatology by at least one degree. DHW values aggregate over a rolling twelve-week period (Liu *et al.* 2014).

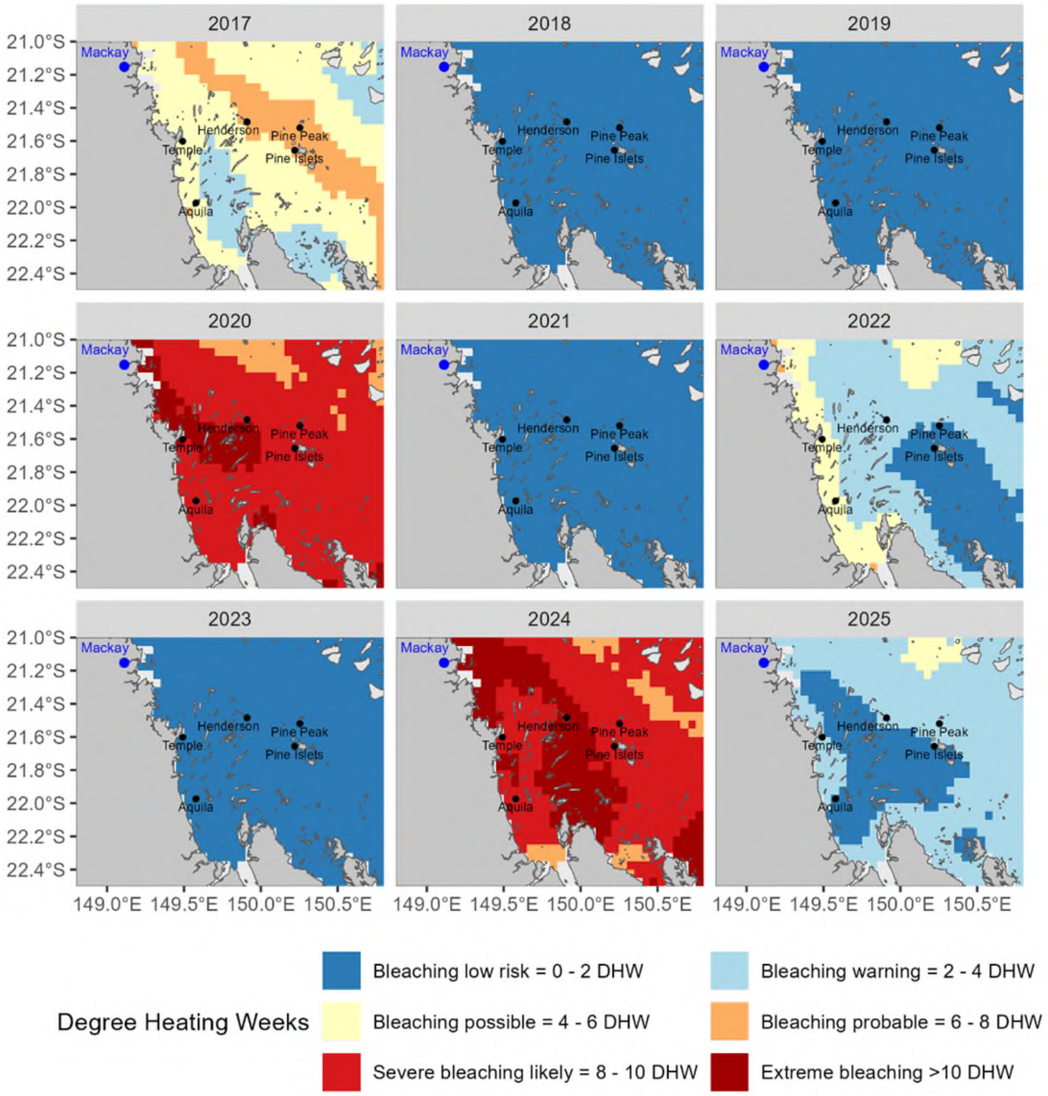

Figure 5 Annual estimates of thermal stress to corals. Data are the annual maximum degree heating week (DHW) estimates for each ~25 km^2 pixel. Data were sourced from NOAA coral reef watch. DHW values as indicators of thermal stress on the Great Barrier Reef are interpreted as follows: DHW values from 0 - 2: low risk of bleaching (i.e., normal summer conditions), 2 - 4: coral bleaching warning, 4 - 6: coral bleaching possible, 6 - 8: coral bleaching probable,8 – 10: severe coral bleaching likely, >10: extreme coral bleaching

4.1.2 Runoff

Discharge from the region's catchments over the 2024-2025 water-year (October to September) exceeded the long-term median by a factor of 2.2 in the Pioneer basin and 2 for the Plane basin, contrasting near median discharge for Waterpark Creek (Table 4). Although exposure to reduced salinity has proven lethal to coral communities in the inshore GBR (van Woesik 1991; Jones and Berkelmans 2014), the levels of discharge observed in this region since 2018 do not appear to have resulted in direct impacts to the coral communities monitored. The influence of the very high levels of freshwater entering the area in 2011 -2013 (Table 4) is unknown.

Table 4 Annual freshwater discharge for the catchment basins bordering the Southern Inshore Zone. Values represented as proportional to the long-term median (1991-2020). Flows are corrected for ungauged area of catchments. Levels of exceedance of median flow expressed as multiples of median flow: Yellow = 1.5-1.9, Orange = 2.0-2.9, Red = 3.0 and above.

Basin	Gauge Station_Id	LT median (ML)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Pioneer	125016A	616216	5.9	2.5	1.9	1	0.2	1	2.3	0.4	1.9	0.6	0.4	0.5	1.2	1.0	2.2
Plane	126001A, 126003A	1058985	3.9	2.4	1.8	0.8	0.4	0.9	2.4	0.4	1.2	1.1	0.6	0.5	1.4	0.6	2.0
Waterpark Creek	129001A	392614	4.4	1.4	4.7	2.7	1.9	1.7	2.5	1.4	0.7	1.4	1.7	2.1	1.5	2.0	1.1

4.1.3 Cyclones and Storms

There were no cyclones likely to have impacted reefs in the Southern Inshore Zone during the 2024-2025 cyclone season. Observations of recent physical damage in 2025 was limited to a few overturned or broken corals at Henderson Island (Table A 1).

The most recent cyclone likely to have damaged reefs in this region was Tropical Cyclone Marcia, a category 5 system that came closest to the reefs reported here, tracking southwards past Middle Percy Island with winds in excess of 80 knots before crossing the coast at Shoalwater Bay on February 20th 2015 (Figure 6). Waves from TC Marcia (maximum height 7m) were the fourth highest waves recorded at the Emu Park buoy (Queensland Government 2025b). Of note is that the orientation of the monitoring sites at Henderson and Temple islands that, along with protection offered by surrounding islands, will have afforded some protection from damaging seas produced by TC Marcia.

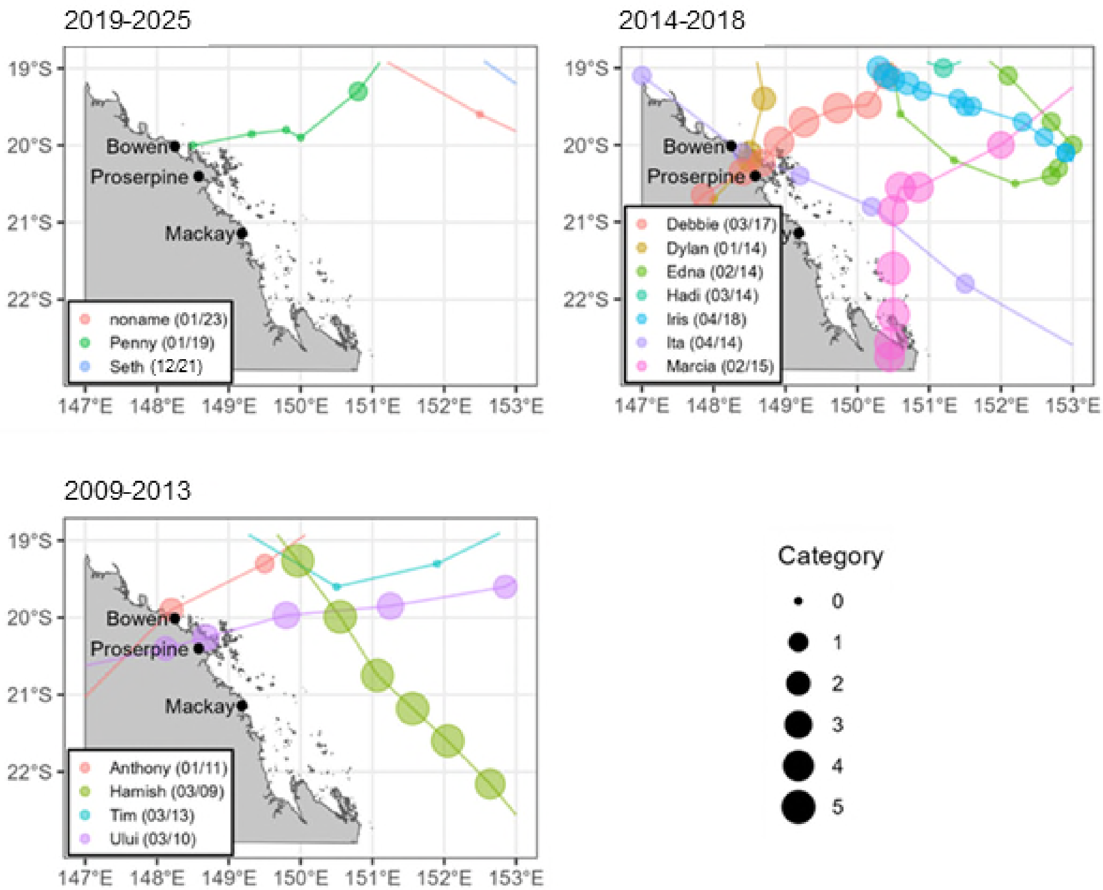

Figure 6 Tracks of tropical cyclones passing through the region. All cyclones crossing through the Mackay Whitsunday Isaac regional report card reporting area over the last 17 years are displayed. Tracks sourced from the Bureau of Meteorology

4.1.4 Biological Damage

There was an overall decline in the number of hard coral colonies affected by either disease, encrusting sponge, or an unknown cause from the previous year. A total of 12 colonies from three reefs were identified with disease, a decrease in number from the 20 observed in 2024 (Table A 1, compared with Table A3 Davidson *et al.* 2024). Disease was limited to branching *Acropora* and foliose *Montipora* (Table A 1) with white syndrome the most prevalent disease. In addition, there were a total of 12 *Acropora* colonies for which recent mortality was unknown. In combination, these 24 colonies, spanning two genera, are a reduction in both number and diversity of impact from last year (43 colonies, seven genera, Table A 3 Davidson *et al*. 2024). Of these 24 impacted coral colonies, 17 were from Henderson Island and all were *Acropora*, which reflects the dominance of *Acropora* amongst the coral community at Henderson Island.

The number of coral colonies being overgrown by the encrusting sponge *Cliona orientalis* has increased from nine colonies and six genera in the 2024 survey to 15 colonies and eight genera in 2025 (Table A 1). While most observations of *Cliona* were made in the shallows at Temple Island and Aquila

Island, *Cliona* was also observed at Henderson Island and Pine Islets. Afflicted genera included *Cyphastrea, Favites, Paragoniastrea, Platygyra, Porites, Psammocora, Montipora,* and *Turbinaria*.

No crown-of-thorns starfish have been observed in this study. Another coral predator, the gastropod *Drupella,* were observed at Henderson Island (5 m) in 2022 where 20 individuals were observed feeding on branching *Acropora* colonies. However, there have been no further sightings of *Drupella* since 2022 at any location in this study.

4.2 Coral Community Condition Assessment

The overall Coral Index score for the Southern Inshore Zone in 2025 was graded as D, categorising the coral communities as being in 'poor' condition (Table 5). While the Report Card category remains unchanged from 2024, the Report Card score has slightly improved due to an increase in the Coral cover and Juvenile density indicator scores (Table 4). The ongoing 'poor' score for the Cover change demonstrates that, while coral cover improved, the rate of hard coral increase remains below expected levels. The Macroalgae indicator score remained unchanged at the minimum possible value of zero ensuring the ongoing 'very poor' classification of this indicator (Table 5).

Across the reporting zone there has been a general, though modest, improvement in mean coral cover to 35%. Hard coral cover rose to 23%, the highest value in the seven years of this study (Table 6). While juvenile density remains low in 2025 at 2 per m^2, this figure represents a 33% improvement from the previous year. Benthic habitats across the zone were also improved with a 12% relative decline in the proportion of macroalgae from 69.3% to 60.9% (Table 6).

Table 5 Coral Index and indicator scores 2019 to 2025. The Cover change indicator was added in 2022 and back calculated for 2021. Scores are coloured as per Table 3.

	Year	Juvenile density	Coral cover	Macroalgae	Cover change	Report Card Score	Report Card Grade
Zone Scores	2019	0.12	0.47	0	NA	0.20*	E*
	2020	0.14	0.44	0	NA	0.19*	E*
	2021	0.1	0.37	0	0.29	0.19	E
	2022	0.13	0.4	0	0.46	0.25	D
	2023	0.12	0.4	0	0.36	0.22	D
	2024	0.13	0.44	0	0.4	0.24	D
	2025	0.17	0.46	0	0.39	0.26	D

* Report card scores not directly comparable to latter years as do not include the Cover change indicator

Table 6 Indicator values for Southern Inshore Zone. Juvenile densities are corrected for area of algal covered substrate, as a potential area for colonisation.

Year	Juvenile density (per m²)		Coral cover (%) Total (Hard + Soft)		Coral cover (%) Hard only		Macroalgae proportion (%)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2019	1.42	0.96	35.6	26.5	22	20.3	65.8	23.6
2020	1.59	0.84	33	21.3	22.5	19	60.5	25.6
2021	1.11	0.86	27.9	15.6	16.7	13.1	65.8	17.6
2022	1.46	1.13	30.4	17.1	19.3	14	58.9	20.4
2023	1.39	1.08	30.1	21.9	19.4	16.9	69.7	19.4
2024	1.51	1.44	33.3	24.3	21.6	19.6	69.3	18.8
2025	2.01	1.94	34.8	23.3	23.0	19.3	60.9	23.1

The overall Coral Index score continues to mask the substantial differences in the condition of coral communities among depths and reefs (Table 7). The 2 m depths at Pine Peak Island and Pine Islets remain in 'very poor' condition with slight declines in Coral Index scores since 2024. The Coral Index score at Aquila Island also remained 'very poor' although this has slightly improved. The coral community at 5 m depth at Henderson Island remains the only location classified as being in 'satisfactory' condition. At Temple Island and the 5 m depths of Pine Peak Island and Pine Islets Coral Index scores were 'poor' but improved (Table 7). In contrast the 2 m depth at Henderson Island was also classified as being in 'poor' condition and the Coral Index score declined in 2025 (Table 7).

Table 7 Index grade and scores for each reef and depth combination. Comparison of Index figures from 2019 to 2025. * indicate scores prior to the inclusion of the Cover change indicator and are not directly comparable to later years. Scores are coloured as per Table 3.

Reef	Depth	Index 2019	Index 2020	Index 2021	Index 2022	Index 2023	Index 2024	Index 2025	Grade
Pine Peak Island	2	0.05*	0.09*	0.08*	0.14	0.09	0.12	0.11	E
	5	0.12*	0.14*	0.12*	0.36	0.23	0.23	0.28	D
Pine Islets	2	0.04*	0.06*	0.06*	0.24	0.16	0.12	0.09	E
	5	0.12*	0.20*	0.15*	0.26	0.17	0.19	0.21	D
Henderson Island	2	0.41*	0.34*	0.19*	0.27	0.32	0.40	0.35	D
	5	0.36*	0.33*	0.28*	0.36	0.45	0.50	0.49	C
Temple Island	1	0.32*	0.21*	0.23	0.18	0.22	0.27	0.36	D
Aquila Island	1	0.19*	0.16*	0.14	0.14	0.12	0.12	0.15	E

4.3 Coral Cover

Coral Cover scores are based on the combined cover of hard and soft corals. The modest improvement in the Coral cover scores in 2025 reflected minor and variable changes across the reefs. While hard coral cover increased at six of the eight reef-depth locations, the combined cover, and related scores, improved at five reef-depth locations (Figure 7a, Table 8).

Across the region mean hard coral cover was 23%, up from 21.6% observed in 2024 (Table 8). Gains occurred on the lower reef slopes (5m) of Pine Peak Island, Pine Islets, and Henderson Island, and in the shallows of Temple Island and Aquila Island (Figure A 2). The largest increases in hard coral cover occurred at Temple Island and at Pine Peak Island (5 m), due mostly to increased cover of *Montipora* and *Acropora* respectively (Table 8, Table A 2, Figure A 2). Hard coral cover remains high at Henderson Island, and while cover of the dominant *Acropora* gained 4% at 5 m depth this countered reduced cover of other taxa, possibly due to overgrowth by the *Acropora* colonies, overall cover at both depths remained similar to levels observed in 2024. (Table 8, Figure A 2). A similar pattern of slow or stalled hard coral recovery can be seen on the most distant reefs from the coast at Pine Peak Island and Pine Islets (Table A 2, Figure A 2). At Aquila Island small gains in *Acropora* (0.3%) and *Montipora* (0.5%) raised the hard coral cover to 15% (Table 8, Table A 2).

Soft coral cover was essentially unchanged, with a regional mean of 11.8% in 2025 compared to 11.7% in 2024 (Table 6).

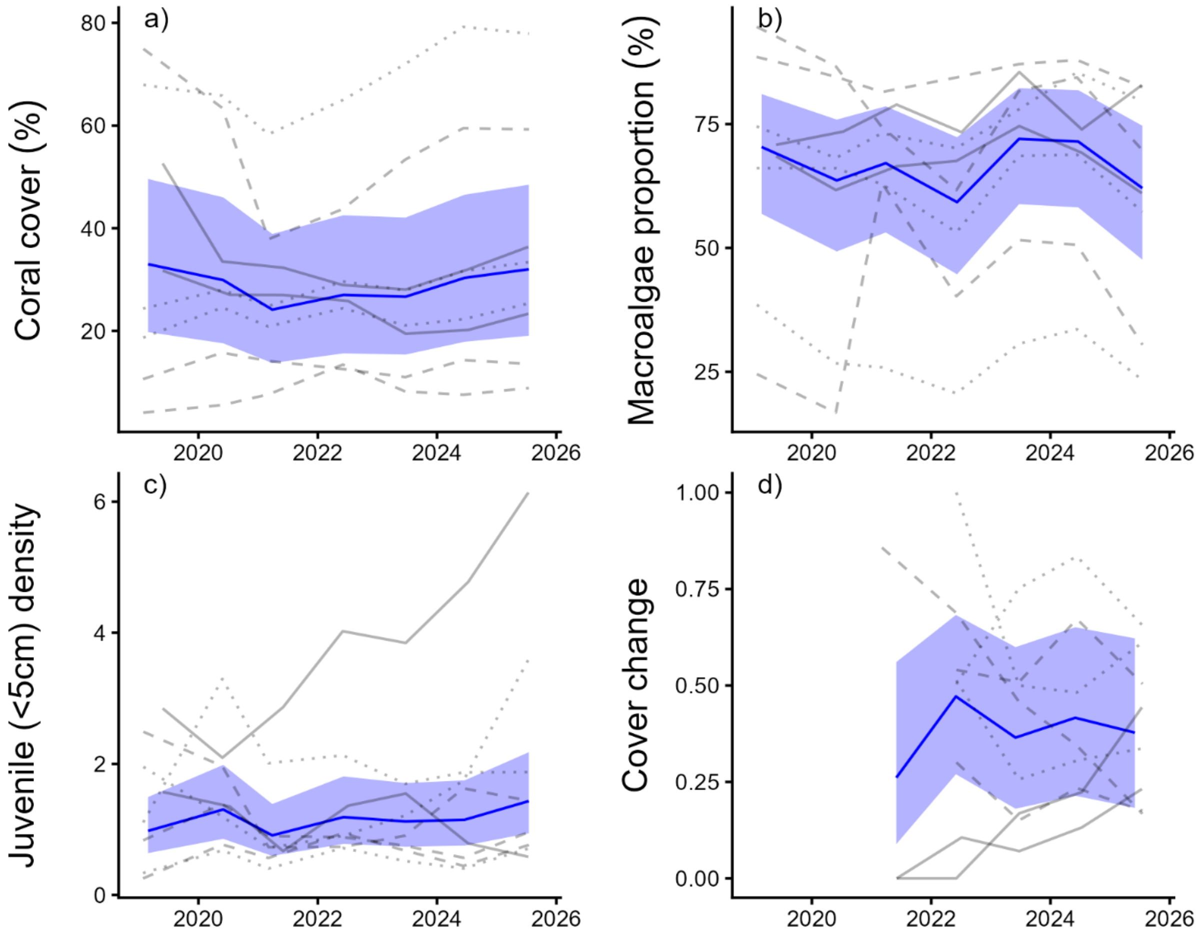

Figure 7 Indicator trends for Southern Inshore Zone. Blue lines represent the temporal trends in each indicator: a) coral cover, b) macroalgae proportion of total algae cover, c) juvenile density per m^2 of available substrate, d) cover change. Trends are bound by 95% confidence intervals of those trends (blue shading), grey lines represent observed profiles at 5 m (dotted lines), 2 m (dashed lines), and 1 m (solid lines) for individual reefs.

Table 8 Coral cover and indicator scores for each location. Comparing percent cover and scores for 2025 and 2024. Scores are coloured as per Table 3.

Reef	Depth (m)	Year	Hard coral cover (%)	Soft coral cover (%)	Coral cover (%)	Coral cover Score
Pine Peak Island	2	2024	4.7	9.6	14.4	0.19
		2025	4.2	9.4	13.6	0.18
	5	2024	10.9	20.8	31.7	0.42
		2025	14.0	19.4	33.4	0.45
Pine Islets	2	2024	4.9	2.6	7.5	0.1
		2025	5.3	3.6	8.9	0.12
	5	2024	16.5	5.8	22.3	0.3
		2025	18.3	7.1	25.4	0.34
Henderson Island	2	2024	44.2	15.3	59.5	0.79
		2025	43.9	15.3	59.2	0.79
	5	2024	59	20.3	79.3	1
		2025	59.5	18.5	78	1
Temple Island	1	2024	18.6	13.4	32	0.43
		2025	23.5	12.9	36.4	0.49
Aquila Island	1	2024	14	6.2	20.2	0.27
		2025	15.4	8.1	23.5	0.31

4.4 Macroalgae Proportion

All reef-depth locations for this indicator continue to return the minimum score of zero (Table 9) with the proportion of algae classified as macroalgae continuing to exceed the threshold of 23%, deemed to result in negative impacts to coral community resilience (Table 2). However, the mean proportional macroalgal cover for the region in 2025 has declined from 69.3% to 60.9%, most notably among the brown macroalgae (Table 6, Table A 4). This decline was relatively consistent across the region with macroalgae proportion declining at seven of the eight reef-depth locations (Figure 7b).

The largest contributor to macroalgae cover across the region remains the family Sargassacae, clearly dominant at Pine Peak Island (2 m), Pine Islets, Temple Island, and Aquila Island (Table A 4). However, in 2025 changes within macroalgae groups were more variable at the reef-depth level (using Table A 6 in Davidson *et al.* 2024 for reference):

- At Pine Peak Island Sargassaceae, *Lobophora* and *Stypopodium* collectively declined from 66% to 43% at 2 m and from 53% to 44 % at 5 m. Red macroalgae increased fourfold to 21% at 2 m, the highest cover of Red macroalgae among these reefs

- At Pine Islets Sargassaceae declined from 65% to 41% at 2 m and from 32% to 20% at 5m
- At Henderson Island *Lobophora* is the only macroalgal genus with cover greater than 1%. This declined from 19% to 12% at 2 m. Cover also declined slightly to 3% at 5 m but was already relatively low at 5% in 2024. Further, Henderson Island is the only location in this study where corals have greater cover than macroalgae
- At Temple Island *Lobophora* declined from 5% to 3%, Sargassaceae from 21% to 19%, and Red macroalgae from 14% to 11%
- At Aquila Island Sargassaceae decreased from 35% to 20% and Red macroalgae increased from 10% to 16%

Note: at Aquila Island in 2025 the visibility was so poor that approximately 10% of the various macroalgae could not be differentiated by analysis of the photo-transects and has been tabled under a separate column heading of 'Unidentifiable macroalgae' (Table A 4).

Table 9 Macroalgae cover and indicator scores for each location. Comparison of 2025 and 2024 data. Scores are coloured as per Table 3.

Reef	Depth	Year	Macroalgae cover (%)	Macroalgae proportion (%)	Macroalgae score
Pine Peak Island	2 m	2024	72.7	88	0
		2025	68.6	82.5	0
	5 m	2024	55.6	85.5	0
		2025	51.2	79.7	0
Pine Islets	2 m	2024	73.7	84.5	0
		2025	58.9	69.7	0
	5 m	2024	47.6	68.8	0
		2025	36.6	57.3	0
Henderson Island	2 m	2024	20.1	50.6	0
		2025	12.1	30.5	0
	5 m	2024	5.6	33.6	0
		2025	3.9	23.3	0
Temple Island	1 m	2024	41.9	69.2	0
		2025	34.3	61.1	0
Aquila Island	1 m	2024	46.8	73.9	0
		2025	52.4	83	0

4.5 Juvenile Density

The overall density of juvenile hard corals, increased to 2m^{-2}, the highest density recorded over the duration of the project (Table 6). Despite this increase, the Juvenile score remains 'very poor' (Table 5). At most reef-depth locations the category for the Juvenile score also remained 'very poor', with low densities reflecting the combination of low juvenile abundance and high algal cover (Table 10). However, at Henderson Island (5 m) a doubling of juvenile density lifted the score from 'very poor' to 'poor' (Table 10). Temple Island continues to support much higher densities of juvenile corals than anywhere else in the region and in 2025 the Juvenile score continued to rise within the 'satisfactory' range (Table 10).

Juvenile indicator scores increased everywhere except for Pine Islets (5 m), Henderson Island (2 m) and Aquila Island (Table 10, Figure 7c, Figure A 2). Influential in the increases were higher numbers of juvenile *Pocillopora* at Pine Peak Island (2 m), *Turbinaria* (Family Dendrophylliidae*)*, *Pocillopora and Monitpora* at Temple, and *Acropora* at Henderson Island (5 m) (Figure A 2). No one genus stood out at Pine Islets 2 m where the richness of juveniles is high but none are in particularly high abundance (Figure A 2, Table A 5).

Pine Islets (5 m) continues to have the highest genus richness of juvenile hard corals among reef-depth sites (23) and Temple Island has the highest abundance of a single genus, *Turbinaria* (68). The high relative abundance of this genus is mirrored in the adult *Turbinaria* community at Temple Island (3% cover) (Table A 2, Table A 5, Figure A 2).

Table 10 Juvenile hard coral abundance, density and indicator scores for each location. Comparison of 2025 and 2024 data. Density has been adjusted for the area of algal covered substrates. Scores are coloured as per Table 3.

Reef	Depth	Year	Juvenile abundance	Juvenile density (per m^2)	Juvenile score
Pine Peak Island	2 m	2024	24	0.43	0.04
		2025	43	0.76	0.07
	5 m	2024	21	0.41	0.04
		2025	31	0.71	0.06
Pine Islets	2 m	2024	33	0.55	0.05
		2025	57	0.96	0.08
	5 m	2024	85	1.83	0.16
		2025	80	1.88	0.16
Henderson Island	2 m	2024	40	1.63	0.14
		2025	36	1.44	0.12
	5 m	2024	20	1.74	0.15
		2025	41	3.61	0.31
Temple Island	1 m	2024	189	4.75	0.41
		2025	219	6.14	0.51
Aquila Island	1 m	2024	33	0.76	0.07
		2025	25	0.58	0.05

4.6 Cover change indicator

The regional Cover change indicator score in 2025 was 0.39, a slight decline from 0.40 in 2024 (Table 5). Although, the regional score has remained in the 'poor' range since 2023, both the current scores, and their change since 2024, remain highly variable among the reefs surveyed. (Figure 7d, Table 11).

No acute disturbances recorded at any reefs in the region since the 2020 coral bleaching event. At several reefs, the subsequent loss of coral cover through to 2021 is attributed to the prolonged stress associated with the 2020 bleaching. As such, the cover change indicator in 2025 reflects the average of inter-annual changes in hard coral cover since 2021.

The lowest scores in 2025 occurred at the two metre depths of Pine Peak Island and Pine Islets 2025 where scores declined from 'poor' in 2024 to 'very poor'. These low scores reflect both the limited improvement in hard coral cover over the last year and the general lack of hard coral recovery since 2021 (Table 11, Figure A 2).

'Poor' scores were recorded for Aquila and at the 5 m depth of Pine Islets. At Pine Islets (5 m) hard coral cover has improved since 2023, with Cover change scores also improving. Influential in the 'poor' scores was the slight decline in cover recorded in 2023 (Table 11). Similarly, a reduction in hard coral cover in 2023 at Aquila Island reduced the Cover change score to 'very poor' with the subsequent modest year-on-year increases occurring at a sufficient rate to lift the Cover change score to 'poor' for the first time (Table 11,).

On the reef slope at Pine Peak Island (5 m) hard coral cover has also increased after a slight reduction in 2023. The magnitude of the rise observed in 2025 lifted the cover-change score from 'satisfactory' to 'good'. (Table 11). The largest rise in hard coral cover in 2025 was at Temple Island (5%), and, while hard coral cover has been improving since 2022, the magnitude of the recent recovery has doubled the Cover change score (0.22 to 0.44) and increased the indicator from the 'poor' to 'satisfactory'.

By far the largest increases in hard coral cover over the last four years has occurred at Henderson Island where the relatively fast-growing genus *Acropora* dominates the coral community (Table 11, Figure A 2). The 2025 scores of 'satisfactory' (2 m) and 'good' (5 m) indicate recovery at expected rates at 2 m and above-expected rates at 5 m (Table 11). However, despite this these scores have declined since 2024 due to a halt in the recovery of hard coral cover over the last year (Table 11, Figure A 2).

Table 11 Reef level Cover change scores. Only years for which Cover change was estimated are included. Annual scores for each reef are a running mean of scores based on inter-annual changes in hard coral cover during years within the "Period" that reefs were not designated as having been impacted by an acute disturbance.

Reef	Depth	Year	Period	Change in percent cover of hard coral cover		Cover change score
				Over period	From previous year	
Pine Peak Island	2 m	2022	2021-2022	0.7	0.7	0.3
		2023	2021-2023	0.4	-0.3	0.15
		2024	2021-2024	1.1	0.7	0.23
		2025	2021-2025	0.5	-0.6	0.18
	5 m	2022	2021-2022	4.8	4.8	1
		2023	2021-2023	2.8	-2	0.5
		2024	2021-2024	3.4	0.6	0.48
		2025	2021-2025	6.5	3.1	0.61
Pine Islets	2 m	2021	2020-2021	1.9	1.9	0.86
		2022	2020-2022	5.3	3.3	0.69
		2023	2020-2023	1.6	-3.7	0.46
		2024	2020-2024	0.7	-0.9	0.34
		2025	2021-2025	-0.9	0.3	0.17
	5 m	2022	2021-2022	2.7	2.7	0.51
		2023	2021-2023	1.4	-1.2	0.26
		2024	2021-2024	2.7	1.3	0.31
		2025	2021-2025	4.5	1.8	0.34
Henderson Island	2 m	2022	2021-2022	6.9	6.9	0.54
		2023	2021-2023	12.1	5.2	0.51
		2024	2021-2024	19.3	7.1	0.67
		2025	2021-2025	19.0	-0.3	0.5
	5 m	2022	2021-2022	3.4	3.4	0.5
		2023	2021-2023	8.6	5.2	0.75
		2024	2021-2024	14.7	6.1	0.83
		2025	2021-2025	15.1	0.5	0.66
Temple Island	1 m	2021	2020-2021	-3.1	-3.1	0
		2022	2020-2022	-4.9	-1.8	0
		2023	2020-2023	-2.7	2.2	0.17
		2024	2020-2024	-1.3	1.4	0.22
		2025	2021-2025	6.8	4.9	0.44
Aquila	1 m	2021	2020-2021	-2.1	-2.1	0
		2022	2020-2022	-1.5	0.6	0.11
		2023	2020-2023	-5.5	-4	0.07
		2024	2020-2024	-4.5	1	0.13
		2025	2021-2025	-1.0	1.4	0.23

5 DISCUSSION

The overall condition of Southern Inshore Zone reefs in 2025 remained ‘poor’ and were graded ‘D’, although the underlying Coral Index score of 0.26 was a slight improvement to the score of 0.24 in 2024. Contributing to this improvement were very modest increases in scores for Coral cover and Juvenile density indicators. The relatively low Coral Index score remains influenced by the prevalence of high macroalgae cover across the region.

In early 2025, the reefs across the study zone were exposed to above average summer water temperatures. The maximum temperature recorded in 2025 was at Aquila Island (30.3^{O}C), comparable to that recorded at Aquila Island in 2024 (30.7^{O}C), which remains the highest recorded temperature during this study. However, temperatures exceeded the baseline for potential bleaching only briefly, resulting in limited accumulation of heat stress. In contrast, corals in the region were severely bleached by marine heat wave conditions in 2020. During our surveys in late May 2020 a high level of bleaching was still evident, and we considered both the loss of cover between 2019 and 2020 and the subsequent loss through to 2021 as the cumulative impact of the 2020 marine heat wave. Although DHW estimates for 2024 were comparable to those for 2020, surveys in mid-June 2024 recorded limited bleaching with only 3% of corals (Davidson *et al.* 2024) bleached and coral cover generally increased in 2024. This possibly reduced susceptibility is perhaps not unexpected given corals present in 2024 were survivors of the severe marine heatwave of 2020.

Since the impacts attributed to the 2020 marine heatwave, the average coral cover in 2025 of 34.8% has almost recovered to the 35.6% observed at the start of the program in 2019. Indeed, the regional hard coral cover of 23% in 2025 has surpassed the previous high of 22.5% recorded in 2020. However, the Cover change indicator score has remained close to the threshold between ‘poor’ and ‘satisfactory’ for the last three years, indicating that the rate of hard coral recovery has been toward the lower end of, or below, modelled expectations, suggesting that there are still pressures limiting the growth or survival of corals. While coral cover in 2024 was not clearly impacted by the 2024 marine heat wave, the physiological stress imposed by this event is likely to have reduced colony growth or survival (Gold and Palumbi 2018). Coral mortality following from marine heatwaves has been linked to coral disease as pathogens overcome corals weakened by thermal stress (Sparagon *et al.* 2024, Bruno *et al.* 2007, Brodnicke *et al.* 2019, Howells *et al.* 2020). The elevated levels of disease noted in 2024 add weight to the compromised health of corals at that time.

In contrast to the more offshore reefs, the cover change score at Temple Island and Aquila Island improved from ‘poor’ to ‘satisfactory’ and from ‘very poor’ to ‘poor’ respectively, despite Aquila Island experiencing the highest water temperatures of the reef studied in 2025. Sully and van Woesik (2020) suggest that shallow inshore reefs regularly exposed to higher turbidity levels may have reduced levels of irradiance due to the shading effect of the turbidity, offering the shallow inshore coral communities a less stressful environment during thermal heatwaves. Alternatively, there is a different mix of species at each reef and so it is possible that differing susceptibility to thermal stress among taxa (Marshall & Baird 2000) may play a part in the variation in changes in Coral cover and Cover change scores in recent years. The low cover of most hard coral genera at reefs in this in this study, along with the relatively small changes between years, make it difficult to determine the cause of changes that occur between incidents of obvious widespread disturbance.

Across the region there was a 20% increase in the abundance of juvenile corals in 2025, however, densities remain low with only Temple Island retuning a score in the ‘satisfactory’ range for this indicator. Temple Island received increased numbers of *Montipora*, a genus with the highest adult cover at Temple Island, but also *Pocillopora*, and *Cyphastrea*, genera with very low cover. The variable recruitment of genera with low local abundance suggests variable connectivity to remote broodstocks but possibly also the limited viability of these taxa in the longer-term. Irrespective, the continued low Juvenile scores suggest coral recruitment continues to be a limiting factor in the resilience of coral communities in this region. This is of particular concern given the link between thermal stress and a reduction in the reproductive health of corals that may have a long-lasting effect on the resilience of communities dependent on successful spawning, dispersal, settlement, and recruitment from other coral communities (Page *et al*. 2023, Ward *et al.* 2002, Hughes *et al.* 2019).

Of ongoing concern for the resilience of coral communities in this region are high levels of macroalgae. Dense canopies of macroalgae compete with corals and dominate the benthic communities at most of the reefs in this study. There are a number of pathways by which macroalgae competition occurs; from limiting the space or light available to corals (Tanner 1995, Hauri *et al.* 2010), physically damaging corals via abrasion (Clements *et al.* 2018, Clements *et al.* 2020), chemically interfering with coral recruitment process (Foster *et al.* 2008, Monteil *et al.* 2020), or promoting bacterial communities pathogenic to corals (Smith *et al.* 2006, but see Clements and Hay 2023). At the regional level the macroalgae proportion has been consistently high, with the Macroalgae indicator score consistently in the ‘very poor’ range since the beginning of this study in 2019. The macroalgae proportion had reached its highest value of 70% in 2023 and while declining to 61% in 2025 remains at levels that will almost certainly be influencing the resilience of coral communities at most reefs.

The Southern Inshore Zone is a section of the Great Barrier Reef where the extensive continental shelf isolates the region from the more offshore reef matrix. The large tidal range of this region causes strong tidal currents, and the proximity to the shallow, silt-laden Broad Sound, results in environmental conditions that challenge the resilience of coral communities and match the primary variables described by Fabricius *et al.* 2023 as supporting sustained abundance of macroalgae cover. The location has few well-developed reef structures, with most formation over the last 6000 years being in the form of incipient reefs derived from accumulated detritus rather than consolidated carbonate substrate. Indeed, examining inshore reef structures and coral reef communities between the Whitsundays and Keppel Island groups, Kleypas (1996), van Woesik (1992), and van Woesik & Done (1997) interpreted the reduced reef development, reduced abundance, and reduced diversity of hard corals as reflecting environmental conditions that are less than favourable for coral reef development. These physical environmental conditions need to be kept in mind when considering the condition of these communities as summarised by the Coral Index, a scoring tool developed for reefs where historical reef development occurred in a less challenging environment.

The results from the 2025 survey suggest continued, albeit slow, recovery of coral communities since the severe impacts caused by the 2020 marine heat wave. However, the overarching conclusion remains that very high levels of macroalgae continue to challenge the resilience of coral communities.

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8 APPENDICES

8.1 Reef Level data summaries

Table A 1 Coral health survey results.
The number of colonies along the ten 20 m long and 2 m wide transects searched at each reef and depth combination in 2025 having recently lost tissue (patches of bare white skeleton) attributed to a range of causes. Anchor or physical damage to corals is recorded as a proportion of coral cover at the site effected: 0 = absent, 0+ = individual colonies, 1- = 1-5%, 1+ = 6-10%, 2- = 11-20%, 2+ = 21-30%, 3- = 31-40%, 3+ = 41-50%, 4- = 51-62%, 4+ = 63-75%, 5- = 76-82%, 5+ = 83-100%. Bleached hard corals are reported as a percentage of the total hard corals from photo-transect analysis.

Cause	Genus	Pine Peak		Pine Islets		Henderson		Temple	Aquila
		2 m	5 m	2 m	5 m	2 m	5 m	1 m	1 m
Disease	*Acropora*					3	2		
	Lobophyllia								
	Merulina								
	Montipora				2			5	
	Pocillopora								
	Porites								
Unknown cause	*Acropora*					7	5		
	Montipora								
	Pocillopora								
	Porites								
	Turbinaria								
Sponge - *Cliona orientalis*	*Cyphastrea*								1
	Dipsastraea								
	Favites					1			
	Paragoniastrea								1
	Platygyra							1	
	Porites							1	1
	Psammocora							1	2
	Montipora				1			1	3
	Turbinaria							1	
Total number of Colonies		0	0	0	3	11	7	10	8
Bleaching (% of hard corals)		0	0	0	0	0	0	0	0
Physical (proportion of colonies)		0	0	0	0	0+	0	0	0

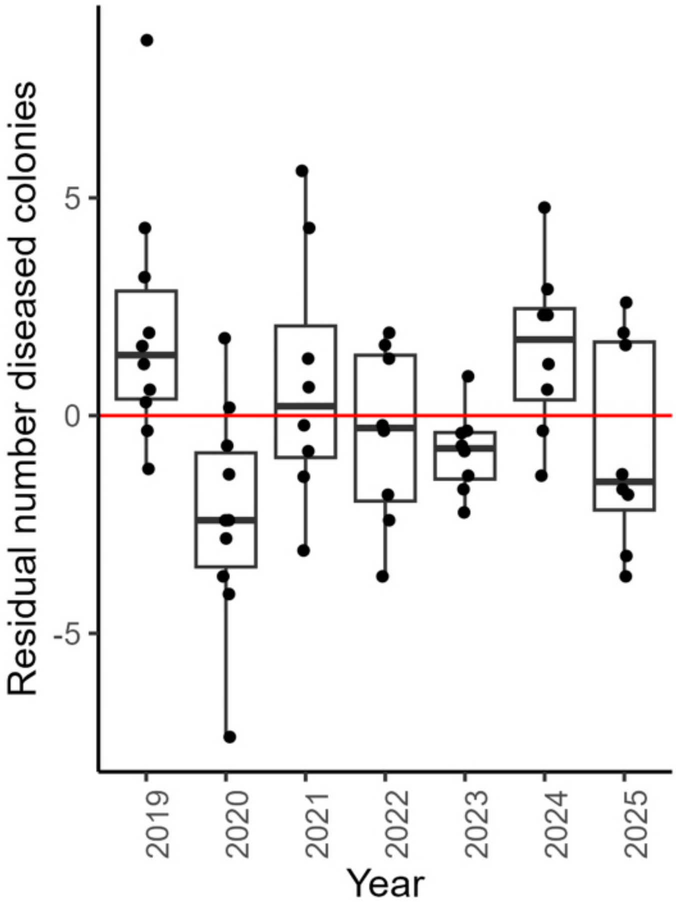

Figure A 1 Relative coral disease by year. Data are standardised to the reef and depth mean across years. Boxplots show the median (bold horizontal line), 25th to 75th quartiles (box), and 1.5 times the inter-quartile range (whiskers). Solid dots are the relative number of coral colonies suffering ongoing mortality attributed to disease for each reef, depth and year

Table A 2 Cover of hard coral genera in 2025. Genus with a minimum cover of 1% at any reef are included. All less abundant genera are grouped as Other HC. Total number of genera observed is presented as Genus Richness. Data from photo-transect analysis.

Reef	Depth	*Acropora*	*Galaxea*	*Goniopora*	*Lobophyllia*	*Montipora*	*Pachyseris*	*Pectinia*	*Platygyra*	*Porites*	*Turbinaria*	Other HC	Genus Richness
Pine Peak Island	2	0.06	0	0	0.06	0.38	0	0	0.06	2.31	0	1.32	13
	5	1.88	0	0.38	0.06	0.69	0	1	0.12	6.01	1.12	2.75	20
Pine Islets	2	0.19	0	0.06	0	2.06	0.06	0	0.12	0.94	0.38	1.44	15
	5	0.5	0	1.81	0.25	7.56	1.06	0	0.31	1.62	1.12	4	28
Henderson Island	2	41.8	0.06	0.38	0.69	0.19	0	0	0.25	0	0	0.56	12
	5	47.18	1.69	0.25	4.5	2.13	0	0.19	0.25	0	0	3.26	19
Temple Island	1	4.81	0	0.25	0	10.69	0	0	1.25	0.5	3.12	2.88	17
Aquila Island	1	0.45	0	0.13	0	11.87	0	0	0	0.25	0.06	2.66	12

Table A 3 Cover of soft coral genera in 2025. Genus with a cover of at least 1% at any reef are included. All less abundant genera are grouped as Other SC. Data from photo-transect analysis.

Reef	Depth	*Briareum*	*Cladiella*	*Klyxum*	*Lobophyton*	*Rhytisma*	*Sarcophyton*	*Sclerophytum*	Other SC
Pine Peak Island	2	6.75	0.06	0	0.31	0.12	0.38	1.69	0.06
	5	14.13	0	0.75	0.88	1.13	1.12	1.25	0.12
Pine Islets	2	0.56	0.19	0	2.56	0	0.06	0.19	0.06
	5	2.94	0	1.06	0.62	0	0.81	1.56	0.12
Henderson Island	2	1.06	1.06	5.76	0	0	1.75	5.69	0
	5	0.5	0.31	12.52	0	0	2.56	2.57	0
Temple Island	1	3.62	0.56	0	0.75	0	0.69	7.12	0.12
Aquila Island	1	0.19	0	0.25	1.13	0	0.13	5.73	0.63

Table A 4 Cover of algae in 2025. Identified macroalgae genera with a cover of at least 1% at any reef are separated. All less abundant or un-resolved brown macroalgae are grouped as 'Other' algae. Data from photo-transect analysis. Note: At Aquila Island poor visibility prevented differentiation of 10.48% of macroalgae in photo-transect analysis. This undifferentiated macroalgae has been tabled under a separate column of 'Unidentified macroalgae' and is included in all calculations involving the term macroalgae

Reef	Depth	Brown macroalgae				Red macroalgae	Green macroalgae	Turf algae	Coralline algae	Unidentifiable macroalgae
		Lobophora	Family Sargassaceae	Stypopodium	Other					
Pine Peak Island	2	15.6	26.6	1.2	3.5	21.3	0.5	12.5	2.1	0
	5	34.7	8.1	0.9	2.3	4.6	0.56	9.8	3.3	0
Pine Islets	2	5.6	40.8	0.4	5.5	6.5	0.12	22.8	2.7	0
	5	10.2	20.3	0.7	2.3	2.5	0.62	24.8	2.5	0
Henderson Island	2	11.6	0	0	0	0.6	0	27.5	0.2	0
	5	3.8	0	0	0	0.12	0	12.7	0.06	0
Temple Island	1	2.9	19	0.2	0.6	11.4	0.19	20.4	1.5	0
Aquila Island	1	0.3	20.2	0	3.7	16.4	1.21	10.4	0.2	10.48

Table A 5 Abundance of juvenile hard corals by genus in 2025. Total number observed per Reef and Depth, genera with at least 4 corals observed on any reef separated. All less abundant genera are grouped as Other genera. Data from visual census of juveniles along transect.

Reef	Depth	*Acropora*	*Acanthastrea*	*Cyphastrea*	*Dipsastraea*	*Duncanopsammia*	*Favites*	*Galaxea*	*Lobophyllia*	*Montipora*	*Moseleya*	*Paragoniastrea*	*Pocillopora*	*Porites*	*Stylocoeniella*	*Turbinaria*	Other genera	Genus Richness	Number
Pine Peak Island	2	3	0	0	1	0	0	1	2	3	0	0	22	6	0	1	4	10	43
	5	2	0	1	1	0	0	0	5	1	0	0	7	8	0	0	7	13	32
Pine Islets	2	6	0	0	1	0	4	0	3	1	0	0	7	6	4	6	19	22	57
	5	3	6	1	9	1	5	4	3	2	1	0	4	6	1	15	19	23	80
Henderson Island	2	10	3	0	2	0	2	0	2	3	0	0	6	1	0	0	8	14	37
	5	14	2	0	2	1	1	3	4	2	0	0	1	0	0	0	11	16	41
Temple Island	1	36	0	19	18	4	13	0	0	15	3	7	13	14	0	68	9	17	219
Aquila Island	1	2	0	2	1	0	1	0	0	9	5	0	1	1	0	1	2	10	25

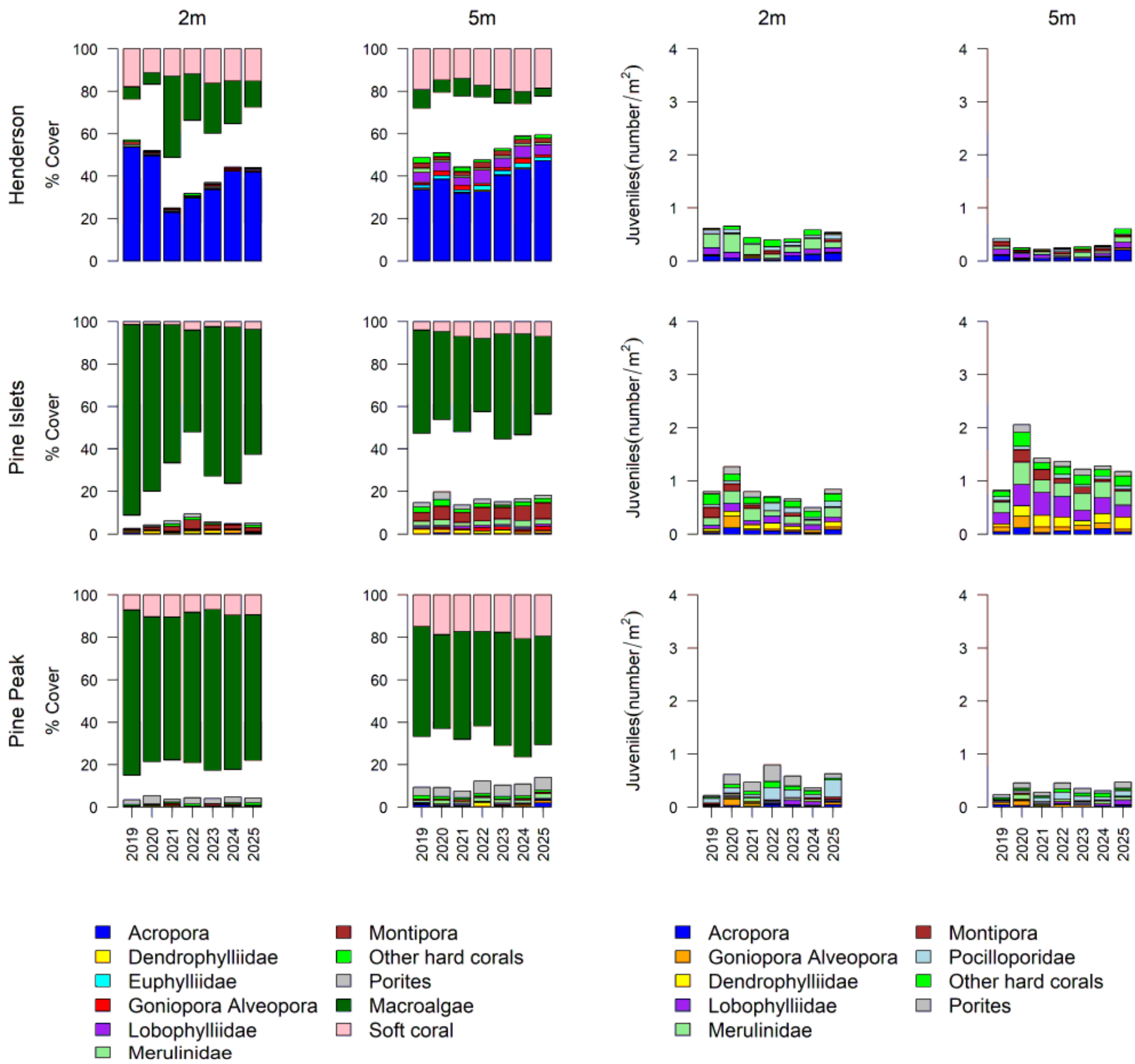

Figure A 2 Composition of benthic cover and hard coral juveniles. The left-hand plots show the breakdown of cover for hard coral families at 2 m and 5 m depths. Families that had a cover of at least 3% at either depth of any reef in the Zone are differentiated. Cover of all other families are grouped as Other. The cover of Macroalgae and soft corals are also included (hanging). The right-hand plots show the density of juvenile (< 5 cm) hard corals per m^2 of transect area by family at 2 m and 5 m depths.

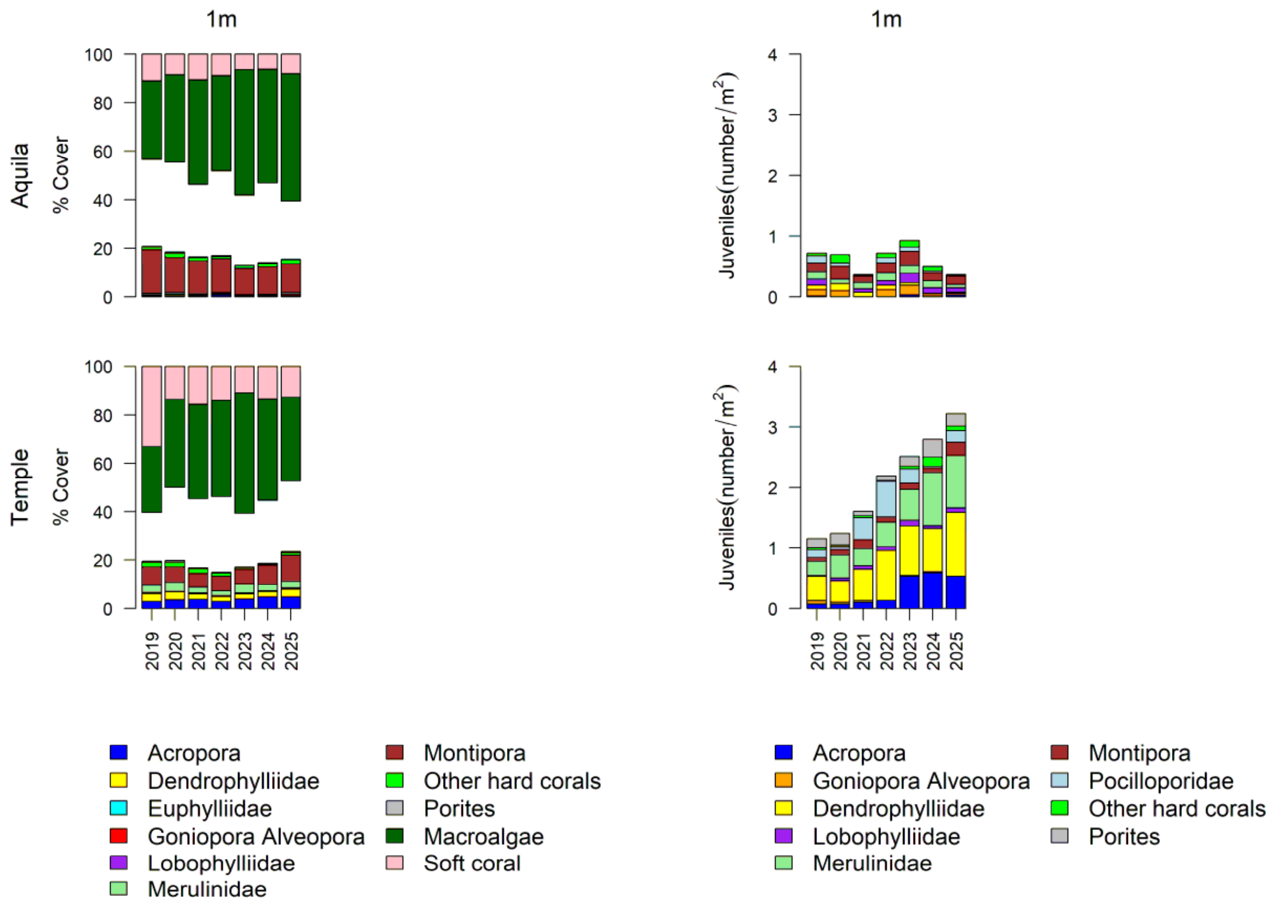

Figure A 2 continued, for the 1 m deep sites at Aquila and Temple Islands.

8.2 Images of benthic communities

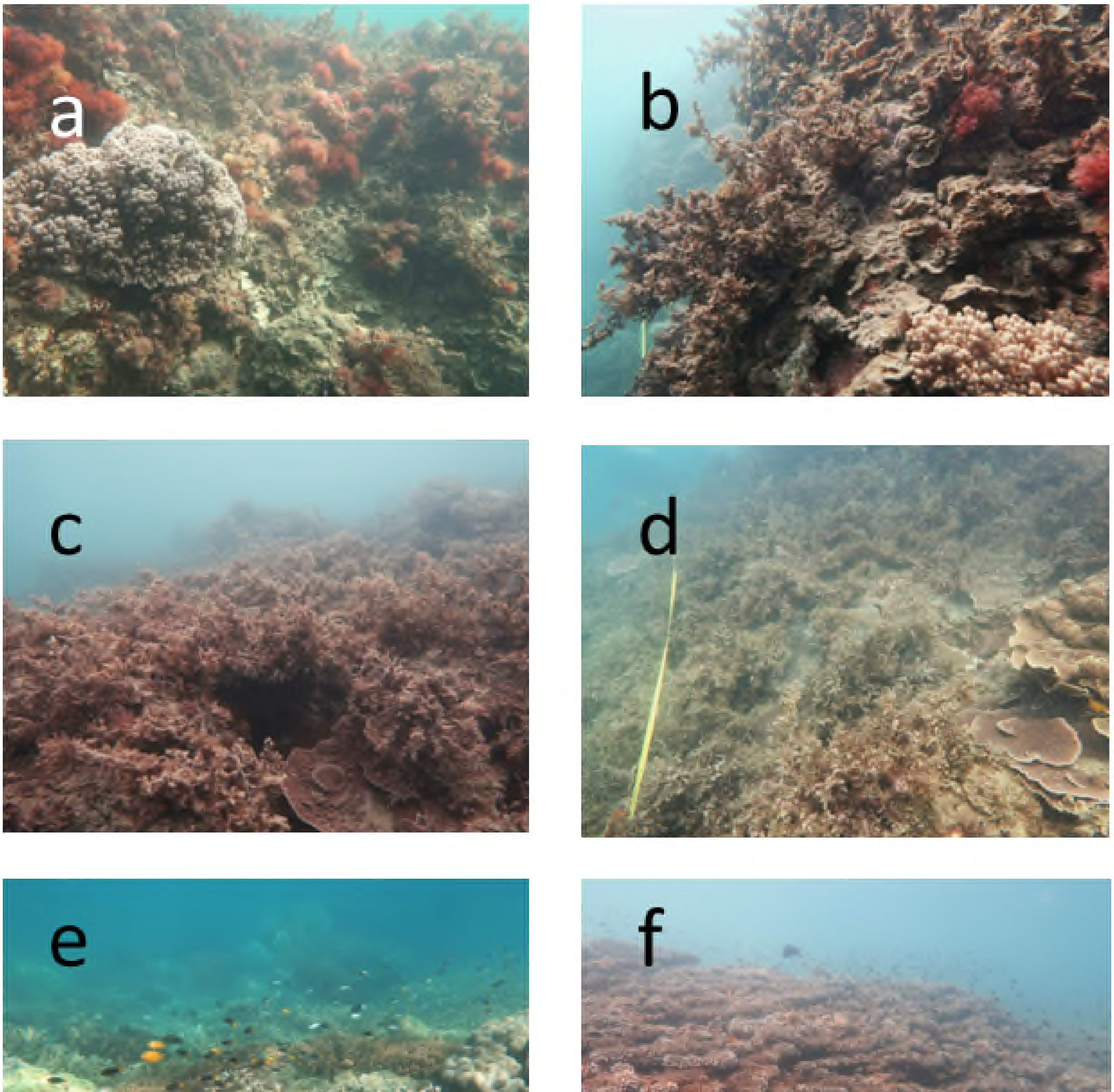

Figure A 3 Benthic community photos at outer reefs in 2025. Communities dominated by macroalgae at a) Pine Peak Island 2 m, b) Pine Peak Island 5 m, c) Pine Islets 2 m, d) Pine Islets 5 m, contrast with the fields and large colonies of *Acropora* at e) Henderson Island 2 m and f) Henderson Island 5 m.

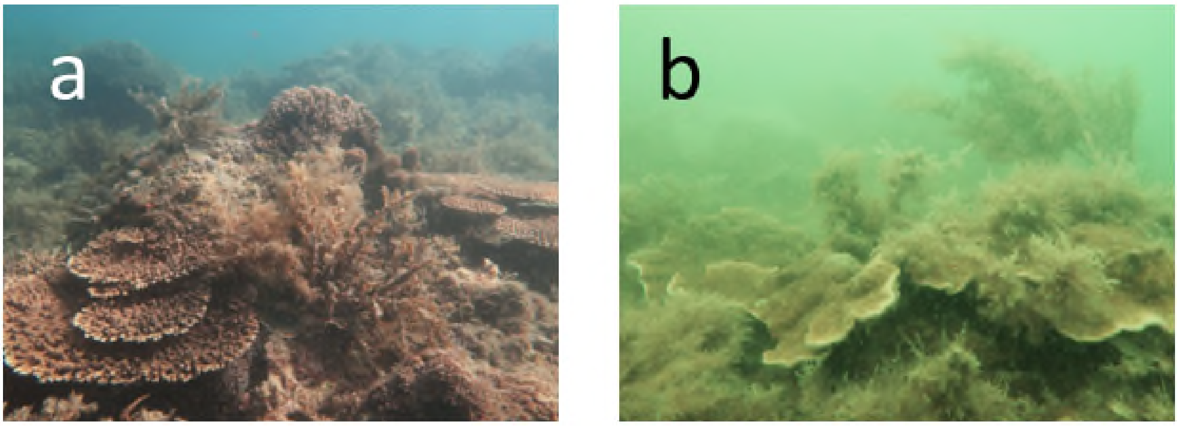

Figure A 4 Benthic community photos at inner reefs in 2025 a) mixed colonies of hard corals and soft corals at Temple Island, b) *Montipora* colonies among brown macroalgae at Aquila Island.

8.3 Logistical Considerations

The are several environmental constraints that need to be considered for the future monitoring of the Southern Inshore Zone coral communities.

The Broad Sound-Shoalwater Bay area has the highest tidal range along the Queensland coast. Surveys must be timed to coincide with neap tide periods to reduce the risk of strong currents and elevated turbidity. The resurveys were all undertaken during neap tides (generally < 3 m change between high and low tide over the period of survey). Wind driven resuspension can also reduce in-water visibility, and periods of wind speeds above 15kts require a following day or two of calm weather to allow settlement of suspended particles before surveys can begin.

The proximity of the survey locations in relation to coastal access points is a further consideration. In combination with the need to survey during periods of neap tides and low winds, the availability of suitable periods within which to undertake sampling is severely restricted. Access to Aquila Island is most convenient via Carmila Creek. This requires ~3.5 m of tide at McEwen Island (Bureau of Meteorology Tide Predictions). Surveying Aquila Island from Carmila Creek meets the demand for quick access to the site and egress from falling tide. The most accessible launch point for Temple Island and the more offshore reefs is Sarina Beach, some 80 km from Pine Islets and Pine Peak Island. Given the distance to be travelled on the open waters, predicted winds below 15 knots are required. These reefs can be successfully resurveyed with winds in this range. Table A 8 provides a reference point for the conditions experienced during 2025 re-surveys and notes on the state required to avoid strong currents.

AIMS, however, will no longer agree to monitor coral communities at Aquila Island as AIMS considers diving at these sites imposes an unacceptable risk to personal safety. Experience has proven that there is an insufficient period of slack water in which surveys can be safely conducted. Compounding the strong currents at the site is the consistently very high turbidity that poses both an additional risk to diving activities and limits the quality of data that can be obtained.

Table A 6 Weather conditions and tide heights experienced during 2025 works, with additional information on local currents. Tidal range taken from Percy Island for Pine Peak Island, Pine Islets and Henderson Island, Hay point for Temple Island and McEwen Islet for Aquila Island.

Reef	Date	Wind (knots)	Tide State during survey and range between nearest high and low water ()	Observations	Local currents typically experienced during tide cycle that may limit surveys
Temple Island	15/07/2025	N 5	Mid rise (3.5 m)	Visibility 7-8 m, current began to increase as tide rose at site 2	Both sites: Manageable current on rising tide. No limitation from local current on rising tide.
Aquila Island	15/07/2025	NW 4	High (4.6 m)	Visibility 1 m, strong current on rising tide at Site 1.	Site 2: Current workable on last hour of rising tide. Site 1: Strong current on rising tide – much less around high tide. Visibility much reduced by tidal resuspension
Pine Peak Island	17/07/2025	ENE 4	Mid rise (3.1 m)	Visibility 9-12 m, no current.	Site 1: Current on falling tide. Both sites: Less current on rising tide.
Pine Islets Site 1	17/07/2025	SE 7	High (3.1 m)	Visibility 7-8 m, no current	No limitation from local currents at time of survey.
Pine Islets Site 2	18/07/2025	W 3	Low (3.1 m)	Visibility 8-10 m, no current	No limitation from local currents at time of survey.
Henderson Island Site 2	18/07/2025	W 3	Mid rise (3.1 m)	Visibility 9-11 m, no current	Current on falling tide. Much less current from mid-rise to high tide.
Henderson Island Site 1	18/07/2025	NW 3	Mid-rise (3.1 m)	Visibility 9-11 m, no current	Current on falling tide. Much less current from mid-rise to high tide.

Table A 7 Waypoints and compass directions for transects and monitoring sites

Reef	Latitude S	Longitude E	Depth	Site	Tran	Compass directions
Pine Peak Island	**21.51447**	**150.25145**	**2**	**1**	**1**	350, 90@10 m rod
	Waypoint between transects 3 & 4				2	140, 120@10 m rod, 30@15 m, 340 to T3
					3	0, 120@12 m
					4	210, 300@4 m
					5	150, note first rod is at 3 m, contour
	21.51433	**150.25125**	**5**	**1**	**1**	340 then contour, 90 @ 10m
	Waypoint between transects 3 & 4				2	150, 110@6 m, 60@10 m rod, 320 to T3
					3	320 then contour
					4	240, 180@14 m
					5	contour
	21.51392	**150.25532**	**2**	**2**	**1**	190, 90@ 10 m rod
	Waypoint between transects 3 & 4				2	10, 50@10 m rod
					3	80, 200@10 m
					4	260, 300@3 m
					5	210, 340@4 m
	21.51375	**150.25513**	**5**	**2**	**1**	90 330@11 m
	Waypoint between transects 3 & 4				2	0, 100@2 m, 30@10 m rod, 120@15 m
					3	150, 90@10 m rod
					4	330, 260@7 m
					5	270, 190@9 m
Pine Islets	**21.65762**	**150.22165**	**2**	**1**	**1**	20, 0@5 m
	Waypoint between transects 3 & 4				2	300, 230 to T3
					3	240
					4	120
					5	50, 180@10 m
	21.65782	**150.22162**	**5**	**1**	**1**	280
	Waypoint between transects 3 & 4				2	350
					3	270, 240@10 m rod, 300@13 m
					4	120
					5	60, 100@10 m
	21.65717	**150.21898**	**2**	**2**	**1**	230, 190@10 m rod
	Waypoint between transects 3 & 4				2	340, 350@10 m
					3	240
					4	50, 90@10 m
					5	130
	21.65743	**150.21917**	**5**	**2**	**1**	200
	Waypoint between transects 3 & 4				2	270, 320@10 m rod
					3	270, 200@10 m rod
					4	30, 120@10 m rod
					5	180, 60@10 m rod

Table A 9 continued.

Reef	Latitude S	Longitude E	Depth	Site	Tran	Compass directions
Henderson Island	**21.48542**	**149.90965**	**2**	**1**	**1**	340
	Waypoint between transects 3 & 4				2	340, 330@10m
					3	330, 350@10 m rod
					4	150
					5	160, start shoreside PM
	21.4856	**149.90907**	**5**	**1**	**1**	310, 330@10 m rod
	Waypoint between transects 3 & 4				2	300 over large Lobophyllia to end
					3	320, 20@10 m
					4	130, 100@10 m rod
					5	150
	21.48313	**149.90868**	**2**	**2**	**1**	310
	Waypoint between transects 3 & 4				2	300
					3	310, 300@10 m rod
					4	120
					5	150
	21.48317	**149.90845**	**5**	**2**	**1**	0, 350@10 m rod
	Waypoint between transects 3 & 4				2	300, 320@10 m rod
					3	330, 310@10 m rod
					4	180, 170@10 m rod
					5	180, 120@10m rod
Temple Island	**21.59608**	**149.50102**	**1**	**1**	**1**	200, 170@10 m
	Waypoint between T1-T4				2	150, 180@10 m
					3	190
					4	350
					5	330, 310@10 m
	21.60285	**149.49932**	**1**	**2**	**1**	240, 220@10 m
	Waypoint between T1-T4				2	190, 200@10 m
					3	180, 190@10 m
					4	90, 30@10 m, 340@12 m, 300 to T5
					5	30, 50@10 m
Aquila Island	**21.95682**	**149.58102**	**1**	**1**	**1**	190, 180@10 m, 140 to T2
	Waypoint between T1-T4				2	140
					3	170
					4	310
					5	330, 310@10 m
	21.96112	**149.58158**	**1**	**2**	**1**	120
	Waypoint between T1-T4				2	90
					3	110
					4	0
					5	30