# **Southern Inshore Zone:** Coral Indicators for the 2020 Mackay-Whitsunday-Isaac Report Card

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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 fringing reef showing distinctive coral bleaching May 2020
Image: Joe Gioffre

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# 1 EXECUTIVE SUMMARY

This report presents 2020 results of the coral component of the Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership's Southern Inshore Monitoring Program. 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 Southern Inshore Zone in the 2020 Mackay-Whitsunday-Isaac Report Card.

Between May and July 2020, the Australian Institute of Marine Science (AIMS) resurveyed benthic communities at permanent coral monitoring locations at six reefs in the Southern Inshore Zone. The overall report card grade for community condition in 2020 was D ('poor'), based on a coral index score of 0.21 (Table 1). This was a marginal improvement from the 2019 coral index score of 0.20 that translated to a grade of E ('very poor'). Most influential in this improvement was an increase in the abundance of juvenile corals at most reefs, particularly Pine Islets and Connor Island, although overall scores for juvenile corals remain 'very poor' (Table 1).

The report card grades are based on the assessment of three 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, and
- Juvenile corals - the density of juvenile hard corals

The 2020 coral index score was heavily influenced by the high cover of macroalgae found across all reefs that resulted in a score of 0 for this indicator (Table 1). The ongoing presence of a high proportion of macroalgae at all reefs is likely to be limiting the replenishment of coral communities in this region and contributing to the 'very poor' grade for juvenile corals (Table 1). In contrast, the overall score for coral cover was in the 'satisfactory' range, bolstered by high cover at Henderson Island and moderate cover at Connor Island and Temple Island.

**Table 1. Coral indicator and sub-indicator scores for 2019 and 2020.**

| | Year | Juvenile corals | Coral Cover | Macroalgae | Report Card | |
|---|---|---|---|---|---|---|
| | | | | | **Score** | **Grade** |
| Regional Scores | 2019 | 0.13 | 0.49 | 0 | 0.20 | E |
| | 2020 | 0.17 | 0.47 | 0 | 0.21 | D |

The most influential environmental pressure in 2020 was the marine heatwave in January to March that led to widespread coral bleaching. The Southern Inshore Zone was exposed to some of the highest estimates of heat stress across the Great Barrier Reef during this event. Coral bleaching was observed at all reefs in the monitoring program. At Henderson Island, with the highest hard coral cover of the six surveyed reefs, 67% of the corals were bleached at the time of survey in May 2020. Although mortality among corals was relatively low at the time of survey, the high proportion of corals still under thermal stress suggests further mortality may occur. Mortality associated with the heat stress event will be apparent by the time of the next survey, in 2021.

There were no cyclone impacts on the east coast of Queensland during the 2020 cyclone season. While the 2019-2020 wet season brought heavy cloud cover and occasional rain, local rivers remained below flood levels.

Finally, we present a rationale for removing Connor Island from the program based on logistical and safety constraints realised during this year's surveys.

# 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 (Thompson *et al*. 2020a). 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), 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 second annual survey of six 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 2020 that expands on the necessarily succinct summary of overall condition presented by the 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 2019, as reported in detail in Davidson *et al.* (2019).

In brief, suitable sites were identified at six 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 1).


**Figure 1. Map showing islands selected of coral monitoring in the Southern Inshore Zone.**

At each reef, two replicate sites separated by at least 150m 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, Pine Islets and Connor Island as predicted by Navionics electronic charts on the day of site construction.

Sites at Henderson Island were setup in 2018 by a third party and the depth of some transects at site 1 are set 1-3 m deeper than the intended 5 m datum. At Temple Island and Aquila Island the reef slope transitioned to sand at 1-1.5m below LAT and as such transects were set at 1m 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 1.

Most reefs were monitored in May 2020, with the exception of Aquila Island that was monitored in July 2020 (Table 2).

**Table 2. Dates of coral monitoring.**

| Island | 2019 | 2020 |
|---|---|---|
| Pine Peak Island | 27$^{th}$ January | 26$^{th}$ May |
| Pine Islets | 28$^{th}$ January | 27$^{th}$ May |
| Henderson Island | 29$^{th}$ January | 25$^{th}$ -26$^{th}$ May |
| Connor Island | 30$^{th}$ - 31$^{st}$ January | 28$^{th}$ May |
| Temple Island | 27$^{th}$ May | 27$^{th}$-28$^{th}$ May |
| Aquila Island | 27$^{th}$ May | 12$^{th}$ 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.* 2008). Along the upslope side of each transect line, digital images of the substrate were taken at ~40cm elevation at 50cm intervals. Benthos beneath 5 evenly spaced points on each image was identified to the finest taxonomic resolution possible, typically genus level for corals and larger algae. In addition, the state of bleaching observed at each 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: 0-2cm and >2-5cm found within a strip 34cm 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. which result 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.* 2009) and serves to help identify probable causes of any declines in coral community condition.

For each 20m transect a search was conducted within a 2m 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 sea stars, 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.* 2020a), the development of which is described in detail in Thompson *et al* 2020b. Of the five indicators included in the Reef report card two require multiple annual observations for estimation and as such were not estimated here. The rate of coral cover change indicator requires at least three annual visits. The change in community composition indicator scored is based on the deviation in community composition beyond baseline condition confidence intervals. The estimation of confidence intervals in community composition requires five observations. It is envisaged that both indicators for the rate of coral cover increase and changes in community composition will be incorporated as the time-series of this program develops. This section provides an overview of the rationale for the selection of the three indicators used to assess coral community condition in 2020. A full description of these and the additional indicators can be found in Thompson *et al.* (2020b).

### 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 though 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). 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 estimated as the proportion of the total cover of algae 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.

### 3.3.4 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 2uses coral cover as an example). Conversely, lower bounds were set to represent minimal resilience (Table 3). 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]

[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.*

**Table 3. Indicator score thresholds.**

| Indicator | Location | Upper bound (score=1) | Lower bound (score=0) |
|---|---|---|---|
| Coral cover | All | 75% | 0% |
| Macroalgae | Pine Peak Island 2m | 0.2% | 3.4% |
| | Pine Peak Island 5m | 0% | 6.3% |
| | Pine Islets 2m | 0.2% | 5.4% |
| | Pine Islets 5m | 0% | 6.4% |
| | Henderson Island 2m | 0.2% | 3.9% |
| | Henderson Island 5m | 0% | 6.7% |
| | Connor Island 2m | 0.2% | 12.1% |
| | Connor Island 5m | 0.2% | 10.3% |
| | Temple Island 1m | 0.3% | 23% |
| | Aquila Island 1m | 0.3% | 23% |
| Juvenile density | All | 13 $m^{-2}$ | 0 $m^{-2}$ |

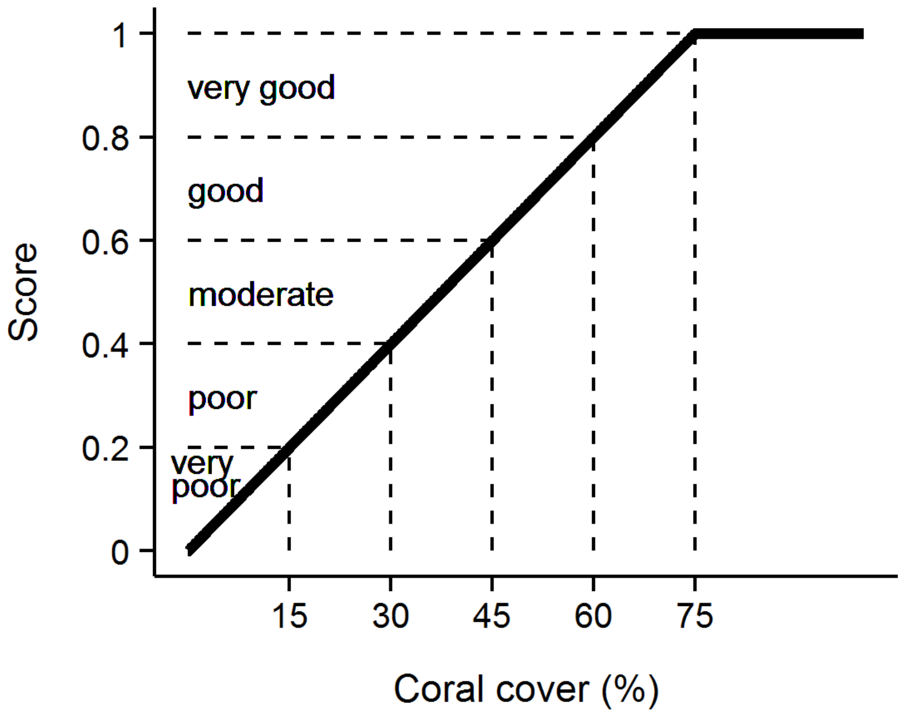


**Figure 2. An example of a scoring diagram, here for the Coral Cover metric.**
Numeric scores and associated condition classifications based on observed coral cover are presented (see also Table 2).

### 3.3.5 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 classification for coral communities were derived from the index scores, according to the conversions described in Table 4.

**Table 4. Indicator scores, condition descriptions and report card grade conversions.** Scores are rounded to the nearest single decimal place.

| Score | Condition description | Grade |
|---|---|---|
| > 0.80 | 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 |

### 3.3.6 Data Analysis

A panel of plots provide temporal trends in the coral condition index and the three indicators on which the index for the Southern Inshore Zone is based.

For each of the three 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 2, Table A 3, Table A 6, and Table A 7. Family level bleaching data is available at Appendix Table A 4, with reef-level summary at Table A 5.

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. Photos representative of coral communities at each reef and depth in 2020 are at Appendix Figure A 3 (a-f) and Figure A 4 (a-d).

### 3.3.7 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), and anomalously high summer temperatures resulting in coral bleaching (Berkelmans *et al.* 2004; Sweatman *et al.* 2007). 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.

### 3.3.8 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 (2m and 5m), Henderson Island (2m and 5m), and Aquila Island (1m). These loggers were retrieved during our resurveys in 2020. 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 of maximum summer temperatures from time-series of temperatures recorded by the MMP at Whitsunday Islands reefs has been adopted as a visual reference for temperatures recorded in the Southern Inshore Zone.

Two sources of 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 days (DHD) sourced from the Bureau of Meteorology's ReefTemp (Garde *et al.* 2014) and Degree Heating Weeks (DHW) sourced from NOAA coral reef watch. Thresholds at which moderate and severe bleaching are expected have been approximated as 60 and 100 DHD respectively (Maynard *et al.* 2008; Garde *et al.* 2014) and severe coral bleaching is likely at DHW values greater than eight (Lui *et al*. 2014). For both DHD and DHW estimates, realised severity of bleaching will depend on the pattern of warming and differences in the tolerances of coral species.

DHD are the sum of positive daily temperature anomalies from the seasonal climatology of a location across the period 1st December to the 31st March. A single degree heating day results from a temperature of one degree higher than the climatology mean for that day. The climatology used for this report was the IMOS 14 Day mosaic. In contrast 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.

In addition to annual maps of DHD estimates, location specific estimates were extracted for a set of nine 1 $km^2$ pixels centred on waypoints selected in open water approximately 2 km out from the monitored reefs (Table 5).

**Table 5. Location of satellite derived environmental information.**

| Location | Latitude | Longitude |
|---|---|---|
| Pine Peak Island | -21.5467 | 150.2599 |
| Pine Islet | -21.6656 | 150.1978 |
| Henderson Island | -21.5291 | 149.9218 |
| Conner Island | -21.6957 | 149.67 |
| Temple Island | -21.6239 | 149.5132 |
| Aquila Island | -21.9428 | 149.5535 |

### 3.3.9 Runoff

Median discharge for the water-year are calculated from available data 1986 – 2016 and 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. The factors were supplied by James Cook University and reflect those reported in Gruber *et al.* (2020).

### 3.3.10 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.

### 3.3.11 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. 2016). 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

In-situ temperature records clearly captured the higher water temperatures over early 2020 compared to 2019 (Figure 3). Note that the reference line used in **Error! Reference source not found.** was derived from temperatures recorded at reefs in the Whitsunday Islands and are expected to provide a conservative estimates of the mean summer maximum baseline for the region.

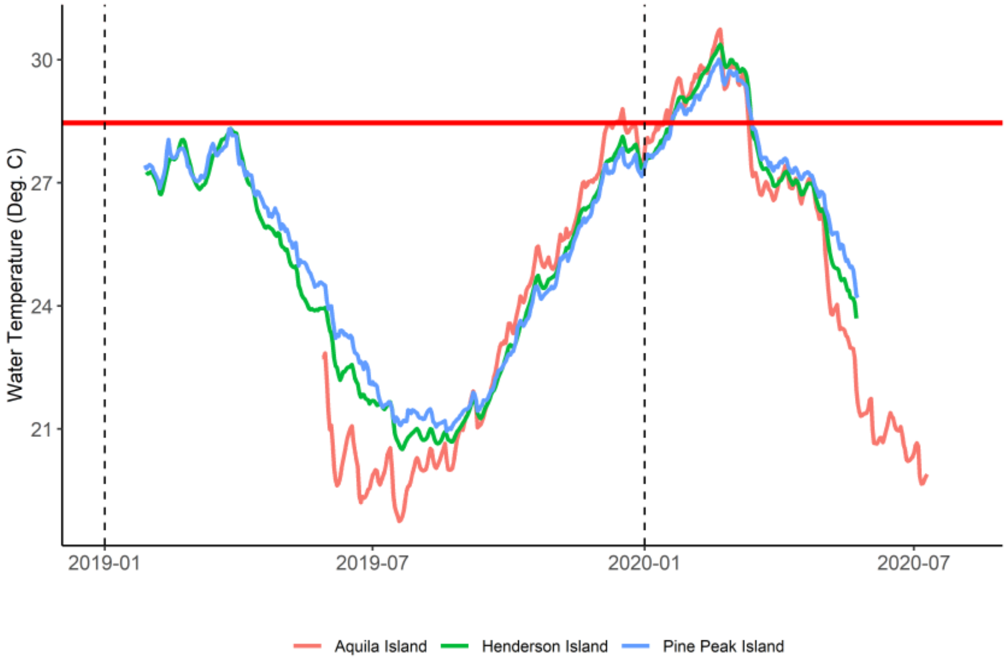


**Figure 3. Temperature profiles recorded by in-situ loggers.**
The horizontal reference line was derived from the mean of the means of the hottest month each year observed over timeseries of in situ temperature data available from reefs in Whitsunday Islands. This baseline excluded years in which bleaching was observed.

The observed high temperatures are almost certain to have been the cause of coral bleaching observed during surveys in 2020, a conclusion supported by the magnitude of both degree heating days (DHD) and degree heating weeks (DHW) estimates. In 2020 both DHD and DHW estimates exceeded those expected to cause severe coral bleaching (Figure 4, Garde *et al.* 2014, Lui *et al.* 2014).

Degree heating week estimates for 2020 were the highest recorded over the last five years, where DHD estimates were slightly higher in 2017 (Table 6). DHD are the sum of positive daily temperature anomalies from the seasonal climatology of a location across the period 1st December to the 31st March. In contrast 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. This difference explains the slight discrepancy in estimated stress in 2017 relative to 2020 between the two indices. Higher DHD values in 2017 compared to 2020, in contrast to the relative values for DHW, suggest anomalies in 2020 occurred during the hotter period of the summer window.

Reef level DHD estimates for 2020 suggest higher anomalies at Aquila, Temple and Connor Islands compared to the those further offshore (Table 6), a result captured in marginally higher observed temperatures at Aquila Island than those at either Henderson Island or Pine Peak Island (Figure 3).

**Table 6. Annual degree heating days (DHD). Calculated for reefs across the coastal shelf from 'outer' to 'inner'.** Values above 100 are highlighted as a visual cue to where and when there was a high likelihood of thermal stress.

| Year | Pine Peak | Pine Islets | Henderson | Connor | Temple | Aquila |
|---|---|---|---|---|---|---|
| 2003 | 3 | 0 | 9 | 11 | 20 | 11 |
| 2004 | 63 | 34 | 66 | 58 | 64 | 72 |
| 2005 | 21 | 13 | 20 | 38 | 56 | 44 |
| 2006 | 63 | 64 | 75 | 74 | 65 | 75 |
| 2007 | 6 | 9 | 8 | 10 | 18 | 21 |
| 2008 | 13 | 9 | 9 | 14 | 17 | 16 |
| 2009 | 44 | 56 | 44 | 57 | 62 | 74 |
| 2010 | 46 | 47 | 48 | 54 | 43 | 23 |
| 2011 | 24 | 23 | 18 | 24 | 28 | 47 |
| 2012 | 25 | 23 | 35 | 35 | 36 | 33 |
| 2013 | 30 | 34 | 34 | 42 | 47 | 43 |
| 2014 | 5 | 15 | 6 | 7 | 22 | 16 |
| 2015 | 72 | 80 | 91 | 105 | 115 | 112 |
| 2016 | 74 | 61 | 77 | 81 | 90 | 84 |
| 2017 | 120 | 124 | 121 | 118 | 145 | 140 |
| 2018 | 47 | 54 | 46 | 52 | 81 | 73 |
| 2019 | 28 | 24 | 28 | 47 | 57 | 50 |
| 2020 | 97 | 106 | 116 | 128 | 131 | 120 |

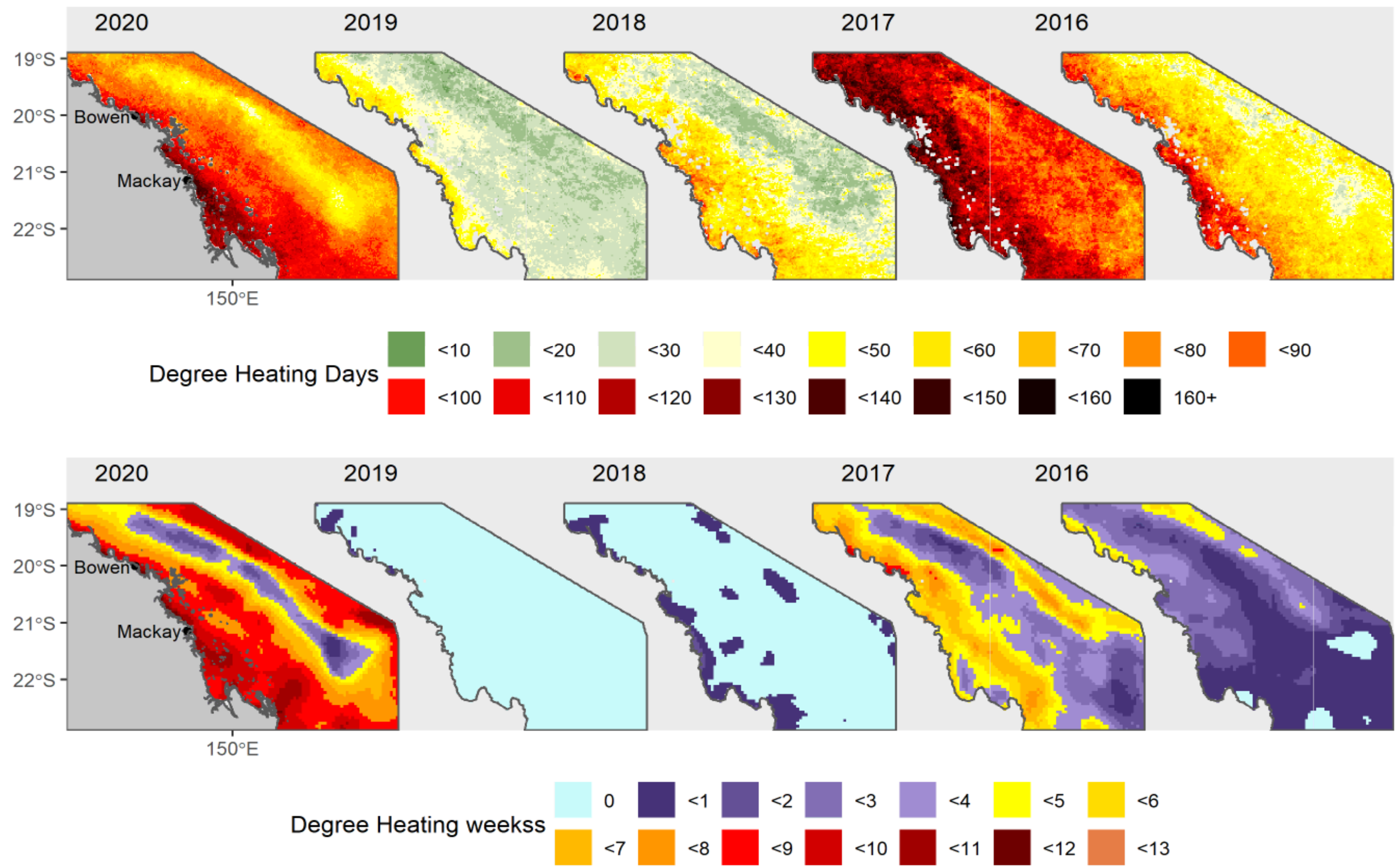


**Figure 4. Annual estimates of thermal stress to corals.**
Top panel provides Degree Heating Day estimates downloaded from the Australian Bureau of Meteorology ReefTemp. The bottom panel provides Degree heating Week estimates downloaded from NOAA coral reef watch.

### 4.1.2 Runoff

River discharge data highlights a period of very high discharge in 2011 and again in 2013, with the amplitude of exceedance reduced in later years (Table 7). Discharge from the region's catchments over the 2019-2020 water-year (October to September) increased slightly from below median levels in the north to 1.5 time median levels for Water Park Creek (Table 7). Although exposure to reduced salinity has proven lethal to coral communities in the inshore GBR (van Woesik 1991; Jones and Berkelmans 2014; Thompson *et al.* 2016) the moderate flows in recent years are unlikely to have resulted in direct impacts to the coral communities monitored.

**Table 7. Annual freshwater discharge for the catchment basins bordering the Southern Inshore Zone.** Values represented as proportional to the long-term median (1986-2016). 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pioneer | 124001B | 692,342 | 5.2 | 2.3 | 1.7 | 0.9 | 0.2 | 0.9 | 2.0 | 0.4 | 1.7 | 0.6 |
| Plane | 126001A, 126003A | 309,931 | 4.1 | 2.5 | 1.7 | 0.7 | 0.2 | 0.8 | 2.5 | 0.2 | 1.1 | 1.0 |
| Styx<br>Shoalwater<br>Waterpark Creek | 129001A | 381,986 | 4.8 | 1.5 | 5.2 | 2.9 | 2.0 | 1.8 | 2.7 | 1.4 | 0.7 | 1.5 |

### 4.1.3 Cyclones and Storms

There were no cyclones likely to have impacted reefs in the Southern Inshore Zone during the 2019-2020 cyclone season. However, recovery from severe disturbance caused by cyclones can be slow and exposure to high waves during past cyclones likely continues to influence coral cover. Four of the top five wave heights recorded by the Mackay buoy since 1975 have occurred since 2010 and, in descending order, can be attributed to cyclones Dylan (2014), Ului (2010), Debbie (2017) and Iris (2018). While each of these cyclones are likely to have impacted coral communities in the Southern Inshore Zone, Cyclone Marica, a category 5 system, came closest to the reefs reported here, tracking southwards past Middle Percy with winds in excess of 80 knots, crossing the coast at Shoalwater Bay on February 20$^{th}$ 2015 (Figure 5). Although waves attributable to Cyclone Marica do not feature in the 10 highest waves recorded at either the Mackay or Hay Point wave-buoys, this can be explained by the track of the storm being to the south east of the buoy. Higher seas are expected to the south of cyclone tracks. Indeed, the fourth highest waves recorded at the Emu Park buoy can be attributed to this cyclone. Of note is that the orientation of the monitoring sites at Henderson and Temple islands, along with protection offered by surrounding islands, will have afforded some protection from damaging seas produced by Cyclone Marcia.

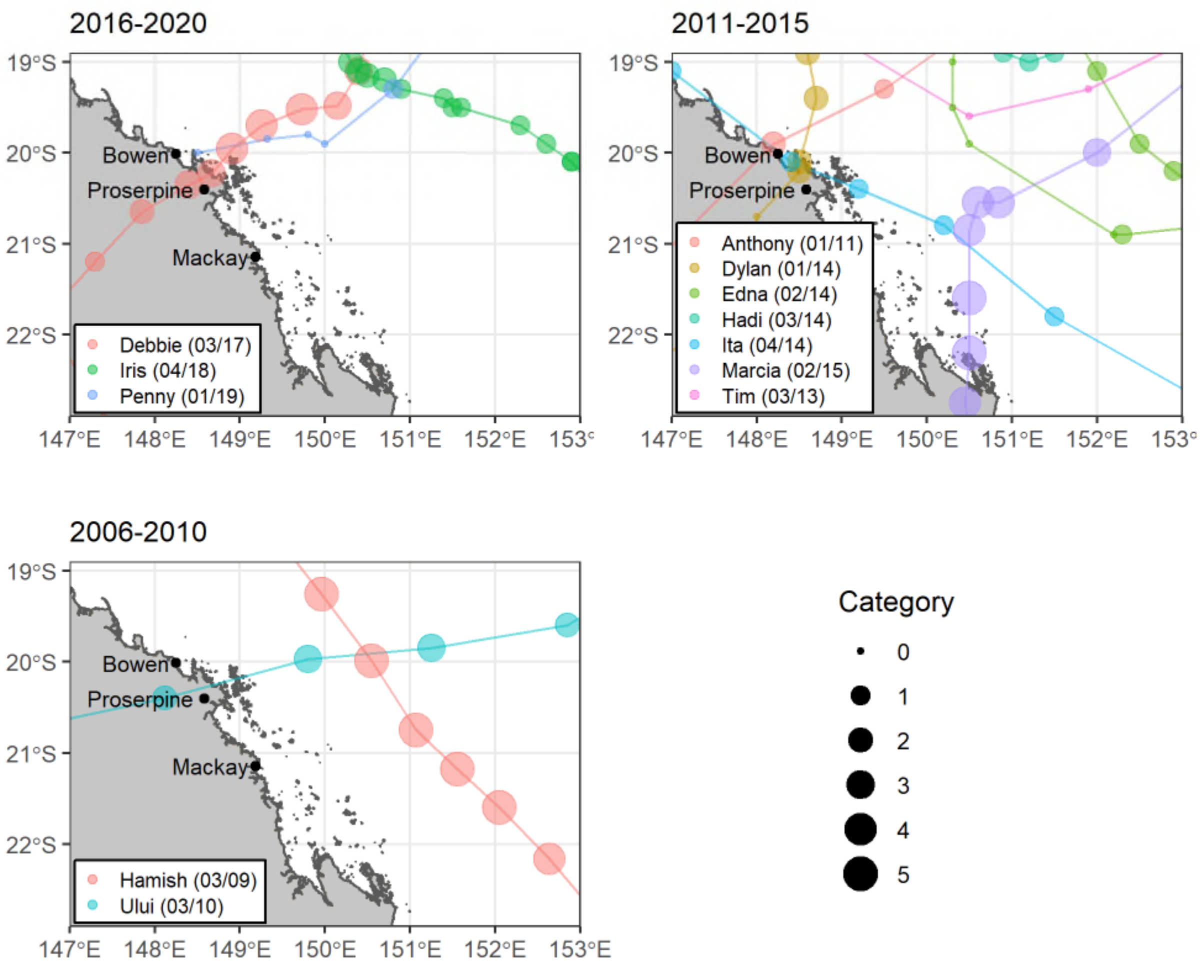


**Figure 5. Tracks of tropical cyclones passing through the region.**
All cyclones crossing through the Mackay Whitsunday Isaac regional report card reporting area over the last 15 years are displayed.

### 4.1.4 Biological Damage

Corals scarred by disease or unknown cause were hard to detect on the bleached corals during 2020 surveys, limiting the inference that should be ascribed to the reduced number of colonies afflicted (14), compared to 2019 observations (55), (Figure A 1, Table A 8) The number of colonies being overrun by the encrusting sponge *Cliona orientalis* have not risen greatly (from 11 colonies to 15 colonies), and most observations continue to occur among inshore reefs with higher turbidity; Connor, Temple, and Aquila islands. Afflicted colonies represent a range of genera including *Turbinaria*, *Montipora, Platygyra,* and *Favites spp* (Table A 8).

## 4.2 Coral Community Condition Assessment

The overall coral index score for the Southern Inshore Zone in 2020 was graded as D, categorising the coral communities as being in 'poor' condition (Table 8**Error! Reference source not found.**Table 9). This represents a minor improvement on the previous year's grade of E (very poor condition). This overall index score continues to mask the substantial differences in the condition of coral communities between reefs.

The index scores were lowest at the 2 m depths of Pine Peak Island and Pine Islets (Table 10) with scores of 0.05 and 0.04 respectively. While the condition score for Henderson Island contrasts with others, the minor loss of hard coral and a drop in juvenile numbers at the 2 m level meant a decline to a grade D (poor condition) for Henderson Island (Table 10). Consistently minimum scores of zero for the macroalgae indicator are highly influential in the low grade for this zone (Table 9).

**Table 8. Indicator values for Southern Inshore Zone.**
Juvenile densities are corrected for area of algal covered substrate, as a potential area for colonisation. Comparison between 2020 and 2019.

| | Year | Juvenile Density (per m$^2$) | | Coral Cover (%) | | Macroalgae proportion (%) | |
|---|---|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD | Mean | SD |
| Zone summary | 2019 | 1.48 | 0.86 | 36.39 | 23.54 | 62.41 | 22.96 |
| | 2020 | 1.89 | 1.07 | 35.17 | 19.39 | 56.64 | 24.32 |

**Table 9. Coral indicator and sub-indicator scores for 2020.**
Comparison with 2019 demonstrates the increase in juveniles in 2020 improved the Report Card score for 2020.

| | Year | Juvenile corals | Coral Cover | Macroalgae | Report Card | |
|---|---|---|---|---|---|---|
| | | | | | Score | Grade |
| Zone Scores | 2019 | 0.13 | 0.49 | 0 | 0.20 | E |
| | 2020 | 0.17 | 0.47 | 0 | 0.21 | D |

**Table 10. Index grade and scores for each reef and depth combination.**
The 2019 Index figures are included for comparison.

| Reef | Depth | Grade | Index 2019 | Index 2020 |
|---|---|---|---|---|
| Pine Peak Island | 2 | E | 0.05 | 0.09 |
| | 5 | E | 0.12 | 0.14 |
| Pine Islets | 2 | E | 0.04 | 0.06 |
| | 5 | E | 0.12 | 0.20 |
| Henderson Island | 2 | D | 0.41 | 0.34 |
| | 5 | D | 0.36 | 0.33 |
| Connor Island | 2 | D | 0.21 | 0.25 |
| | 5 | D | 0.24 | 0.32 |
| Temple Island | 1 | D | 0.32 | 0.21 |
| Aquila Island | 1 | E | 0.19 | 0.16 |

## 4.3 Coral Cover

Coral Cover scores are based on the combined cover of hard and soft corals. Small gains and losses in both hard and soft coral cover across reefs caused minor fluctuations in coral cover scores with little overall effect on grades from 2019 (Table 11, Table 6).

Pine Islets continued to have low scores of D, at 5 m and E, at 2 m. Minor increases in cover of both hard and soft corals at Pine Peak Island (2 m) resulted in an improved grade of D, while similar minor decreases at Aquila changed the grade to E. Both Henderson and Connor islands retained A and B grades respectively with good cover of hard coral (Table A 2).

The largest change in coral cover scores occurred at Temple Island where a 59% reduction in soft corals (**Error! Reference source not found.**), principally *Briarium*, *Sinularia,* and *Xenia* spp, caused a reduction in coral cover grade from B to C ('good' to 'satisfactory').

While both Pine Peak Island and Pine Islets are at the low range of hard coral cover, modest gains have been made at both depths. Indeed, in the shallows of Pine Peak Island (2 m), hard coral diversity has more than doubled from 5 to 11 genera since 2019 (Davidson *et al*. 2019), though genera richness remains lowest among the reefs in this study (Table A 2). It should be noted, (see section 4.4) that macroalgal cover had declined at all sites in 2020 except at the inner locations of Temple and Aquila Islands (Table 11, Figure A 2). Slight increases in richness and cover of corals may result as a higher proportion of corals become available to observation with the photo point intercept method as overlaying algae thins.

At Henderson Island, hard coral cover decreased at 2m depth and increased at 5 m these changes driven primarily by changes in the cover of Acroporidae (Table 11, Figure A 2). Given the low cover of macroalgae at this reef seasonal changes in macroalgae cover are not expected to have influenced changes in coral cover here. Declines in hard corals (primarily *Acropora* sp) at 2 m and soft corals (primarily *Klyxum* sp) at both depths is most likely a result of high-water temperatures.

At Connor Island there was an increase in hard coral cover at 2 m depth Acroporidae and Dendrophylliidae (genus *Turbinaria* ) (Table 11, Figure A 2). There was little change in soft coral cover, or genus richness of soft or hard corals (Table A 2, Table A 3, Davidson *et al*. 2019).

Closest inshore, Aquila Island had a minimal loss of hard and soft coral; principally a 19% reduction of the dominant *Montipora* sp to 14%, and a 38% reduction in *Sinularia* sp to 5%. In absolute terms this represents a change in hard and soft coral at Aquila Island of 2% and 2.5% respectively. However, the change was enough to transit the coral cover grade of C to D.

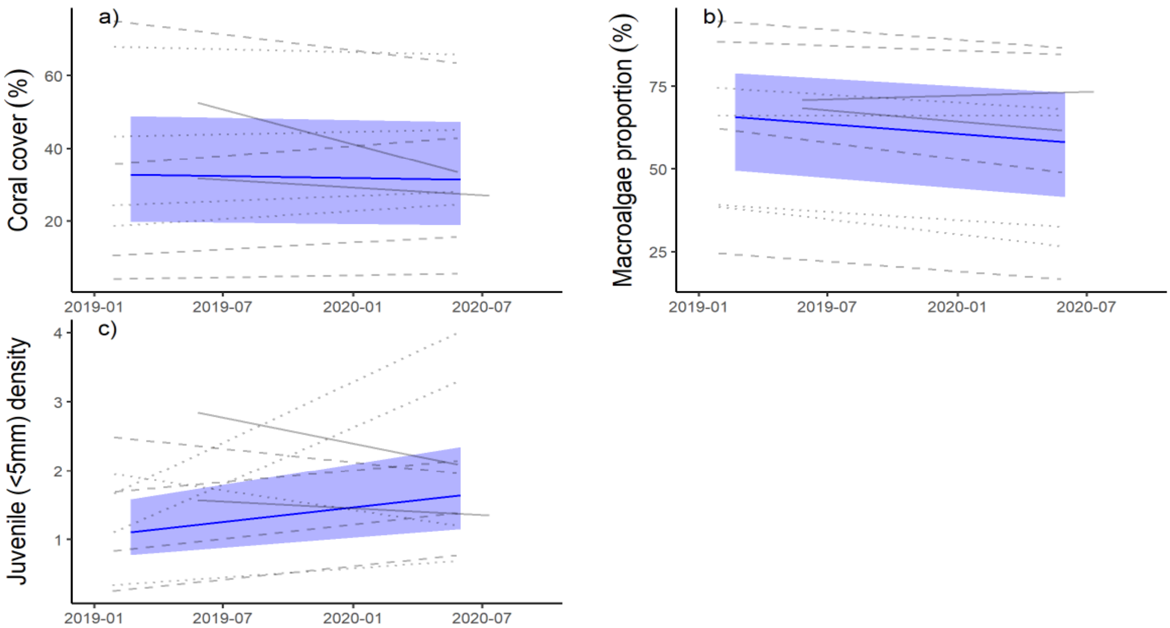


**Figure 6. Indicator trends for Southern Inshore Zone.**
Blue lines represent trends in: a) coral cover, b) macroalgae proportion, c) juvenile density. Trends are bound by 95% confidence intervals of those trends (shading), grey lines represent observed profiles at 5m (dotted lines), 2m (dashed lines), and 1m (solid lines) for individual reefs.

**Table 11. Coral cover and indicator scores for each location in 2019 and 2020.**
Coral cover scores are coloured as per Table 3.

| Reef | Depth | Year | Hard coral | Soft coral cover | Coral cover (%) | Coral cover Score |
|---|---|---|---|---|---|---|
| Pine Peak Island | 2 | 2019 | 3.45 | 7.15 | 10.60 | 0.14 |
| | | 2020 | 5.44 | 10.31 | 15.75 | 0.21 |
| | 5 | 2019 | 9.39 | 14.96 | 24.35 | 0.32 |
| | | 2020 | 9.31 | 18.69 | 28.00 | 0.37 |
| Pine Islets | 2 | 2019 | 2.69 | 1.38 | 4.06 | 0.05 |
| | | 2020 | 4.25 | 1.31 | 5.56 | 0.07 |
| | 5 | 2019 | 14.75 | 3.94 | 18.69 | 0.25 |
| | | 2020 | 19.80 | 4.76 | 24.56 | 0.33 |
| Henderson Island | 2 | 2019 | 57.05 | 17.9 | 74.96 | 1.00 |
| | | 2020 | 52.12 | 11.31 | 63.44 | 0.85 |
| | 5 | 2019 | 48.75 | 19.19 | 67.94 | 0.91 |
| | | 2020 | 51.00 | 14.82 | 65.82 | 0.88 |
| Connor Island | 2 | 2019 | 22.77 | 12.9 | 35.66 | 0.48 |
| | | 2020 | 30.56 | 12.38 | 42.94 | 0.57 |
| | 5 | 2019 | 33.06 | 10.25 | 43.31 | 0.58 |
| | | 2020 | 35.25 | 9.81 | 45.06 | 0.60 |
| Temple Island | 1 | 2019 | 19.50 | 33.13 | 52.63 | 0.70 |
| | | 2020 | 20.07 | 13.69 | 33.51 | 0.45 |
| Aquila Island | 1 | 2019 | 20.75 | 11.00 | 31.75 | 0.42 |
| | | 2020 | 18.53 | 8.51 | 27.04 | 0.36 |

While changes in hard and soft coral cover between 2019 and 2020 were relatively minor, undoubtedly the main impact to the region has been the marine heatwave and resulting coral bleaching. Coral bleaching was still clearly evident during surveys in May-June three months after peak of the marine heatwave (Figure 3). An average of 41% of hard corals were bleached (Table A 4), ranging between 10% (Aquila Island, 1m) and 76% (Henderson Island, 2m, Table A 5). The influence of bleaching was varied among reefs, between depths, and within and among coral genera. For example, the family Acroporiidae, particularly *Acropora* sp, is common at Henderson Island (Figure A 2, Figure A 3). While the proportion of bleaching is high at both depths (68%), the coral communities share adjacent bleached and non-bleached *Acropora* colonies. At Pine Islets, the proportion of bleached Acroporiidae was lower (19%). Importantly, there is little indication of whether the non-bleached corals observed in this survey have resisted bleaching or have recovered early.

Although, the bleaching response within families was inconsistent among reefs general patterns of sensitivity suggest:

- Agariciidae (principally *Pachyseris* sp), and Oculinidae (represented by *Galaxea* sp) were found to be highly vulnerable, with bleaching rates of 90%-100% at most locations,
- Pocilloporidae (*Pocillopora* sp), Acroporiidae, Dendrophylliidae (*Turbinaria* sp), and Poritidae (*Gioniopora* sp, *Porites* sp) had varying degrees of bleaching response, often within the same location.
- Of those families with < 20% responding to thermal stress, only one, Merulinidae (*Hydnophora* sp) was present at >1% cover; the others were rare (<1% cover) within the reef communities. (Table A 4)

## 4.4 Macroalgae Proportion

The proportion of macroalgae continued to exceed thresholds (Table 3) across all reefs, resulting in a macroalgae grade of E ('very poor', Table 12). There was a slight reduction in the proportion of macroalgae across the zone (Figure 6b). Reductions in the overall cover of macroalgae at Pine Peak, Pine Islets, Henderson, and Connor islands since 2019 were minimal likely confounded by the different sampling seasons; in 2019 these reefs were surveyed in summer (January), in 2020 they were resurveyed in winter (May), which subjects some algal groups to natural, seasonal, depletions (Vuki and Price 1994). Reductions in macroalgae cover are most likely to reveal more benthic fauna to survey observation, improving the accuracy of target estimates. For this reason, mid-winter resurveys were described as preferable in the 2019 baseline report (Davidson *et al.* 2019).

The cover of macroalgae continues to be extremely high at both Pine Peak Island and Pine Islets (Table 12, Figure A 2) with the community dominated by large brown algae of the genus *Sargassum* in the shallows, and an increasing presence of *Lobophora* at the 5 m depths (Table A 6). *Stypopodium* was also common at Pine Peak Island (Table A 6). *Sargassum* remains the dominant macroalgae at both Temple and Aquila islands, increasing at Temple Island by 71%, while at Connor Island the higher representation of red algae has dropped by 66% at both depths which may indicate some degree of seasonality (Table A 6). Although the total cover of macroalgae continues to be low at Henderson Island due to the high cover of corals, macroalgae do occupy approximately a quarter of the limited substrate available to coral recruitment (Table 12). As with the reefs further offshore, the most common macroalgae at the 5 m depth at Henderson Island was *Lobophora* sp.

**Table 12. Macroalgae cover and indicator scores for each location, depth, and year.**

| Reef | Depth | Year | Macroalgae cover (%) | Macroalgae proportion (%) | Macroalgae score |
|---|---|---|---|---|---|
| Pine Peak Island | 2 | 2019 | 77.86 | 88.44 | 0 |
| | | 2020 | 68.30 | 84.59 | 0 |
| | 5 | 2019 | 51.69 | 74.46 | 0 |
| | | 2020 | 44.25 | 67.97 | 0 |
| Pine Islets | 2 | 2019 | 89.75 | 94.69 | 0 |
| | | 2020 | 78.75 | 86.78 | 0 |
| | 5 | 2019 | 48.69 | 65.79 | 0 |
| | | 2020 | 41.43 | 65.82 | 0 |
| Henderson Island | 2 | 2019 | 5.76 | 23.77 | 0 |
| | | 2020 | 5.56 | 16.54 | 0 |
| | 5 | 2019 | 8.81 | 36.48 | 0 |
| | | 2020 | 5.64 | 26.92 | 0 |
| Connor Island | 2 | 2019 | 37.33 | 61.38 | 0 |
| | | 2020 | 22.69 | 49.13 | 0 |
| | 5 | 2019 | 18.75 | 38.42 | 0 |
| | | 2020 | 12.00 | 33.02 | 0 |
| Temple Island | 1 | 2019 | 27.19 | 69.90 | 0 |
| | | 2020 | 36.16 | 62.05 | 0 |
| Aquila Island | 1 | 2019 | 32.31 | 70.79 | 0 |
| | | 2020 | 35.92 | 73.53 | 0 |

## 4.5 Juvenile Density

In 2020, there was a marginal increase in the density (Figure 6c) and abundance of juvenile hard corals (Figure A 2) at most reefs, however, the indicator continued to be classified as 'very poor' (Table 13). The only locations to have densities above those classified as very poor, grade E, were at 5 m depth at Pine Islets and Connor Island (Table 13). The richness of genera found as juveniles was similar to or slightly higher than recorded in 2019 (Davidson et al. 2019, Table A 7). The maximum number of juvenile genus groups (31) were observed at Pine Islets (5m) (Table A 7). Aquilla Island had the lowest richness of juvenile hard corals (9 genus). There were extremely low numbers of juvenile corals at Henderson Islands, particularly at 5 m depth (Figure A 2).

**Table 13. Juvenile hard coral abundance, density and indicator scores for each location.** Density has been adjusted for the area of algal covered substrates.

| Reef | Depth | Year | Juvenile abundance | Juvenile density (per $m^2$) | Juvenile score |
|---|---|---|---|---|---|
| Pine Peak | 2 | 2019 | 7.5 | 0.25 | 0.02 |
| | | 2020 | 21 | 0.77 | 0.07 |
| | 5 | 2019 | 8 | 0.33 | 0.03 |
| | | 2020 | 15 | 0.68 | 0.06 |
| Pine Islets | 2 | 2019 | 27 | 0.83 | 0.07 |
| | | 2020 | 43 | 1.38 | 0.12 |
| | 5 | 2019 | 28 | 1.11 | 0.1 |
| | | 2020 | 69.5 | 3.3 | 0.29 |
| Henderson Island | 2 | 2019 | 21 | 2.49 | 0.22 |
| | | 2020 | 22.5 | 1.97 | 0.17 |
| | 5 | 2019 | 14.5 | 1.95 | 0.17 |
| | | 2020 | 8.5 | 1.2 | 0.1 |
| Connor Island | 2 | 2019 | 34 | 1.69 | 0.15 |
| | | 2020 | 35 | 2.15 | 0.19 |
| | 5 | 2019 | 27.5 | 1.67 | 0.15 |
| | | 2020 | 53.5 | 4 | 0.35 |
| Temple Island | 1 | 2019 | 39 | 2.85 | 0.25 |
| | | 2020 | 42 | 2.09 | 0.18 |
| Aquila Island | 1 | 2019 | 24.5 | 1.57 | 0.14 |
| | | 2020 | 23.5 | 1.35 | 0.12 |

## 4.6 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 < 3m change between high and low tide over the period of survey). Only once was work suspended due to currents – at Henderson Island during a falling tide (Table 13).

Wind driven resuspension can also reduce in-water visibility. Winds of 10-15 knots at Conner Island on a rising tide, despite coinciding with neap tides, resulted in visibility levels below 1 m at which point surveys are impossible to complete. From our visits in 2019 and 2020 it became clear that Connor Island is susceptible to frequent periods of low visibility (<1m) that precludes work despite neap tides and calm conditions.

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 ~3.5m 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. However, the most accessible launch point for Temple Island, Connor 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 and the open waters, winds <15 knots are required. These reefs were all successfully resurveyed with winds in the range of 5-10 knots generally from the East. The 2020 resurvey was fortunate to have a rare spell of ideal weather for work based out of Sarina Beach in May. Suitable conditions to survey Aquila Island did not occur until August. **Error! Reference source not found.** provides a reference point for the conditions experienced during 2020 re-surveys. It should also be noted here that all field work activities, including time on boat, mealtimes and overnight accommodation, were carried out under a comprehensive risk assessment protocol with strict compliance to COVID-19 controls.

Should future planning consider removing one of the locations from the survey list, Connor Island would be a logical choice based on a combination of logistical commitment given the distance involved, and the risk of conditions being unsuitable for survey work. Planning for future resurveys of Henderson Island, Pine Islets, and Pine Peak Island should consider the use of a suitable vessel for a limited charter of 2-3 nights. This would give the monitoring team access to work sites without the need for a daily four-hour journey, with reduced time on water adding an extra element of safety. It would also allow greater control over trip planning as access to these outer reefs would be less wind dependant, and the need for sufficient tide to launch from Sarina Beach alleviated.

**Table 14. Weather conditions and tide heights experienced during 2020 works.**

| Reef | Date | Wind (knots) | Tide (Range) | Observations |
|---|---|---|---|---|
| Pine Peak Island | 26/05/20 | 10 ESE | Rising->High (4.3m) Falling (3.0m) | Visibility 5-7m negligible current. |
| Pine Islets | 27/05/20 | 5-10 E | Rising->High (3.5) | Visibility 6-7m slight |
| Henderson Island 5m depths | 25/05/20 | 5-10 ESE | High->Falling (3.5m) | Visibility 4m current increased to become unworkable as tide passed halfway through ebb. |
| Henderson Island 2m depths | 26/05/20 | 5 E | Falling (3.5m) | Visibility 4m no current |
| Connor Island | 25/05/20 | 10-15 SE | Rising (3m) | Visibility <1m, conditions precluded work. |
| Connor Island | 28/05/20 | 5 E | Rising (2.5m) | Visibility 1-2m, negligible current |
| Temple Island Site 2 | 27/05/20 | 5 E | High- falling (3.8m) | Visibility 4m no current |
| Temple Island Site 1 | 28/05/20 | 5 E | High (3m) | Visibility 4m no current |
| Aquila Island | 12/07/20 | 5 SE | Rising-High (5.0m) | Visibility 1m little current |

# 5 DISCUSSION

The overall condition of Southern Inshore Zone reefs in 2020 was categorised as 'poor'. This is a marginal improvement from the initial 2019 report card grade of 'very poor' and reflects scores for three metrics that, in combination, have been formulated to represent not only reef state, but also processes that support reef resilience (Thompson *et al.* 2020b).

In general, the coral community has changed little since 2019. Differences in coral cover, macroalgae, and juvenile density metrics were relatively minor and variable among reefs and depths.

Given the exposure of these reefs to marine heat wave conditions and the ensuing coral bleaching it is not surprising there was not a clear improvement in coral index scores. Across the GBR, the effect of the 2020 marine heatwave on reef communities has been widespread and highly variable (GBRMPA, 2020). While temperatures have exceeded long-term averages at large spatial scales, the accumulation of elevated temperatures was greatest for the inshore reefs of the central-south GBR, including the Southern Inshore Zone (Figure 4). Coral bleaching was still on-going in the months of May to August during the 2020 inshore monitoring surveys by AIMS MMP. A strong latitudinal pattern was observed, with bleaching of less than 5% occurring in regional communities between Cairns and Innisfail and marked increases southward through Burdekin Region (23%) to Fitzroy Basin (30%), (MMP unpublished data). Remarkably, reefs of the Mackay / Whitsunday region reported much less bleaching (3%).

Following marine heat waves coral mortality has been be linked to coral disease as pathogens overcome corals weakened by thermal stress (Bruno *et al* 2007, Brodnicke et al 2019, Howells *et al* 2020).

With an average of 41% of the coral cover bleached at the time of surveys in the Southern Inshore Zone, and similar figures for MMP reefs in the Burdekin and Fitzroy regions a full appreciation of the impact of this event on coral cover at various scales will be enabled by the next round of surveys in 2021.

Thermal stress has also been linked to a reduction in the reproductive health of corals that may have a long-lasting effect on the resilience of communities dependent on successful spawning, settlement, and recruitment (Ward *et al* 2002, Hughes *et al* 2019). This is of particular concern in context of the Southern Inshore Zone reefs where low juvenile scores indicate coral recruitment is already limiting coral community resilience.

Previous studies (Hopley *et al.* 1983, van Woesik 1992, Kleypas 1996, van Woesik & Done1997) identify the environmental conditions of the Southern Inshore Zone as a challenging environment for corals. The high levels of macroalgae recorded by this program further supports these conclusions and highlight the competitive advantage of macroalgae in this area. Any erosion of corals survival, because of exposure to thermal stress, or recruitment due to reduced larval supply, must increase the risk of long-term persistence of reefs in a macroalgae dominated state (Hughes *et al* 2007).

Future surveys will build the capacity to expand the indicators used to define the Coral Index score (see Thompson *et al* 2020b for development). For example, coral change is a metric that allows tracking the rate of change in coral cover during periods of coral recovery providing important information on the resilience of communities following disturbances such as the bleaching event observed this year. This requires a minimum of three years of coral data. With a minimum of five years of data a fifth indicator, community composition, can be added.

This indicator will respond to changes in community composition based on the distribution of corals across water quality gradients. Completing the suite of five indicators will improve the information on which future Mackay-Whitsunday-Isaac Report Cards are based, but also help with interpreting the cause of any observed loss of coral community resilience.

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# 8 APPENDICES

**Table A 1. Waypoints and compass directions for transects for monitoring sites.**

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

| 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 | 330 |
| | | | | | 3 | 330, 350@10m rod |
| | | | | | 4 | 150 |
| | | | | | 5 | 160, start shoreside PM |
| | **21.4856** | **149.90907** | **5** | **1** | **1** | 310, 330@10m rod |
| | Waypoint between transects 3 & 4 | | | | 2 | 300 over large Lobophyllia to |
| | | | | | 3 | 320, ends short of large |
| | | | | | 4 | 130, 120@10m rod |
| | | | | | 5 | 150, 200@10m rod |
| | **21.48313** | **149.90868** | **2** | **2** | **1** | 310 |
| | Waypoint between transects 3 & 4 | | | | 2 | 320 |
| | | | | | 3 | 320, 300@10m rod |
| | | | | | 4 | 120 |
| | | | | | 5 | 150 |
| | **21.48317** | **149.90845** | **5** | **2** | **1** | 0, 350@10m rod |
| | Waypoint between transects 3 & 4 | | | | 2 | 300, 320@10m rod |
| | | | | | 3 | 320, 310@10m rod |
| | | | | | 4 | 180, 150@10m rod |
| | | | | | 5 | 180 |
| Connor Island | **21.71732** | **149.67282** | **2** | **1** | **1** | 30, 180@10m rod |
| | Site is convoluted around rocks. Waypoint at transect 1 | | | | 2 | 270, 290@10m rod |
| | | | | | 3 | 140, 190@10m rod |
| | | | | | 4 | 190, 90@10m rod |
| | | | | | 5 | 60, 90@10m rod |
| | **21.71725** | **149.67322** | **5** | **1** | **1** | 180, 90@10m rod |
| | Waypoint between transects 3 & 4 | | | | 2 | 170, 210@10m rod |
| | | | | | 3 | 170, 150@10m rod |
| | | | | | 4 | 30, 0@10m rod |
| | | | | | 5 | 30 |
| | **21.72188** | **149.67168** | **2** | **2** | **1** | 150, 110@10m |
| | Waypoint between transects 3 & 4 | | | | 2 | 150, 140@10m |
| | | | | | 3 | 150, 100@10m |
| | | | | | 4 | 300 |
| | | | | | 5 | 330, 300@10m |
| | **21.7218** | **149.6721** | **5** | **2** | **1** | 150 |
| | Waypoint between transects 3 & 4 | | | | 2 | 120 |
| | | | | | 3 | 120, 180@6m, 150@10m |
| | | | | | 4 | 280, 330@10m |
| | | | | | 5 | 310, 300@10m |

| Reef | Latitude S | Longitude E | Depth | Site | Tran | Compass directions |
|---|---|---|---|---|---|---|
| **Temple Island** | **21.59608** | **149.50102** | **1** | **1** | **1** | 200, 170@10m |
| | Waypoint between T1-T4 | | | | 2 | 150, 180@10m |
| | | | | | 3 | 190 |
| | | | | | 4 | 350 |
| | | | | | 5 | 330, 310@10m |
| | **21.60285** | **149.49932** | **1** | **2** | **1** | 240, 220@10m |
| | Waypoint between T1-T4 | | | | 2 | 190, 200@10m |
| | | | | | 3 | 180, 190@10m |
| | | | | | 4 | 90, 30@10m, 340@12m, |
| | | | | | 5 | 30, 50@10m |
| **Aquila Island** | **21.95682** | **149.58102** | **1** | **1** | **1** | 190, 180@10m, 140 to T2 |
| | Waypoint between T1-T4 | | | | 2 | 140 |
| | | | | | 3 | 170 |
| | | | | | 4 | 320 |
| | | | | | 5 | 330, 310@10m |
| | **21.96112** | **149.58158** | **1** | **2** | **1** | 120 |
| | Waypoint between T1-T4 | | | | 2 | 90 |
| | | | | | 3 | 110 |
| | | | | | 4 | 0 |
| | | | | | 5 | 30 |

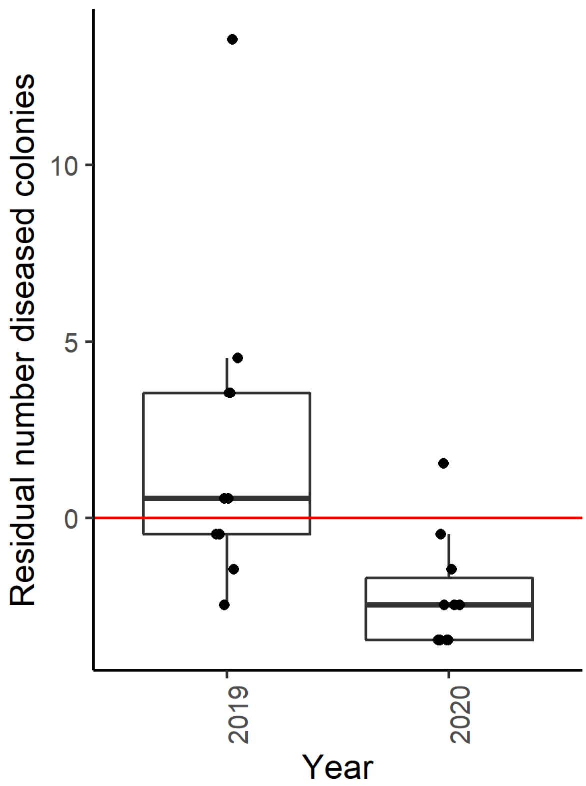


**Figure A 1.Relative coral disease by year.**

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.**

Genus with a minimum cover of 1% at any reef are included. All less abundant genera are grouped as Other HC. Total number of genus observed presented as Genus Richness

| Reef | Depth | *Acropora* | *Alveopora* | *Favia* | *Galaxea* | *Goniastrea* | *Goniopora* | *Hydnophora* | *Lobophyllia* | *Montipora* | *Pachyseris* | *Platygyra* | *Pocillopora* | *Porites* | *Turbinaria* | Other HC | Genus Richness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pine Peak Island | 2 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.31 | 0.00 | 0.00 | 0.19 | 4.06 | 0.00 | 0.56 | 11 |
| | 5 | 0.00 | 0.06 | 0.19 | 0.13 | 0.44 | 0.31 | 0.00 | 0.50 | 0.63 | 0.31 | 0.13 | 0.38 | 4.31 | 0.19 | 1.75 | 25 |
| Pine Islets | 2 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.94 | 0.00 | 0.19 | 0.13 | 0.88 | 1.38 | 0.38 | 12 |
| | 5 | 0.56 | 0.19 | 0.19 | 0.00 | 0.00 | 0.69 | 0.31 | 0.19 | 6.27 | 1.95 | 0.94 | 0.57 | 3.63 | 1.63 | 2.69 | 30 |
| Henderson Island | 2 | 49.63 | 0.19 | 0.00 | 0.00 | 0.00 | 0.06 | 0.19 | 0.19 | 0.69 | 0.00 | 0.13 | 0.25 | 0.31 | 0.06 | 0.44 | 18 |
| | 5 | 38.43 | 1.50 | 0.00 | 1.69 | 0.00 | 0.69 | 0.06 | 3.63 | 1.63 | 0.25 | 0.38 | 0.50 | 0.13 | 0.19 | 1.94 | 25 |
| Connor Island | 2 | 7.88 | 0.44 | 1.00 | 0.00 | 0.38 | 0.88 | 0.63 | 0.13 | 5.94 | 0.00 | 0.50 | 0.38 | 0.50 | 9.75 | 2.19 | 22 |
| | 5 | 3.06 | 0.94 | 1.75 | 2.44 | 1.94 | 1.19 | 1.25 | 0.00 | 8.56 | 0.00 | 1.50 | 0.00 | 0.63 | 9.19 | 2.81 | 21 |
| Temple Island | 1 | 3.56 | 0.00 | 0.19 | 0.00 | 0.88 | 0.06 | 0.44 | 0.06 | 6.31 | 0.00 | 1.88 | 1.69 | 0.69 | 3.31 | 0.75 | 21 |
| Aquila Island | 1 | 0.38 | 0.06 | 0.13 | 0.00 | 0.31 | 0.13 | 0.00 | 0.00 | 14.46 | 0.00 | 0.06 | 0.31 | 0.44 | 0.56 | 1.69 | 16 |

**Table A 3. Cover of soft coral genera.**
Genus with a cover of at least1% at any reef are included. All less abundant genera are grouped as Other SC

| Reef | Depth | *Briareum* | *Cladiella* | *Klyxum* | *Lobophyton* | *Sarcophyton* | *Sinularia* | *Xenia* | Other SC |
|---|---|---|---|---|---|---|---|---|---|
| Pine Peak Island | 2 | 6.06 | 0.25 | 0.00 | 0.31 | 0.31 | 3.00 | 0.25 | 0.13 |
| | 5 | 13.94 | 0.00 | 0.44 | 0.69 | 1.06 | 2.38 | 0.00 | 0.19 |
| Pine Islets | 2 | 0.19 | 0.00 | 0.00 | 0.63 | 0.00 | 0.50 | 0.00 | 0.00 |
| | 5 | 1.63 | 0.00 | 0.56 | 0.63 | 0.38 | 1.44 | 0.00 | 0.13 |
| Henderson Island | 2 | 1.63 | 3.38 | 0.00 | 0.19 | 0.94 | 5.19 | 0.00 | 0.00 |
| | 5 | 0.56 | 1.13 | 6.01 | 0.31 | 1.69 | 5.06 | 0.00 | 0.06 |
| Connor Island | 2 | 1.69 | 0.31 | 0.00 | 0.00 | 1.25 | 8.56 | 0.00 | 0.56 |
| | 5 | 1.00 | 0.06 | 0.13 | 0.06 | 0.50 | 7.38 | 0.00 | 0.69 |
| Temple Island | 1 | 1.75 | 0.50 | 0.00 | 0.94 | 0.19 | 10.13 | 0.00 | 0.19 |
| Aquila Island | 1 | 0.06 | 0.19 | 0.06 | 1.75 | 0.88 | 4.63 | 0.63 | 0.31 |

**Table A 4. Proportion of hard coral cover bleached in 2020.**

Values represent the number of points identified as hard coral and categorised as being bleached white (B), partially bleached (PB) or note bleached (NB). Data are aggregated by taxonomic family consistent with Veron et al. 2016. Proportion of bleaching within family, and overall proportion of hard coral bleaching are given for each reef, Combined depths

| Reef | Family | B | PB | NB | Proportion bleached (%) | Total hard coral (%) | Overall proportion bleached (%) |
|---|---|---|---|---|---|---|---|
| Pine Peak | Acroporidae | 1 | 0 | 18 | 5 | 7.41 | 37.85 |
| | Agariciidae | 1 | 4 | 0 | 100 | | |
| | Dendrophylliidae | 0 | 0 | 3 | 0 | | |
| | Faviidae | 4 | 1 | 11 | 31 | | |
| | Fungiidae | 0 | 0 | 2 | 0 | | |
| | Merulinidae | 1 | 0 | 15 | 6 | | |
| | Mussidae | 3 | 0 | 7 | 30 | | |
| | Oculinidae | 0 | 0 | 2 | 0 | | |
| | Pectiniidae | 2 | 1 | 4 | 43 | | |
| | Pocilloporidae | 0 | 0 | 9 | 0 | | |
| | Poritidae | 49 | 22 | 70 | 50 | | |
| | Siderastreidae | 0 | 1 | 5 | 17 | | |
| Pine Islets | Acroporidae | 23 | 2 | 106 | 19 | 12.08 | 34.33 |
| | Agariciidae | 16 | 13 | 2 | 94 | | |
| | Dendrophylliidae | 4 | 14 | 30 | 38 | | |
| | Euphyllidae | 0 | 0 | 7 | 0 | | |
| | Faviidae | 14 | 2 | 19 | 46 | | |
| | Fungiidae | 0 | 0 | 3 | 0 | | |
| | Merulinidae | 0 | 5 | 6 | 45 | | |
| | Mussidae | 0 | 0 | 3 | 0 | | |
| | Pectiniidae | 0 | 0 | 12 | 0 | | |
| | Pocilloporidae | 0 | 2 | 9 | 18 | | |
| | Poritidae | 39 | 10 | 40 | 55 | | |
| | Siderastreidae | 0 | 0 | 3 | 0 | | |
| Henderson | Acroporidae | 775 | 212 | 460 | 68 | 51.58 | 66.73 |
| | Agariciidae | 0 | 0 | 4 | 0 | | |
| | Dendrophylliidae | 2 | 1 | 1 | 75 | | |
| | Faviidae | 13 | 0 | 4 | 76 | | |
| | Fungiidae | 0 | 0 | 16 | 0 | | |
| | Merulinidae | 3 | 1 | 3 | 57 | | |
| | Mussidae | 10 | 33 | 18 | 70 | | |
| | Oculinidae | 27 | 0 | 0 | 100 | | |
| | Pectiniidae | 4 | 3 | 1 | 88 | | |
| | Pocilloporidae | 8 | 4 | 0 | 100 | | |
| | Poritidae | 6 | 0 | 40 | 13 | | |
| Connor | Acroporidae | 145 | 58 | 204 | 50 | 33.09 | 55.5 |

| Reef | Family | B | PB | NB | Proportion bleached (%) | Total hard coral (%) | Overall proportion bleached (%) |
|---|---|---|---|---|---|---|---|
| | Dendrophylliidae | 143 | 64 | 96 | 68 | | |
| | Faviidae | 55 | 29 | 65 | 56 | | |
| | Merulinidae | 1 | 3 | 26 | 13 | | |
| | Mussidae | 0 | 0 | 2 | 0 | | |
| | Oculinidae | 35 | 3 | 1 | 97 | | |
| | Pectiniidae | 4 | 9 | 4 | 76 | | |
| | Pocilloporidae | 13 | 5 | 0 | 100 | | |
| | Poritidae | 17 | 10 | 46 | 37 | | |
| | Siderastreidae | 2 | 1 | 12 | 20 | | |
| Temple | Acroporidae | 59 | 2 | 97 | 39 | 20.07 | 39.12 |
| | Dendrophylliidae | 10 | 4 | 39 | 26 | | |
| | Faviidae | 6 | 7 | 44 | 23 | | |
| | Merulinidae | 0 | 0 | 7 | 0 | | |
| | Mussidae | 0 | 0 | 1 | 0 | | |
| | Pocilloporidae | 5 | 22 | 0 | 100 | | |
| | Poritidae | 5 | 4 | 3 | 75 | | |
| | Siderastreidae | 0 | 0 | 2 | 0 | | |
| Aquila | Acroporidae | 17 | 9 | 212 | 11 | 18.53 | 10.47 |
| | Dendrophylliidae | 0 | 0 | 9 | 0 | | |
| | Faviidae | 0 | 0 | 9 | 0 | | |
| | Pectiniidae | 0 | 0 | 3 | 0 | | |
| | Pocilloporidae | 1 | 3 | 1 | 80 | | |
| | Poritidae | 1 | 0 | 9 | 10 | | |
| | Siderastreidae | 0 | 0 | 22 | 0 | | |

**Table A 5. Overall bleaching at each reef and depth in 2020.**

Numbers are accumulated data points from photo transects of live hard coral in three bleached states; totally bleached (B), partially bleached (PB), not bleached (NB). Overall proportion of live hard coral exhibiting bleaching is given.

| REEF | DEPTH | B | PB | NB | % bleached |
|---|---|---|---|---|---|
| Pine Peak Island | 2 | 24 | 8 | 55 | 36.78 |
| Pine Peak Island | 5 | 37 | 21 | 91 | 38.93 |
| Pine Islets | 2 | 3 | 17 | 48 | 29.41 |
| Pine Islets | 5 | 93 | 31 | 192 | 39.24 |
| Henderson Island | 2 | 518 | 112 | 204 | 75.54 |
| Henderson Island | 5 | 330 | 142 | 343 | 57.91 |
| Connor Island | 2 | 134 | 55 | 300 | 38.65 |
| Connor Island | 5 | 281 | 127 | 156 | 72.34 |
| Temple Island | 1 | 85 | 39 | 193 | 39.12 |
| Aquila Island | 1 | 19 | 12 | 265 | 10.47 |

**Table A 6. Cover of algae.**

Identified macroalgae genera with a cover of at least 1% at any reef are separated. All less abundant or un-resolved genera and smaller algae are grouped.

| Reef | Depth | Brown macroalgae | | | | | Red macroalgae | | | Green macroalgae | Turf algae | Blue-green algae | Coralline algae |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Dictyota* | *Lobophora* | *Sargassum* | *Stypopodium* | Other | *Peyssonnelia* | Calcareous red macroalgae | Other | | | | |
| Pine Peak Island | 2 | 1.06 | 16.07 | 41.23 | 6.38 | 1.5 | 0.19 | 0.25 | 1.5 | 0.13 | 8.44 | 0.06 | 3.94 |
| | 5 | 0.38 | 24.06 | 14.44 | 2.06 | 2.13 | 0.06 | 0.13 | 0.81 | 0.19 | 15.56 | 0 | 5.13 |
| Pine Islets | 2 | 0.13 | 1.63 | 75.81 | 0 | 0.19 | 0.06 | 0.06 | 0.88 | 0 | 9.06 | 0 | 3.06 |
| | 5 | 0 | 6.95 | 30.4 | 0.38 | 1.44 | 0.63 | 0 | 1.57 | 0.06 | 17.73 | 0 | 3.52 |
| Henderson Island | 2 | 0 | 2.13 | 3 | 0 | 0.44 | 0 | 0 | 0 | 0 | 27.69 | 0 | 0 |
| | 5 | 0 | 3.51 | 0.38 | 0 | 1.69 | 0 | 0 | 0.06 | 0 | 15.33 | 0 | 0.13 |
| Connor Island | 2 | 0 | 3.44 | 5 | 0 | 3.38 | 1 | 3.44 | 6.38 | 0.06 | 19.63 | 0 | 4.06 |
| | 5 | 0 | 2.06 | 1.06 | 0 | 2.25 | 1 | 2.5 | 3.13 | 0 | 20.44 | 0 | 4.5 |
| Temple Island | 1 | 0 | 1.25 | 30.78 | 0 | 0.31 | 0.75 | 0.44 | 2.5 | 0.12 | 18.95 | 0 | 3.5 |
| Aquila Island | 1 | 0 | 2.94 | 22.65 | 0 | 0.13 | 0 | 2 | 7.83 | 0.32 | 11.83 | 0 | 1.13 |

**Table A 7. Abundance of juvenile hard corals by genus.**

Mean abundance per site for genera with at least 2 corals per site at any reef separated. All less abundant genus grouped as Other.

| Reef | Depth | *Acropora* | *Alveopora* | *Coscinaraea* | *Cyphastrea* | *Euphyllia* | *Favia* | *Favites* | *Goniastrea* | *Goniopora* | *Lobophyllia* | *Montipora* | *Moseleya* | *Platygyra* | *Pocillopora* | *Porites* | *Psammocora* | *Turbinaria* | Other genera | Genus Richness | Number | Density |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pine Peak Island | 2 | 1 | 2.5 | 1.5 | 0 | 0.5 | 0 | 0 | 0 | 1.5 | 0.5 | 0.5 | 0 | 1 | 3.5 | 6.5 | 0 | 1 | 1 | 13 | 21 | 0.77 |
| | 5 | 1 | 3 | 1 | 1 | 0 | 0.5 | 0 | 0.5 | 0 | 0.5 | 1 | 0 | 0 | 1.5 | 3.5 | 0 | 0.5 | 1 | 14 | 15.5 | 0.68 |
| Pine Islets | 2 | 4 | 7 | 0 | 0 | 1 | 3 | 2 | 0 | 0.5 | 2 | 4.5 | 1 | 1.5 | 2 | 5 | 0.5 | 3 | 5 | 22 | 43 | 1.38 |
| | 5 | 4 | 2.5 | 2 | 0.5 | 2.5 | 1.5 | 2 | 2 | 5 | 8.5 | 8 | 1.5 | 3.5 | 2 | 5 | 0.5 | 6.5 | 10 | 31 | 70 | 3.30 |
| Henderson Island | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | 9 | 0 | 2.5 | 0.5 | 0 | 0 | 2.5 | 0 | 0.5 | 0 | 2.5 | 10 | 22.5 | 1.97 |
| | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 1.5 | 1 | 0.5 | 0 | 0.5 | 0.5 | 0 | 0 | 2.5 | 12 | 8.5 | 1.20 |
| Connor Island | 2 | 2.5 | 0.5 | 1 | 1 | 0 | 1.5 | 1 | 0.5 | 0.5 | 0 | 3.5 | 0 | 1.5 | 11 | 3 | 0 | 7 | 0.5 | 14 | 35 | 2.15 |
| | 5 | 1.5 | 26 | 0.5 | 0 | 0 | 1 | 2 | 1.5 | 0 | 0 | 1.5 | 2 | 0.5 | 2 | 5.5 | 0 | 8.5 | 1 | 14 | 53.5 | 4.00 |
| Temple Island | 1 | 2.5 | 0 | 0 | 6.5 | 0 | 2.5 | 1.5 | 0.5 | 1 | 0 | 3 | 1.5 | 1.5 | 1.5 | 6.5 | 0.5 | 12 | 1 | 15 | 42 | 2.09 |
| Aquila Island | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 1.5 | 0 | 1.5 | 0 | 7 | 0 | 0 | 2 | 0 | 3 | 4 | 1.5 | 9 | 23.5 | 1.35 |

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**Table A 8. Coral health survey results.**

Number of colonies along the ten 20 m long and 2 m wide transects searched at each reef and depth combination having recently lost tissue (patches of bare white skeleton) attributed to a range of causes. Anchor or physical damage and bleached corals are recorded as a proportion of coral cover at the site effected.

| **Cause** | **Genus** | **Pine Peak** | | **Pine Islets** | | **Henderson** | | **Connor** | | **Temple** | **Aquila** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **2m** | **5m** | **2m** | **5m** | **2m** | **5m** | **2m** | **5m** | **1m** | **1m** |
| Disease | *Acropora* | | | | | 1 | | | | | 1 |
| | *Coscinaraea* | | | | | | | 1 | | | |
| | *Montipora* | | | | | | | | | | 1 |
| | *Pocillopora* | 2 | 1 | | | | | | | | 1 |
| Unknown cause | *Acropora* | | 1 | | | | 1 | | | | |
| | *Mycedium* | | | | | | | | | | 1 |
| | *Pocillopora* | | 3 | | | | | | | | |
| Sponge - *Cliona orientalis* | *Cyphastrea* | | | | | | | | 1 | | 1 |
| | *Favites* | | | | | | | 2 | | | |
| | *Goniopora* | | | | | | | 1 | | | |
| | *Montipora* | | | | | | | 1 | 1 | | |
| | *Platygyra* | | | | | | 1 | | | 1 | |
| | *Porites* | | | | | | | | | | 1 |
| | *Turbinaria* | | | | | | | 3 | | 2 | |
| **Total number of Colonies** | | **2** | **5** | | | **1** | **2** | **5** | **2** | **3** | **6** |
| | | | | | | | | | | | |
| Anchoring (proportion of colonies) | - | | | | | | | | | | |

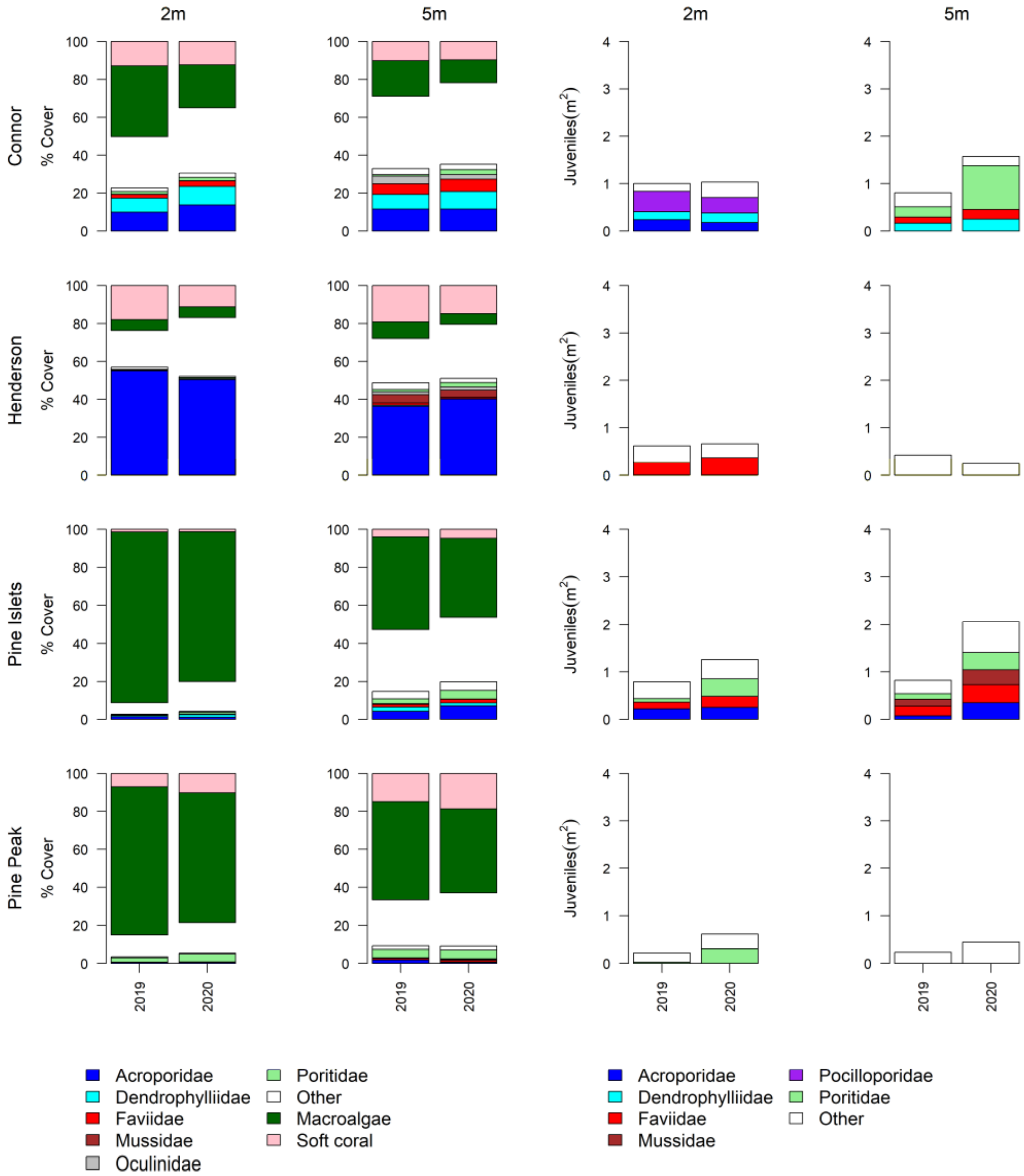


**Figure A 2. Composition of benthic cover and hard coral juveniles.**

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 by family at 2 m and 5 m depths.

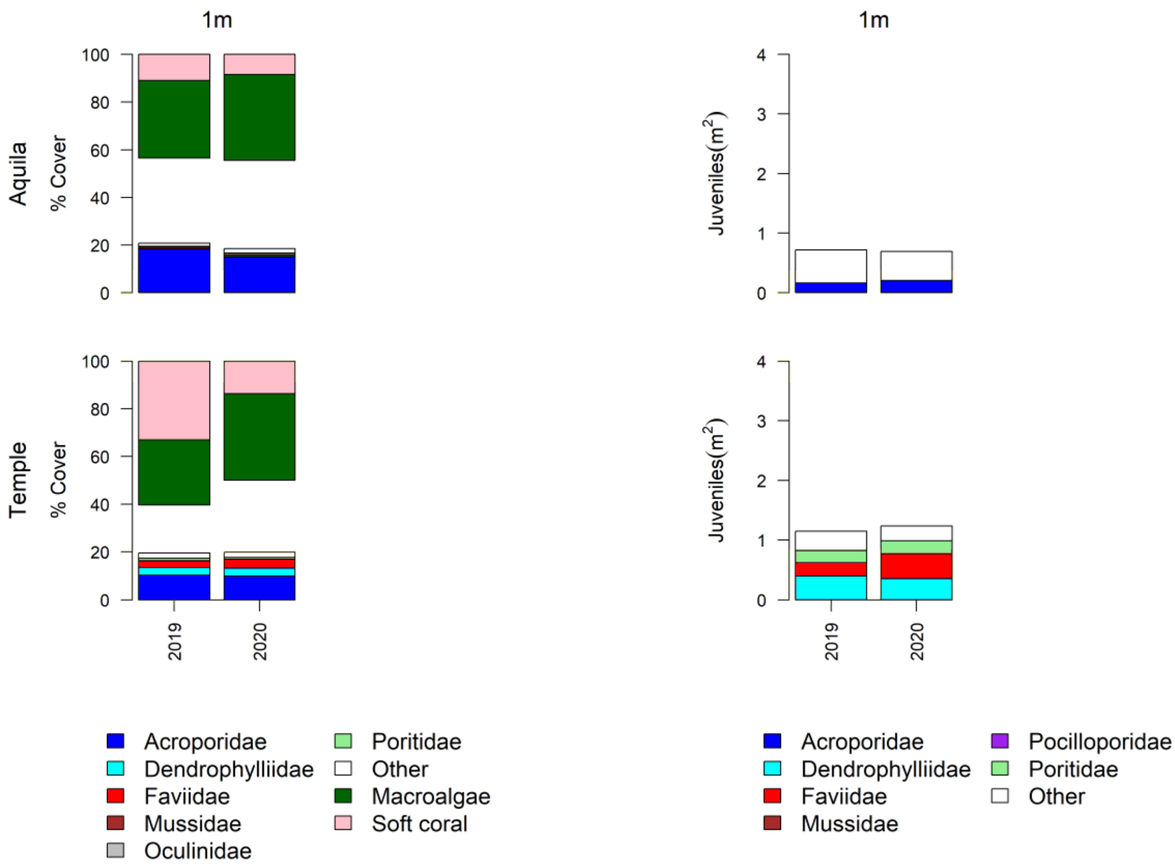


**Figure A 2 continued, for the 1 m deep sites at Aquila and Temple Islands.**

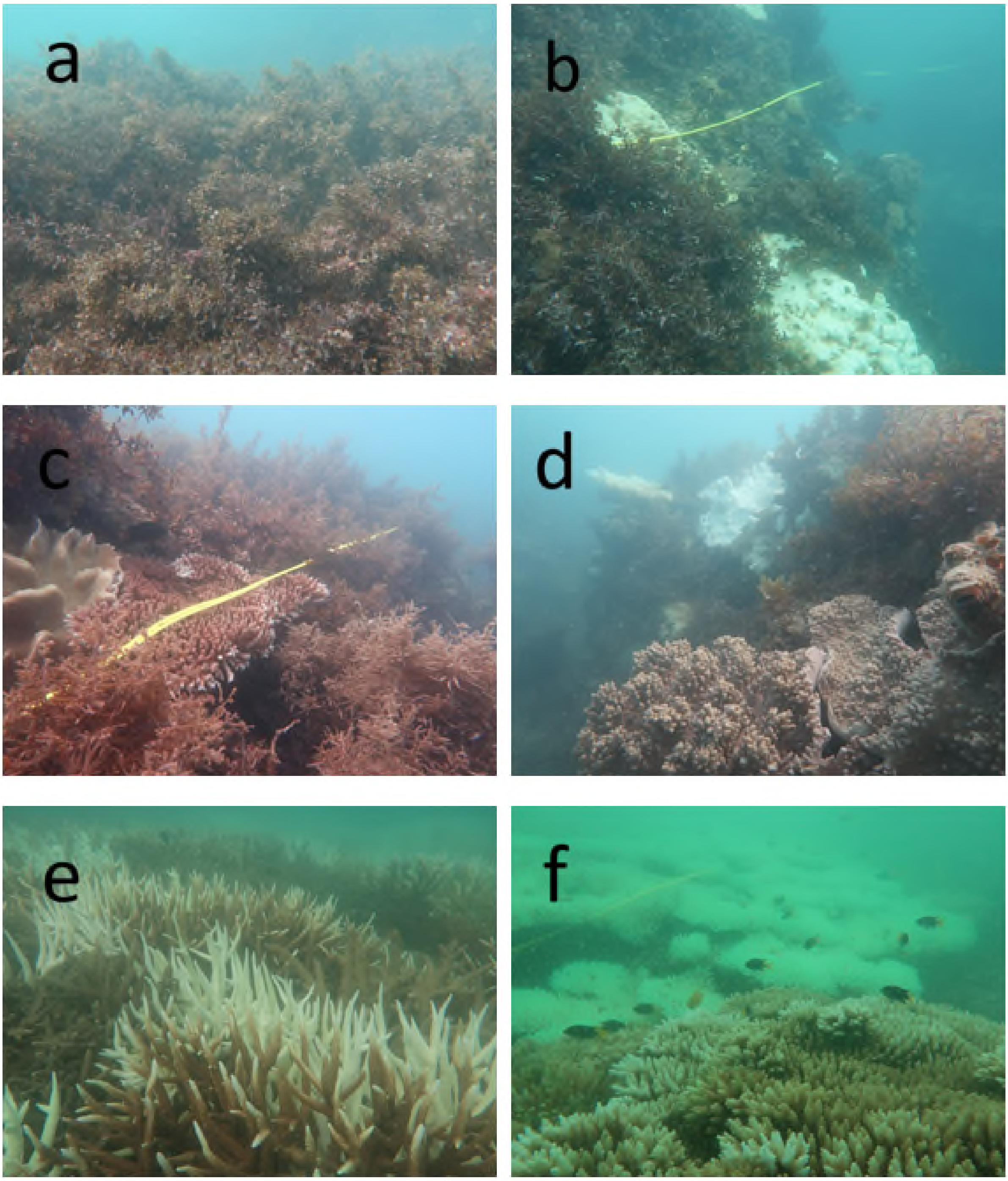


**Figure A 3. Benthic community photos at outer reefs a) Pine Peak Island 2m b) Pine Peak Island 5m c) Pine Islets 2m d) Pine Islets 5m e) Henderson Island 2m f) Henderson Island 5m.**
Macroalgae dominate Pine Peak Island and Pine Islets at 2m and 5m, where scattered *Acropora*, *Montipora,* and *Porites* colonies show varied response to bleaching. By contrast, abundant fields of *Acropora* corals at Henderson Island still show heavy bleaching patterns at both 2m and 5m, three months following the marine heatwave.

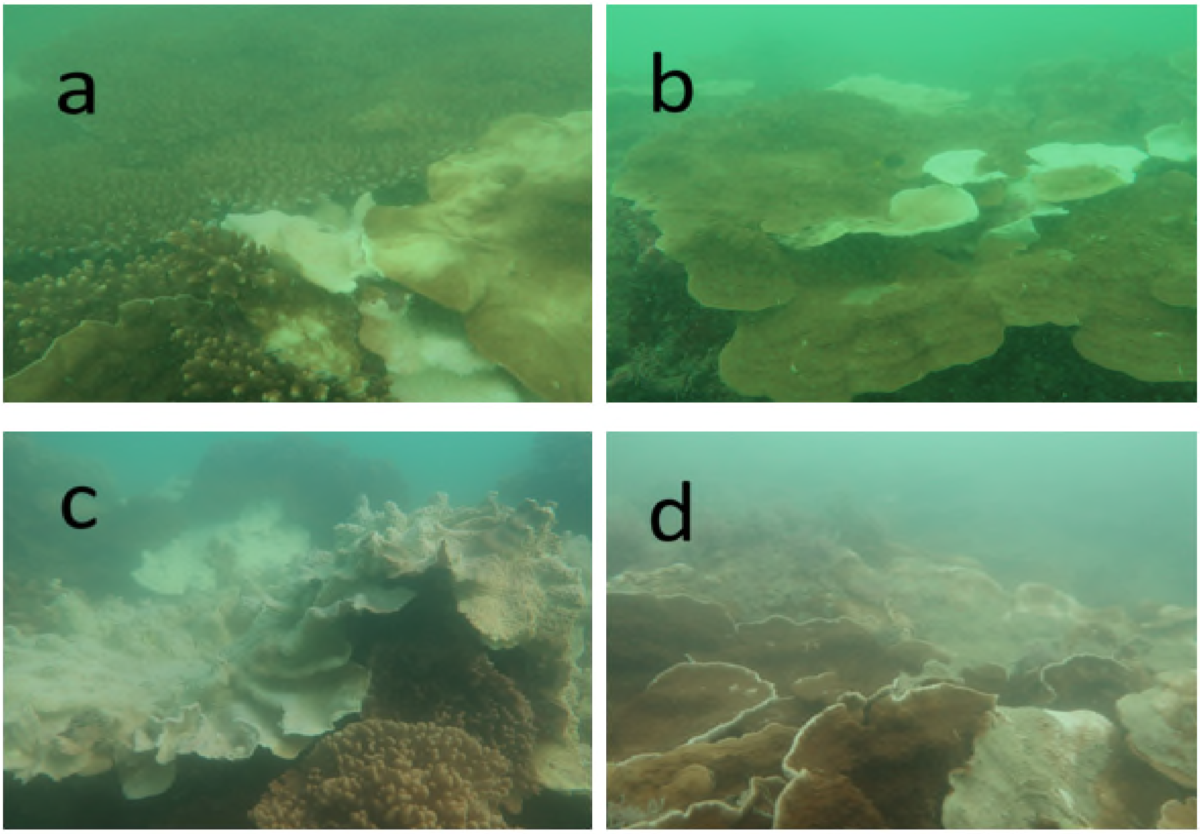


**Figure A 4. Benthic community photos at inner reefs a) Connor Island 2m b) Connor Island 5m c) Temple Island 1m d) Aquila Island 1m.**

Mixed hard corals at Connor Island 2m and 5m show a mixed bleaching response. At Temple Island 1m different bleaching patterns exhibited by large foliose colonies of *Turbinaria* and the soft coral *Sarcophyton*. At Aquila Island 1m, overlapping colonies of foliose *Montipora* have varying bleaching response.