Port of Abbot Point Ambient Coral Monitoring 2021-2022

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Port of Abbot Point Ambient Coral Monitoring Surveys: 2021-2022

A Report for North Queensland Bulk Ports

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Cover Photo: Coral community at Southeast Holbourne Island monitoring site in November 2021 (TropWATER).

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KEY FINDINGS

1. Coral monitoring at Camp Island and Holbourne Island was completed in November 2021 and May/June 2022, part of a bi-annual ambient monitoring program. The 2021/22 results are compared with data collected since May 2016, the program's inception, for the Port of Abbot Point to measure benthic cover, coral health, sedimentation and coral recruitment.

2. Reefs surveyed in the Abbot Point region were in a stable or recovering state following the mass bleaching event and subsequent mortality that took place in 2020. Hard coral cover increased significantly from October 2020 to May 2022 at Camp Island while Holbourne Island coral communities had little change in coral cover since this time when the current site design was also put in place.

3. Hard coral cover at Holbourne Island is on average double that of Camp Island with 24% compared to only 12% at the latter; a reversal of patterns between the two locations prior to the 2020 mass bleaching. The pattern reversal is in large part due to monitoring design changes implemented in 2020 at the Holbourne Island location.

4. Warm water temperatures recorded at local water quality loggers as well as NOAA virtual stations suggested the potential for mass bleaching from warm waters during the 2021/22 summer peak. However, no significant bleaching was observed in the subsequent May 2022 surveys. The warm temperatures reached the same high levels as in 2020 but the period over which time this potential stress persisted was shorter which may explain the lack of impact on these reef communities.

5. The persistent macroalgae community at Camp Island was lower in 2021/22 than the 2020/21 period when, during pre-wet surveys, the highest levels were recorded since monitoring began in 2016. If the return to pre-bleaching macroalgae levels persists, it may allow additional open substrate for corals to expand and recruit onto open substrate, contributing to natural recovery over time.

6. While mass bleaching was the biggest acute impact affecting Camp Island since monitoring began, Cyclone Debbie severely impacted Holbourne Island coral cover more so than bleaching.

7. Original monitoring sites on the western side of the Holbourne Island still have relatively low coral cover from the 2017 major cyclonic event. Very slow increases in coral may be due to in part slow growth rates of surviving coral populations as well as the low documented coral recruitment into these fringing reef communities somewhat isolated from other reefs that could contribute coral larvae. The slow hard coral recovery on these fringing reefs since Cyclone Debbie is a cause for concern.

8. The newly established eastern sites at Holbourne Island provide a more representative spread of coral cover and community assemblage. These sites were not as affected by Cyclone Debbie and appear to be stable in coral cover since monitoring began at these sites in October 2020.

9. Crown-of-thorns starfish continued to be found at the new eastern Holbourne Island sites which will be monitored carefully in case of a larger outbreak affecting these reefs.

10. Coral community composition remains dominated by *Acropora* and *Montipora* corals on the Holbourne and Camp Island sites despite losses from the 2020 bleaching event.

11. Coral recruit densities were very low at Camp Island and Holbourne Island again in 2021/22 compared to broader recruitment densities recorded at other inshore reefs by the AIMS long term monitoring

program. Relative for these locations, however, recruitment densities were on par of the normal range at both locations with no significant changes at any sites or over the last four surveys.

12. Sediment on corals and sediment damage were elevated at both locations in May 2022, albeit the depth of sediment present was relatively low. River discharge from the Don and Elliot systems just prior to surveys may have temporarily increased sediment on coral surfaces which could explain temporary high sediment that did not translate to sediment damage or colony mortality.

13. Data from these surveys was used to determine a coral condition index score under the Mackay Whitsunday Regional Report Card. The regional score was rated 'poor' during the May 2022 survey—unchanged from the 2021 post-wet season score—due to low recruitment at both locations and also driven by relatively high macroalgae at Camp Island which heavily influences overall index scores.

IN BRIEF

Coral monitoring sites were set up at three locations in the vicinity of the Port of Abbot Point in mid-2016 as part of North Queensland Bulk Ports ambient reef monitoring program. These locations were shallow depth stratum on Holbourne Island (~2m below LAT), deep stratum on Holbourne Island (~5m below LAT) and Camp Island (~2m below LAT). Four sites of five permanently marked 20 m survey transects were set up at each location along the required depth contour. The purpose of these surveys is to gain a greater understanding of ambient conditions, and the drivers of these conditions, which also provides a greater capacity to manage potential influences during periods of port related activities such as dredging. The Australian Institute of Marine Science initially established these monitoring sites using their fringing reef survey protocols and carried out three further surveys during 2016/2017. TropWATER, in association with Sea Research, continued this program using the same sites and transects from 2018-2022.

A 2020 review of the program has led to the reduction in the program to two locations, deep Holbourne and Camp Island in order to align with other inshore coral monitoring in the Mackay region. In addition, two sites at Holbourne Island were re-positioned in October 2020 to better represent the coral communities at this location equating to four sites at both Camp Island Holbourne Island locations. Each site continues to have five, 20m long transects. All datasets reviewed in the current report have been back calculated to account for trends at the current four sites to ensure current and future trends in the program are comparable with the historical record.

Holbourne Island is a mid-shelf fringing reef about 30 km offshore from Bowen and 30 km from the Port of Abbot Point. Camp Island is a shallow inshore reef 20 km west of the Port that is only 2.5 km offshore from the mouth of the Elliot River.

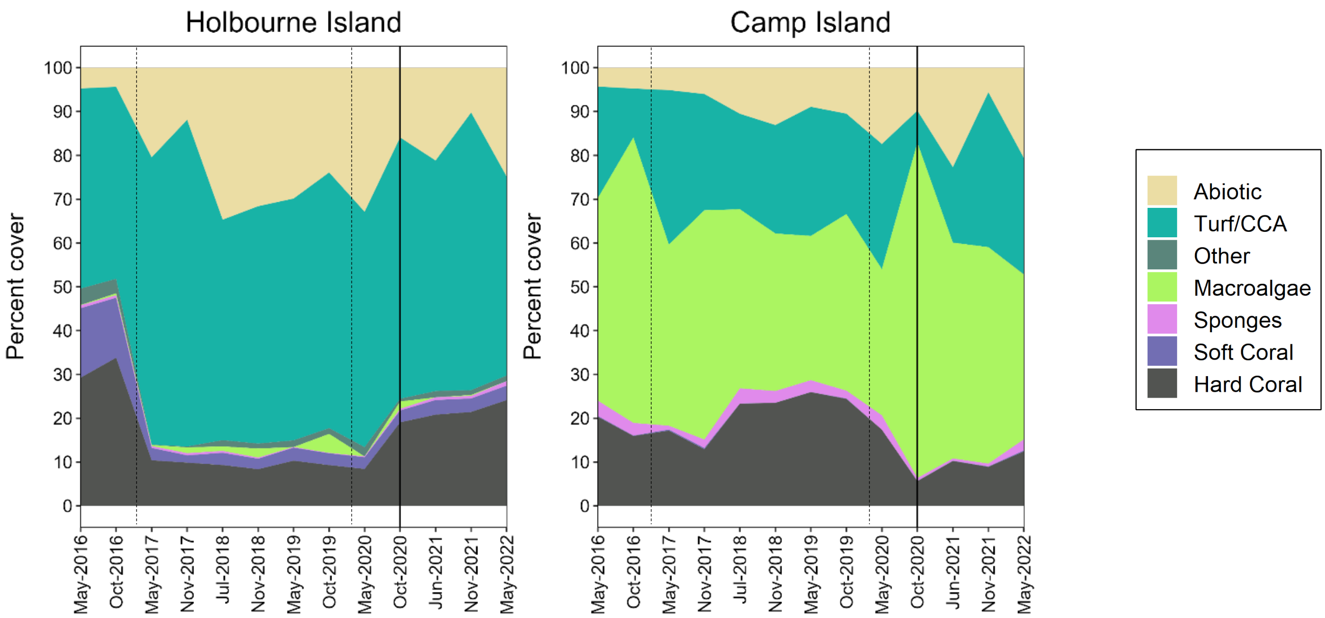

Figure i. Summary of changes in the major benthic categories at the two Abbot Point locations.

Graphs show cumulative percent cover from all ambient surveys. Solid vertical line indicates the change in program design; dashed lines indicate Cyclone Debbie (2017) and the 2020 mass bleaching event. 'Other' is comprised of fire coral and zoanthids.

Camp Island has patchy cover of a dense *Sargassum* forest, especially at the East 1 and West 2 sites (Fig. 3). Macroalgal cover fluctuated on Camp Island over the two ambient surveys from a peak in the pre-wet survey of 49%, down to 38% in the post-wet May 2022 survey. The seasonal fluctuation appears to be normal for this location, and the peak in November was at expected levels recorded prior to the 2020 bleaching event which was associated with a spike in macroalgae in October 2020. In contrast to Camp Island, Holbourne Island is a more mid-shelf location and reefs around this island continue to not support stands of *Sargassum* macroalgae. Benthic communities are unlikely to be impacted by the low levels of macroalgal cover recorded on Holbourne Island but may be damaged by the lush algal communities on Camp Island which also restrict available substrate for coral recruitment, light availability and colony growth.

Acute disturbances have occurred at both Abbot Point coral monitoring locations however by distinct events. Holbourne Island sites were severely impacted by Cyclone Debbie in late March 2017. Extensive physical damage from the wave action generated by this severe category 4 cyclone devastated coral communities on the SW face of Holbourne Island where all the survey sites were located. In the deep Holbourne sites, mean coral cover was less than 8% following the cyclone, down from 29%. Camp Island reef communities, although only 50 km west of Holbourne, were minimally damaged by Cyclone Debbie and mean coral cover actually increased slightly following the cyclone. The proximity of Camp Island to the coastline and the unusually shallow depths around the island (<5m), may have minimised impacts compared to Holbourne where wider fetch and deeper water (25 m at the base of the reef slope) led to the development of 10+ m wave height during this cyclone. The two new sites established in 2020 on the east face of Holbourne Island and two continuing sites on the western face are a better representation of the coral coverage, assemblage and trajectory of these communities which is considered one of the primary goals of the ambient monitoring program.

Camp Island sites were significantly affected by the 2020 mass bleaching event which drove a 54% loss on hard coral cover across sites by October 2020. The major loss was in the Acropora and Montipora coral population. In 2021/22, hard corals at this location significantly increased from the October 2020 low, albeit by a small amount, indicating recovery is possible if given enough time without another acute event to disturb these sites. At Holbourne, 30% of corals bleached at the two continuing sites on the western face but with no major loss at these sites by October as occurred at Camp Island.

Warm water temperatures during the 2021/22 summer period had the potential to lead to a subsequent mass bleaching event with local water quality loggers and NOAA virtual monitoring stations recording sea surface temperatures at the same extremes recorded in early 2020. However, the period of time that warm water persisted was shorter and broken by a period of slightly lower temperatures in part related to local rainfall events which may in part explain the lack of significant bleaching observed in May 2022. In addition corals which survived the 2020 mass bleaching event may be somewhat more tolerant colonies which inherently withstand or have acclimated to withstand the warming conditions that are more frequently occurring on these reefs.

Over time, the sediment found on colonies and sediment depth appears to be increasing in frequency at Camp Island and at Holbourne Island with the highest levels recorded during the last survey period. Timing of surveys may contribute to patterns recorded during surveys. For instance, just prior to the May 2022 surveys, the Abbot Point region received substantial rainfall and subsequent river discharge from the Don and Elliot River systems. Storm activity can also temporarily increase sediment on coral surfaces that may not translate to sediment damage or colony mortality. Despite the increased depth and frequency of corals observed with sediment, sediment damage was absent from Holbourne Island sites and extremely low at Camp Island.

Disease sometimes affects hard coral colonies and may cause partial or occasionally total mortality. Levels of coral disease during these ambient surveys was extremely low. Historically at Camp Island, *Acropora* and *Montipora* colonies were most frequently the groups with disease present in previous surveys. The significant dieback of these populations in 2020 may contribute to the lower disease prevalence since this event. In general, the impact of disease on hard corals is at least an order of magnitude less than physical cyclone damage.

Crown-of-thorns starfish (CoTS) and associated scars were again found at Holbourne Island East site in May 2022. Levels are not significant enough to affect coral cover but sites will be monitored for larger outbreaks or signs of escalating concerns. No CoTS have been observed at Camp Island sites since the monitoring program began.

Coral recruitment remains low at Camp Island and Holbourne Island in 2021/22 with mean recruit density of 1.3 m^{-2}. The AIMS long term monitoring program of inshore reefs shows significantly higher recruitment at reefs receiving a regular influx of recruits compared to these more isolated reef communities which are somewhat far from other reefs to resupply larvae and assist recovery potential (Thompson et al. 2023). As is often the case on near-shore reefs, *Turbinaria* corals were common in the coral recruit population at Camp Island, accounting for 17% of all recruits recorded but somewhat lower than previous which accounted for roughly 22% of the recruit community the previous year. In contrast *Turbinaria* corals only made up about 1% of the overall coral community. Acroporid corals make up the highest proportion of recruits at both locations with 33% and 27% of recruits at Holbourne and Camp respectively in the 2021/22 period. On Holbourne Island, favids made up 22% of recruits in addition to a range of different coral groups present in the recruit population. In comparison, Mackay reef monitoring recorded considerably higher recruitment over the same period, however, mainly *Turbinaria* and not Acroporid recruits.

The slow rates of coral community recovery at the original Holbourne Island sites following Cyclone Debbie, both from coral growth and recruitment, is cause for concern. The small but significant recovery in coral cover at Camp Island following the large mortality form bleaching in 2020 is promising. To gain further recovery in these communities, lower macroalgae, greater recruitment, and low sediment impacts will be important with no further acute disturbances such as bleaching or major storm events to knock back the gains recorded in 2022. Long-term shifts in GBR-wide inshore coral communities suggest full recovery is questionable with increased risks of cyclones and warm water events driving more frequent bleaching due in large part to climate change.

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ACRONYMS AND ABBREVIATIONS

TropWATER	Centre for Tropical Water & Aquatic Ecosystem Research
NQBP	North Queensland Bulk Ports Corporation

1 INTRODUCTION

1.1 Project Background

The Port of Abbot Point is located 25 km north of Bowen and is an offshore coal loading terminal with a current export capacity of 50 million tonnes per annum and a 2018/19 throughput of 29 million tonnes. North Queensland Bulk Ports Corporation Limited (NQBP) is the port authority and port manager for this port under the*Transport Infrastructure Act 1994* (TI Act). The functions of NQBP as a port authority include establishing effective and efficient port facilities and services in its ports and making land available for the establishment, management and operation of port facilities in its ports by other persons.

NQBP began development of ambient coral monitoring programs for two other ports that they manage, the Ports of Mackay and Hay Point, during 2015. These programs were designed to gain a greater understanding of ambient reef conditions and the drivers of these conditions which would also allow for a greater capacity to manage potential influences during periods of Port related activities. Beginning in 2016 NQBP initiated ambient monitoring at key reef locations surrounding the Port of Abbot Point (Figure 1): Holbourne Island (Figure 2) and Camp Island (Figure 3). The Australian Institute of Marine Science (AIMS) carried out the first survey event at these locations late in 2016 and made two more surveys during 2017: a post wet survey in mid-year and a pre-wet survey late in the year. TropWATER and Sea Research have continued the Abbot Point surveys since mid-2018. The last two surveys of these locations were: November 2021 and May/June 2022.

1.2 Objectives of Survey

Survey design is structured to relate to seasons, with the first survey being in the Spring, pre-wet season period and the second in the late Autumn post-wet season period. This ensured that surveys were made before and immediately after the period of maximum likely natural impacts, whether floods, cyclones or bleaching, enabling the causes of any benthic changes to be established reliably. The exact timing of these surveys is not critical; surveys just need to be regular enough to enable the causes of any changes to be established reliably.

AIMS established eight sites on Holbourne Island and four sites on Camp Island for the Abbot Point ambient monitoring program. In keeping with their fringing reef survey protocols they set up sites in two depth strata: 2m and 5m below LAT on Holbourne Island. Coral reefs on Camp Island do not extend below 2m depth and only a single stratum was surveyed there. Sea Research and TropWATER continued the Abbot Point surveys using the same 12 sites established by AIMS.

Surveys considered:

- Diversity and abundance of benthic communities;
- Percentage coral bleaching;
- Percentage coral mortality;
- Rates of sediment deposition on corals; and,
- Rates of coral recruitment.

This report documents the findings of the latest surveys from the two Abbot Point locations made between November 2021 and May/June 2022. As of October 2020, sites within Holbourne Island were adjusted to reflect a review of the monitoring program to better represent coral and the benthic habitat communities. A modification of methods from line-intercept to photoquadrat analysis of benthic cover was also initiated from October 2020 in order to align with broader inshore coral monitoring programs through AIMS.

Figure 1. Location of the Port of Abbot Point showing the position of the Port and the Holbourne Island and Camp Island ambient coral monitoring locations.

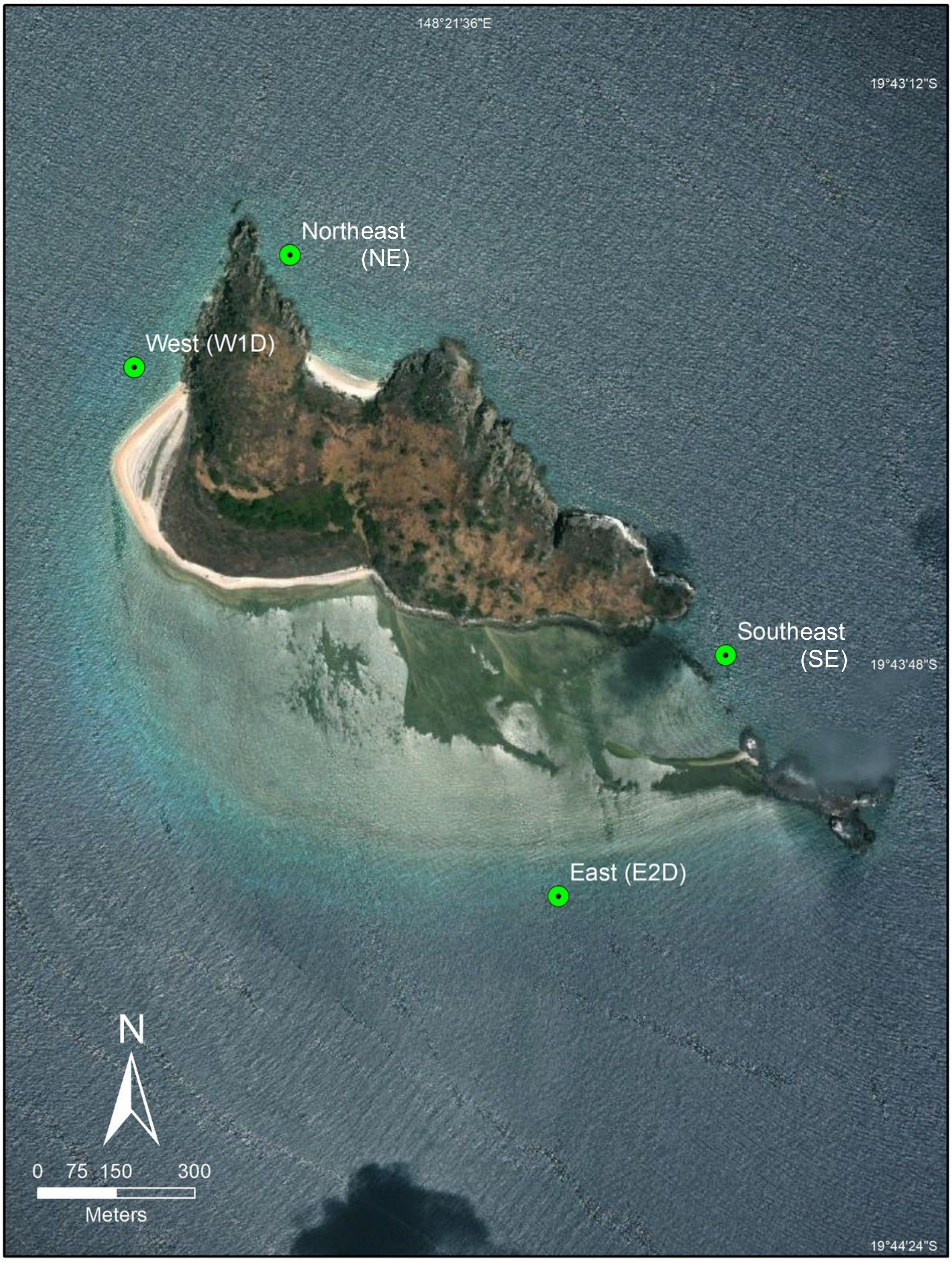


Figure 2. Holbourne Island showing the position of the coral monitoring sites. Note: 'Northeast' and 'Southeast' are the newly commissioned sites.

Figure 3. Camp Island showing the position of the four coral monitoring sites.

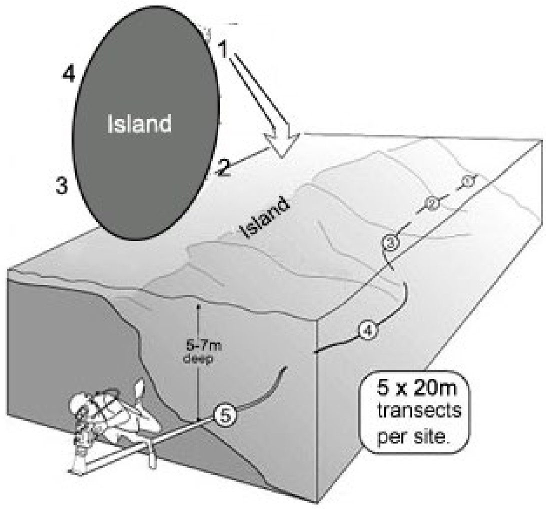
2 METHODS

2.1 Abbot Point Locations

Fringing reefs were surveyed around two island locations in the Abbot Point region (Figure 1, Table 1). Holbourne Island is a small mid shelf island surrounded by a fringing reef that is 32 km NNE of the Port of Abbot Point (Figure 2). Camp Island is a small near-shore island 19 km west of the port and only 2.5 km off the Elliot River mouth near the eastern side of Cape Upstart (Figure 3).

Four monitoring sites of five, 20m long permanently marked transects were established in two depth strata on Holbourne Island and a single depth stratum on Camp Island in 2016 by AIMS.

The sites at Holbourne Island were adjusted in October 2020 following a coral monitoring program review by NQBP and advice by Sea Research and JCU (Table 2). The Holbourne Island shallow locations were dropped from the program due to the lack of coral cover (<2%) making them poor representatives of the slightly deeper local coral communities. These sites were established based on the importance of aspect and depth on key coral community health indicators; noting though that Camp did not have 2 depth strata given the reef slope transitioned to sand beyond 2m depth (and supported seagrass). Two new sites were established in October 2020 at Holbourne Island in a similar depth stratum to the continued deep sites but in areas under represented on the northeast face of the island (Table 1, Figure 2).



Schematic diagram of the sampling design of a single location with four sites per island with five, 20m long transects at a single depth contour (*adapted from AIMS LTMP*).

Table 1. GPS coordinates of each monitoring site.

Location	Ambient monitoring site ID	Latitude	Longitude
Holbourne Island	Northeast (NE)*	-19.723	148.3572
Holbourne Island	East 2 (E2D)	-19.734	148.3618
Holbourne Island	West 1 (W1D)	-19.7249	148.3545
Holbourne Island	Southeast (SE)*	-19.7299	148.3647
Camp Island	East 1	-19.8508	147.9052
Camp Island	East 2	-19.8541	147.9012
Camp Island	West 1	-19.8533	147.8942
Camp Island	West 2	-19.8512	147.8950

* Shallow sites were dropped from the program in October 2020 and two new sites replaced the deep sites at the same depth contour but in reef areas not currently represented in the program on the northeast face of the island.

Table 2. Summary of all coral surveys made at the two Abbot Point survey locations.

Survey date:	Camp Island	Holbourne Island
May 2016†	X	X
Oct 2016†	X	X
May 2017	X	X
Oct 2017	X	X
Jul 2018	X	X
Nov 2018	X	X
May 2019	X	X
Oct 2019	X	X
May 2020	X	X
October 2020*	X	X
June 2021*	X	X
November 2021*	X	X
May/June 2022*	X	X

X indicates locations that were included during each survey. * Surveys covered by this report, † Surveyed by AIMS

2.2 Survey Period

This report provides a summary of coral conditions observed during two different surveys undertaken at all Abbot Point reef locations over the period November 2021 to May/June 2022. The two survey periods were pre-wet 2021: 19-20 November and post-wet 2022: 29 May and 3-4 June (here forward referred to as May 2022). Two surveys are included each year to ensure that the reasons for any observed impact are clear; with more than about eight months between surveys it may be difficult to determine the cause of any change in benthic cover.

Holbourne Island is a mid-shelf location and underwater visibility is usually between 5 and 15 m making the surveys consistently reliable. Although Camp Island is close to the coast and only a few kilometres off the Elliot River mouth underwater visibility there has been good during all surveys to date, ranging from 5-12 m, and surveys have not been compromised by poor water conditions.

2.3 Benthic Transect Surveys

Abundance surveys of the marine communities surrounding these two islands were made at four sites around each island. On Holbourne Island where the reef extends down to over 20 m depth two depth strata were surveyed at each site (2m and 5m below Lowest Astronomical Tide (LAT)) but at Camp Island the reefs were very shallow and only a single depth stratum is routinely surveyed (~2m below LAT). At each site and depth stratum, cover of major benthic reef organisms was assessed by five 20 m line transects run along the required depth contour with a 5m gap between each transect. The transects were permanently marked with a star picket at the start and 12 mm reinforcing rod stakes driven into the seabed at 10 m intervals.

These sites were set up by the AIMS after the wet season in mid-2016 and re-surveyed in October/November 2016. All transects were re-located and repaired by AIMS following Cyclone Debbie in mid-2017. The marker stakes are remarkably resistant to cyclone waves and the majority of markers survived the cyclone although many of them were bent over or broken off near the base. TropWATER and Sea Research took over the survey of these transects in mid-2018 using the same markers (with additional stakes added at 5 m intervals) and methods.

For each transect a survey tape was stretched tightly between the stakes close to the substratum for benthic composition, sediment deposition, coral health including disease and bleaching and coral recruitment to be assessed.

2.4 Benthic composition from photoquadrats

From November 2020 (pre-wet) surveys, methods were modified to use photoquadrats in place of line intercept techniques to estimate reef benthic composition. The line intercept method was used by Sea Research from 2018-2021 for the Abbot Point ambient coral monitoring program and has been used in many other surveys of fringing and offshore reefs in the Great Barrier Reef (GBR) region (Ayling and Ayling 2005; 2002; 1995; Mapstone et al. 1989). However, a desire to align with the Australian Institute of Marine Science (AIMS) methodology for calculating benthic cover (Jonker et al. 2020) and for greater consistency with Great Barrier Reef reporting more broadly led to a review and shift to the current photoquadrat technique. The 2020-2021 coral report (Chartrand et al. 2022) contains a review of local benthic cover based on photoquadrat analysis compares to line intercept data. Overall, trends were not significantly affected except at some sites with high seasonal macroalgae cover. Plotted data in this report shows the historic record with a clear delineation from which the change in methodology takes effect.

The photoquadrat method captures 40 images along each transect taken at approximately 0.5m intervals and analysed using coral point count open source software CoralNet to annotate images and estimate data at the transect, site and location level. This type of analysis is used widely to estimate percent cover data generated as the proportion of points assigned to a given label relative to the total number of points. Twelve points were analysed per photo providing a total of 480 points categorised per transect.

The following labels were assigned under each point analysed:

- Sand and mobile rubble;
- Macroalgae;
- Algal turf and crustose coralline algae;
- Sponges;
- All hard corals identified to genus level (or to growth form if more appropriate); and
- All soft corals.

Substantial updates were also made to the statistical analyses in the ambient coral monitoring program's annual report in the 2020-2021 period (see Section 2.8). Historical line intercept data is still used in all plots but adjusted to represent the reduction in sites and to compare ongoing trends at each location. A clear delineation is provided in all benthic composition plots to indicate the shift in methodology from November 2020 onwards.

2.5 Sediment Deposition on Corals

Depth of sediment deposition (whether natural or dredge derived) was measured on 20 hard coral colonies haphazardly selected within a metre of each transect. If sediment was present on living parts of the colony surface the point of maximum sediment depth was measured in mm using a plastic ruler. Sediment usually only covered a portion of the colony surface and a single measurement of sediment depth was recorded where it was deepest. Sediment depths were not measured during the AIMS surveys of these locations.

2.6 Damaged, Diseased, or Bleached Coral Colonies

In order to assess relatively rare events such as coral disease or sediment damage, a wider area surrounding fixed transects lines was evaluated using the following parameters:

- Counts of bleached or partially bleached colonies along a 20 x 2 metre transect centred on each transect line were recorded for each of the major coral groups.
- Counts of all sediment damaged colonies along a 20 x 2 m transect centred on each transect line were recorded for each of the major hard coral groups. Colonies were not recorded as sediment damaged if there was an actively growing edge encroaching into an old sediment-smothered dead patch.
- Counts of all diseased coral colonies along a 20 x 2 m transect centred on each transect line were recorded for each of the major hard coral groups. As for sediment damage, if there was an actively growing edge reclaiming a disease-caused dead patch that colony was not recorded as diseased.
- Counts of all colonies damaged by sponge overgrowth or *Drupella* or crown-of-thorns (CoTS) grazing along the same 20 x 2 m transects.

2.7 Coral Recruitment

To get an indication of levels of coral recruitment in the study locations measures of coral recruits were made during each of these surveys. The technique employed by the AIMS for their inshore reef surveys was used (Jonker et al. 2008). Using this technique small corals within 30 cm of the shoreward side of each transect were recorded in three size categories: 0-2 cm diameter; 2-5 cm diameter; 5-10 cm diameter. The genus of each young coral was recorded and numbers were summed from all five transects at each site.

2.8 Analysis

Given the large amount of natural patchiness in the abundance of all marine organisms, and the variation in abundance changes through time within each patch, it is necessary to use statistical analysis to determine if any change is significant. The variation may be so high that what appears to be quite a large nominal change may not be a real change but just due to sampling the natural variation within the community differently.

Generalised linear mixed effects models coupled with analysis of variance model output are used to determine the significance of any apparent changes in abundance between successive benthic surveys. The design of the benthic abundance surveys was established to enable such analysis after subsequent surveys. Because the transects were fixed within each site and the same features of the benthic community were assessed during each survey, a transect was incorporated into generalised linear models as a nested random effect to increase the power of the analysis and account for these repeated samplings. This analysis tested the significance of changes in a number of variables that may have influenced benthic abundance at each location over the last four survey periods.

1. The first variable was the four different sites surveyed at each location i.e. to determine whether there were significant differences in benthic abundance among the four sites within each location.
2. The second factor in the analysis design was time i.e. to determine whether there were any significant changes in benthic abundance between successive surveys at the same location.

Interactions between these variables were also determined in the analysis (indicated as Site x Time). If benthic abundance changes caused by ambient conditions are the same at each site then this interaction will not be significant but if benthic abundance decreases at one site and either does not change or increases at another site then the interaction may be significant, even though the mean coral cover may not have changed between the two surveys (the increase at one site could cancel out the decrease at another site and mean coral cover would stay the same).

Changes in sediment depth on coral colonies and the density of damaged and diseased coral colonies were tested for each location using the same analysis. As sediment depth is measured on a different random selection of corals during each survey then repeated measures analysis is not appropriate. The random nested effect term was removed from the generalised linear models for this analysis.

Long-term changes in benthic cover among locations was assessed using generalised additive models (GAMs). A GAM allows for non-linear terms such as time or season to be accounted for inherently in the model design. GAM output is plotted by location over time and with 95% confidence intervals. Differences in locations occur when model output and confidence intervals are non-overlapping. All analyses were performed in R version 4.1.1 (R Core Team) using packages lme4 and mgcv.

3 RESULTS

3.1 Climatic Conditions

One of the key drivers of coral community health is the climatic conditions experienced by that community over time. Major climatic drivers of coral health include local and regional rainfall and river discharges into the nearshore environment, cyclonic conditions, other strong wind episodes and sea water temperatures. The following section deals with the climatic conditions during the present ambient monitoring period from July 2021 to June 2022 and compares these conditions to data collected since coral monitoring began around Abbot Point in 2016. The Don River which discharges into the nearshore environment just north of Bowen, 30 km from Holbourne Island, and the Elliot River which discharges only 2.5 km inshore from Camp Island are used here as indicators of local river inputs.

3.1.1 Rainfall and River Flows

The rainfall measured by the Bureau of Meteorology (BOM) at the Bowen Airport (BOM 2017) is provided graphically in Figure 4. The Don River discharge rate at Reeves (23km from the mouth of the River) is presented using data provided by the Queensland Government Water Monitoring Information Portal (Sea Research 2017; WIMP 2016) in millions of litres per day (ML/day) (Figure 5). Elliot River discharge rates are recorded at Guthalungra seven kilometres upstream from the river mouth and are shown from July 2016 to June 2020 (Figure 5).

The Bowen region is in the dry tropics and mean annual rainfall is only 860 mm with the majority falling in the four-month wet season (Dec-Mar). Rainfall for the 2021/22 wet season was 623 mm from Dec-Mar but was overall above average for the year. Significant rainfall in May and July 2022, typically drier months, contributed over 100 mm each to the annual totals. Maximum daily rainfall during the 2021/22 period was related to a monsoon trough delivering 218 mm on the 27th January 2022 and was the major weather event of the past 12 months for the Abbot Point region (Figure 4 and 5).

Large sustained rainfall events typically cause large river discharges. Peak river flows for 2021/22 were recorded for both the Don and Elliot Rivers during the January 2022 rain event (Figure 5). Water discharges from the Don River was below average during 2021/22 despite the significant discharge of >25,000 ML recorded in late January 2022. This volume is still below the 13 significant events of 35,000 ML/day or greater flow since records began at this site in 1984. Flows of over 100,000 ML/day were recorded in 2008 and during the passage of Cyclone Debbie in March 2017. The Elliot River is a smaller system and flows are usually smaller. For the same monsoon event in January 2022, flows peaked at <5,000, suggesting this monsoonal event was localised more towards the Don River catchment rather than the Elliot (Figure 5). Flows from this river system peaked at 32,000 ML/day during Cyclone Debbie and 25,000 ML/day during 2019 a monsoonal event. Elliot River flows equal to or greater than those recorded during Cyclone Debbie have occurred on only seven occasions since 1973 (TropWATER 2019).

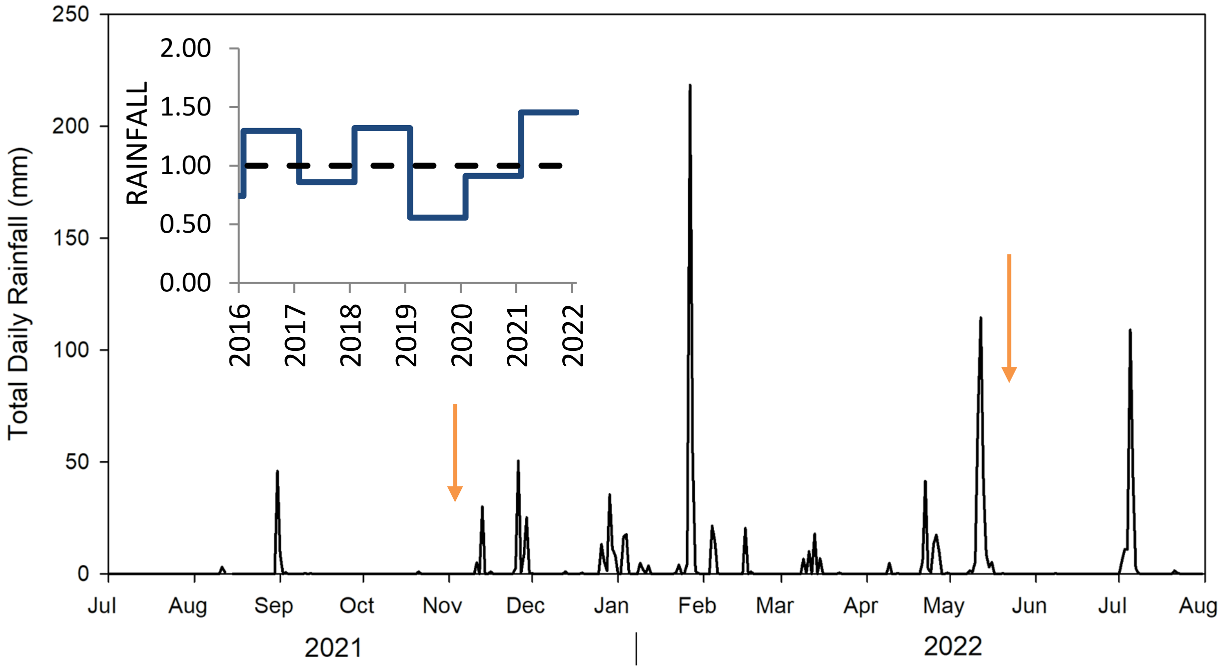


Figure 4. Daily rainfall measured at the Bowen Airport with inset of change in rainfall as a proportion of the long-term average. Orange arrows indicate survey dates.

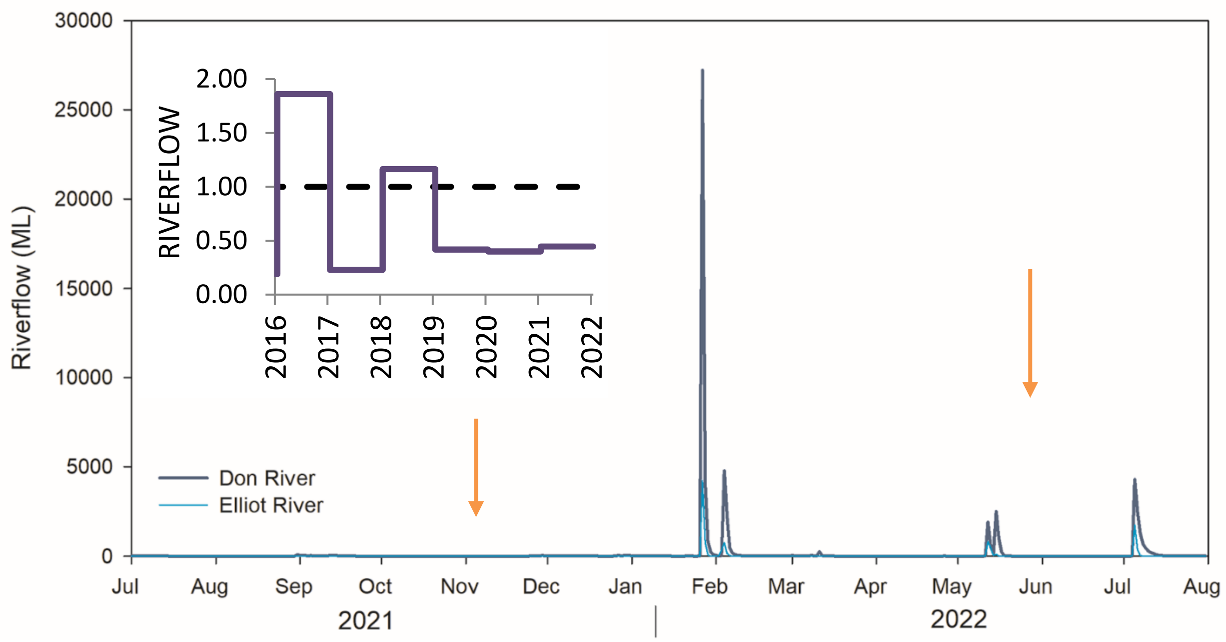


Figure 5. Daily discharge rates (mega litres) for the Don River measured at Reeves, 23 km upstream from the river mouth and the Elliot River discharge at Guthalungra with inset (Don River) of change in river flow as a proportion of the long-term average. Orange arrows indicate survey dates.

3.1.2 Cyclones

During the 2021/22 ambient monitoring period no cyclones passed near Abbot Point and only the single 2021/22 monsoonal rainfall event resulted in >100mm over a 24 hour period in the region.

Prior to 2018 only one cyclone passed close to Abbot Point leading to strong or damaging winds and high rainfall that may have impacted the benthic communities in the coral monitoring locations since they were established. Severe Tropical Cyclone Debbie in late March 2017 generated gale force winds in the Bowen to Mackay region for more than 50 hours. Wave heights recorded near Holbourne Island during this event were over 8 m for many hours and peaked at 11.5 m. This system caused severe physical damage to the Holbourne Island benthic communities but minimal damage at the Camp Island location (AIMS 2018).

3.1.3 Sea Water Temperatures

Sea temperature measurements are collected by TropWATER at a number of sites in the nearshore environment offshore from Bowen and around Abbot Point. Sustained elevated water temperatures that can cause coral bleaching were recorded during the 2021/22 summer period at both Camp and Holbourne Island logger sites from December 2021 to March 2022 (Figure 6). Overall, temperatures were above the long term average in the Central Region of the GBR according to the NOAA sea surface temperature virtual stations generating alert level 1 in January and February 2022 and alert level 2 in February 2022 (Figure 6B). Despite these elevated temperatures, signs of bleaching were minimal during May 2022 surveys (see Section 3.4 for further details). The small drop in extreme temperatures in February 2022 may have helped provide some reprieve. In contrast, the previous mass bleaching event driven by elevated sea surface temperatures in February and March 2020 led to significant bleaching that was recorded during the pre-wet October 2020 surveys. In this event, temperatures continued to rise and were sustained for a longer period of time. Overall, the inshore Camp Island site has the highest and lowest seasonal temperatures compared to the more offshore Holbourne Island (Figure 6A).

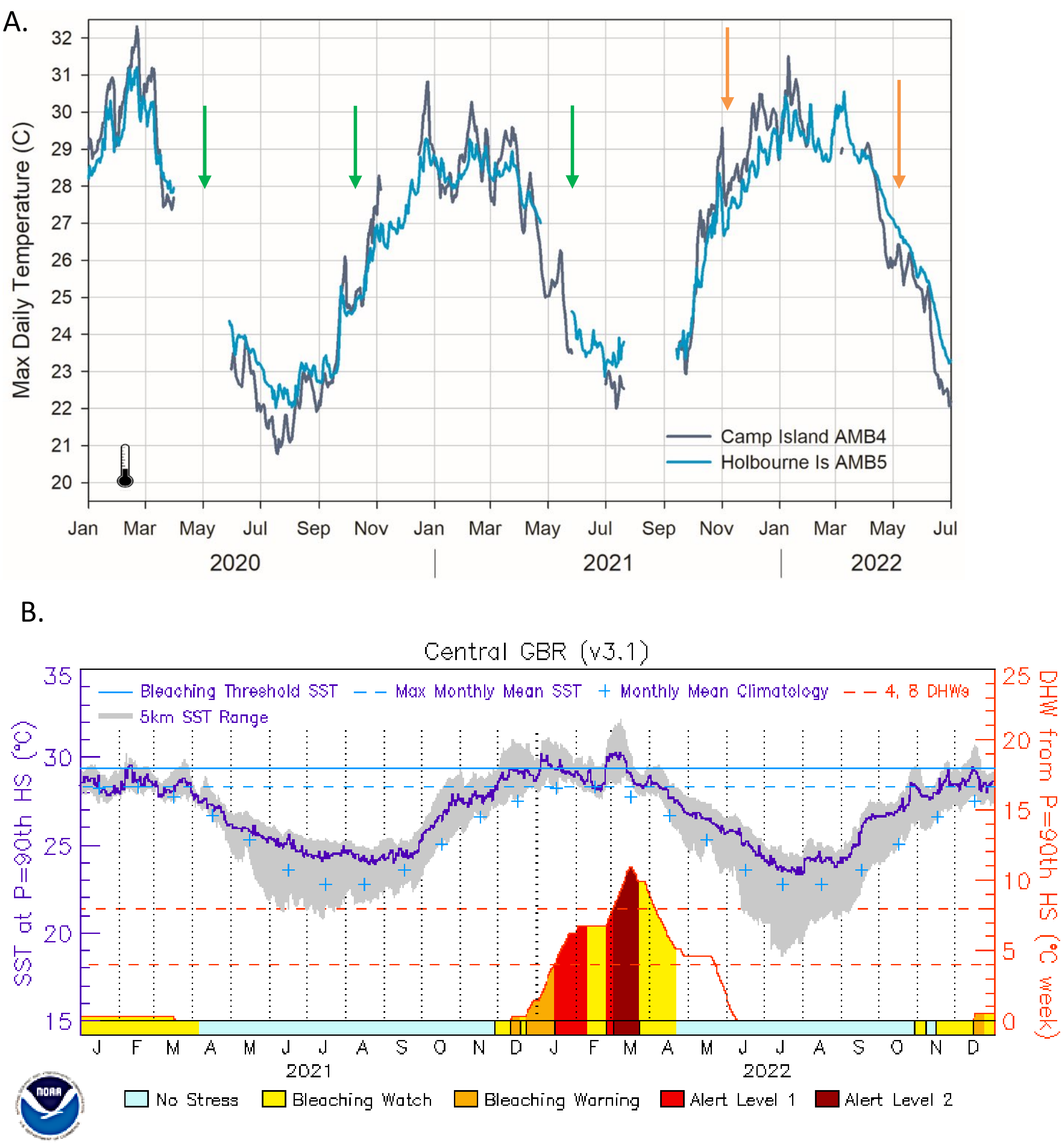


Figure 6. A . Maximum daily temperature recorded from 2020-2022 by the NQBP water quality monitoring team at nearby logger sites (Waltham et al. 2022). Orange arrows indicate approximate survey dates, green arrows are previous surveys. B. NOAA Coral Reef Watch 2021-2022 5km satellite regional virtual station time series data for Central GBR.

3.2 Benthic cover during the ambient surveys

Benthic communities on Camp Island is an inshore location with macroalgal cover that has varied widely between pre-wet and post-wet season surveys since monitoring began with peaks traditionally in the October/November period. In November 2021 however, macroalgae did not increase from the seasonal low of 49% cover recorded in the previous June 2021 survey and dropped further by May 2022 (Figure 7). Sand/rubble, crustose corallines and turfing algae accounted for 40-47% of the substratum in this location during the last two ambient surveys since macroalgae levels were down. Sponges covered only approximately 2.5% of the substratum at Camp Island in May 2022 but this is an increase at all sites and especially at West 1 which has historically had higher sponge levels in some years. Hard coral cover increased slightly from the historic low of 6% in October 2020 to over 12% cover in May 2022. Soft corals continue to be rare at this location covering less than 1% of the substratum.

Benthic communities on the Holbourne Island sites were severely affected by Cyclone Debbie with >75% coral cover lost at Holbourne sites between 2016 and 2017 while Camp Island was largely unaffected by this system (Figure 9; AIMS 2018). At the original sites, East 2 (E2) and West 1 (W1), recovery has been very slow and the majority of the reef surface is still occupied by sand/rubble, crustose coralline algae and turfing algae. These three categories accounted for about 75% of the substratum in the old sites during the latest survey, consistent with the last two years of surveys. The new sites Northeast (NE) and Southeast (SE) add a significant increase of approximately 10% to the Holbourne Island hard coral community (Appendix A1 and A2).

Since the new design in October 2020, hard coral cover has been fairly stable with a mean hard coral cover of 19-24% for Holbourne Island. Little to no macroalgae occurs at Holbourne Island with turf and crustose coralline algae (CCA) dominating otherwise open reef substrate at this location. Soft coral has consistently covered around 3% at all sites.

Macroalgae cover at Camp Island was significantly down in both November 2021 and May 2022 from the October 2020 peak (Figure 8, Table 3). At 38%, macroalgae was also lower in May 2022 than the previous post-wet season survey in June 2021 when algae was 49% of the benthos. At the site level, macroalgae cover has been consistently higher at E1 and W2 but was <60% rather than >80% as in June 2021. This higher site coverage does drive significant site, time and site x time interactions over the last four surveys (Table 3).

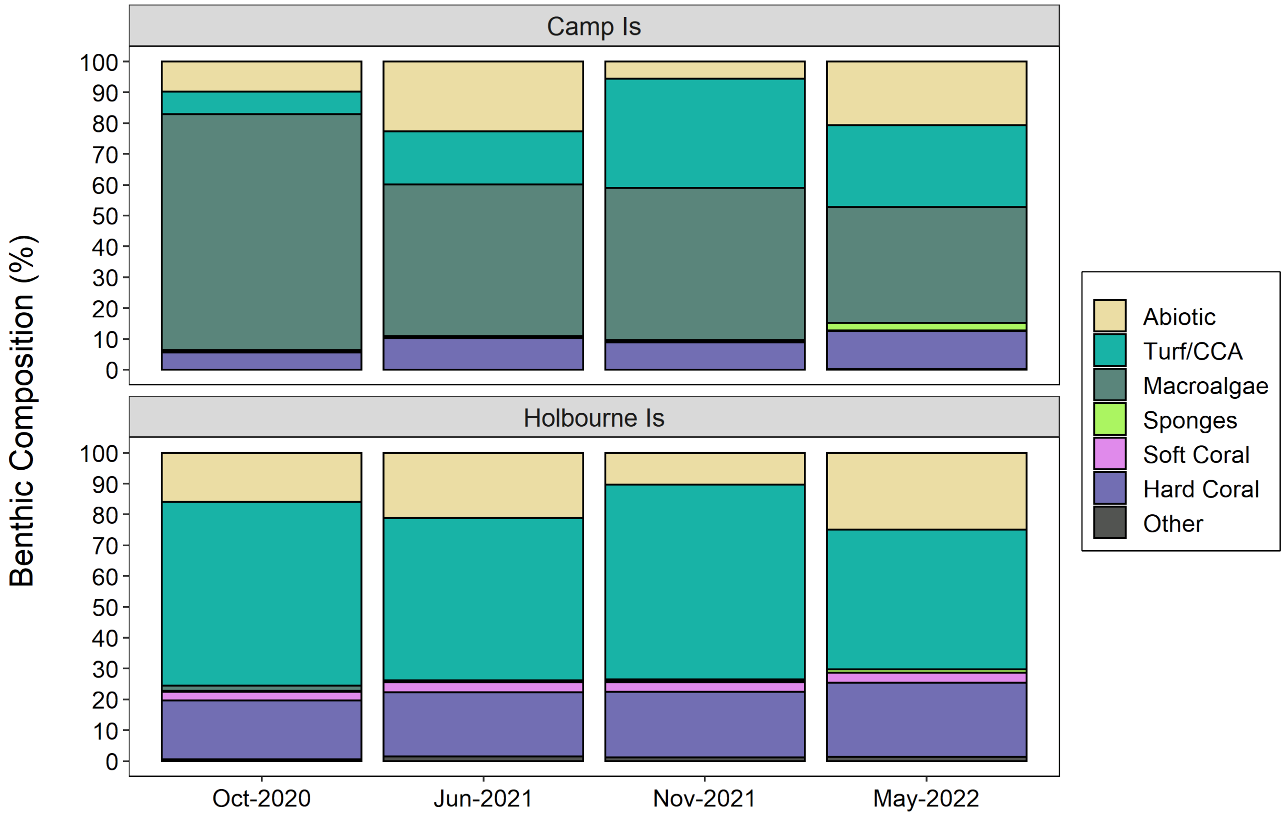


Figure 7. Changes in benthic composition in the two locations between October 2020 and May 2022. Benthic category Benthic category 'Abiotic' = sand + rubble + bare reef, Other = *Millepora* + zoanthids.

Despite the potential to inflate macroalgae at Camp Island using the photoquadrat method compared to historical line intercept techniques, the lower macroalgae cover recorded in the last few surveys were since the change in methods in October 2020. This suggests these estimates may be even lower relative to the historic record if line intercept techniques were in place, providing further confidence that macroalgae is lower than recent year peaks.

Holbourne Island is a mid-shelf location and macroalgae are not usually a feature of the benthic community. The small and temporary bloom of *Padina* macroalgae that appeared in October 2019 and 2020 was absent in the last two surveys (Figure 8). The consistent but small presence of *Padina* in October 2020 created only a significant effect of time but not site at Holbourne (Table 3). The high cover of *Sargassum* macroalgae at the inshore Camp Island drives the significant differences in algal cover among the two locations (Figure 8).

Sponges were not common at either of these locations (Figure 7) but were most abundant on Camp Island where the cover of this benthic group was 2.5% during the May 2022 survey a significant increase out of the last four surveys (Table 3). The most abundant sponge was the green *Haliclona cymaeformis* (formerly known as *Sigmadocia symbiotica*) that often grew amongst the branching corals at this location. Sponge cover, although low, was variable among sites and surveys leading to significant site, time, and site x time interactions (Table 3). Site W1 had significantly more sponge than all other sites and historically has been the case at Camp Island (Appendix Figure A3).

Table 3. Benthic changes between the four most recent surveys (Oct 2020, June 2021, Nov 2021 and May 2022) from the site level data of the two locations of the ambient monitoring project. Results are the anova summary results of a generalised linear mixed effects model output with transect as the random effect run for each location separately.

	CAMP ISLAND			HOLBOURNE ISLAND		
Family/Group	**Site**	**Time**	**S x T**	**Site**	**Time**	**S x T**
Total macroalgae	***	***	***	*	***	NS
Total hard corals	***	**	NS	***	NS	NS
Total sponges	***	**	**	***	NS	NS
Acropora spp.	***	**	*	***	NS	NS
Montipora spp.	***	NS	NS	***	NS	NS
Agariciidae	***	NS	NS	NS	*	*
Faviidae	**	NS	NS	*	NS	NS
Poritidae	***	NS	NS	***	NS	NS
Total soft coral	*	NS	NS	***	NS	NS

NS = not significant; * = 0.05>p>0.01, ** = 0.01>p>0.001; *** = p<0.001

Total hard coral cover had been significantly higher at the Camp Island location than at Holbourne Island following Cyclone Debbie but this trend has reversed since October 2020 (Figure 9). This reversal is in part due to bleaching impacts driving hard coral losses at Camp Island while an equivalent location increase at Holbourne Island with the addition of two sites with higher hard coral cover in October 2020 with the revised monitoring program (Figure 9). At Camp Island, coral cover measurably increased to 12.4% in May 2022 from a program low of 5.6% in October 2020 (Figure 9, Table 3). While no site x time interactions, W1 had overall greater hard coral followed by E2 compared to the other two sites at Camp Island (Table 3, Appendix Figure A2).

As mentioned above, the newly established Holbourne Island sites led to a significant increase in overall hard coral for the location from October 2020. With four surveys since the newly established sites, analysis showed a clear site effect with the new sites SE and NE having significantly greater hard coral (54% and 20%, May 2022) compared to the old sites WD1 and E2D (8% and 14%) still being monitored (Table 3, Appendix Figure A2). There is no time effect or site x time interaction at Holbourne Island over the last four surveys despite a positive trend in hard coral cover (Figure 9). As of May 2022, 12.4% mean hard coral cover at Camp Island was significantly lower than 21.4% at Holbourne Island (Figure 9B).

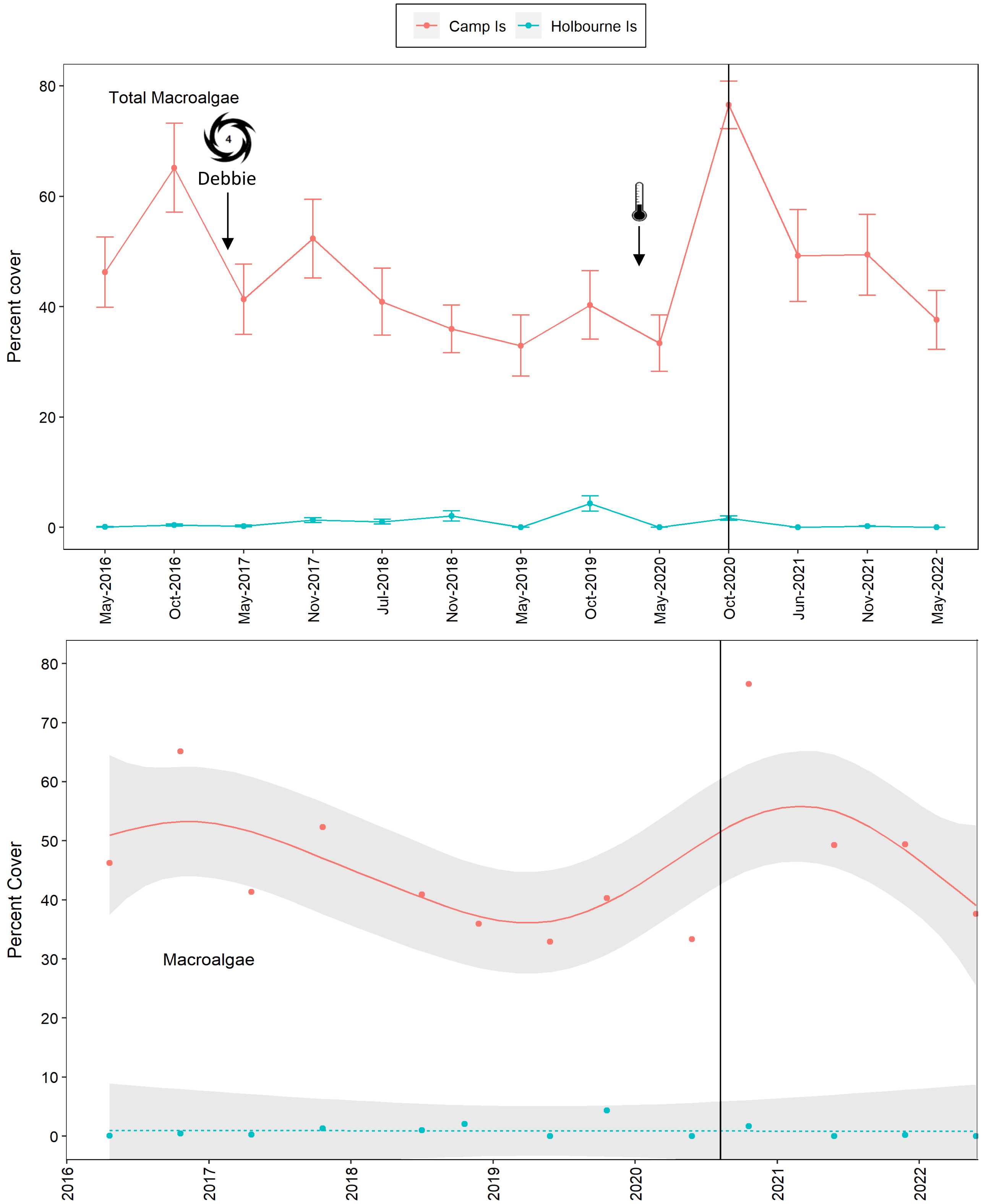


Figure 8. Changes in percentage cover of macroalgae.
Graphs show A) grand mean percentage macroalgal cover ± SE from the 2021/22 ambient surveys and from all previous surveys at each island location (five 20m line intersect transects surveyed at four sites for each location). The black line indicates change to photoquadrat methodology and new Holbourne sites established. B) Generalised additive model of trends in mean coral cover. Significant differences among locations are apparent where 95% confidence bands do not overlap.

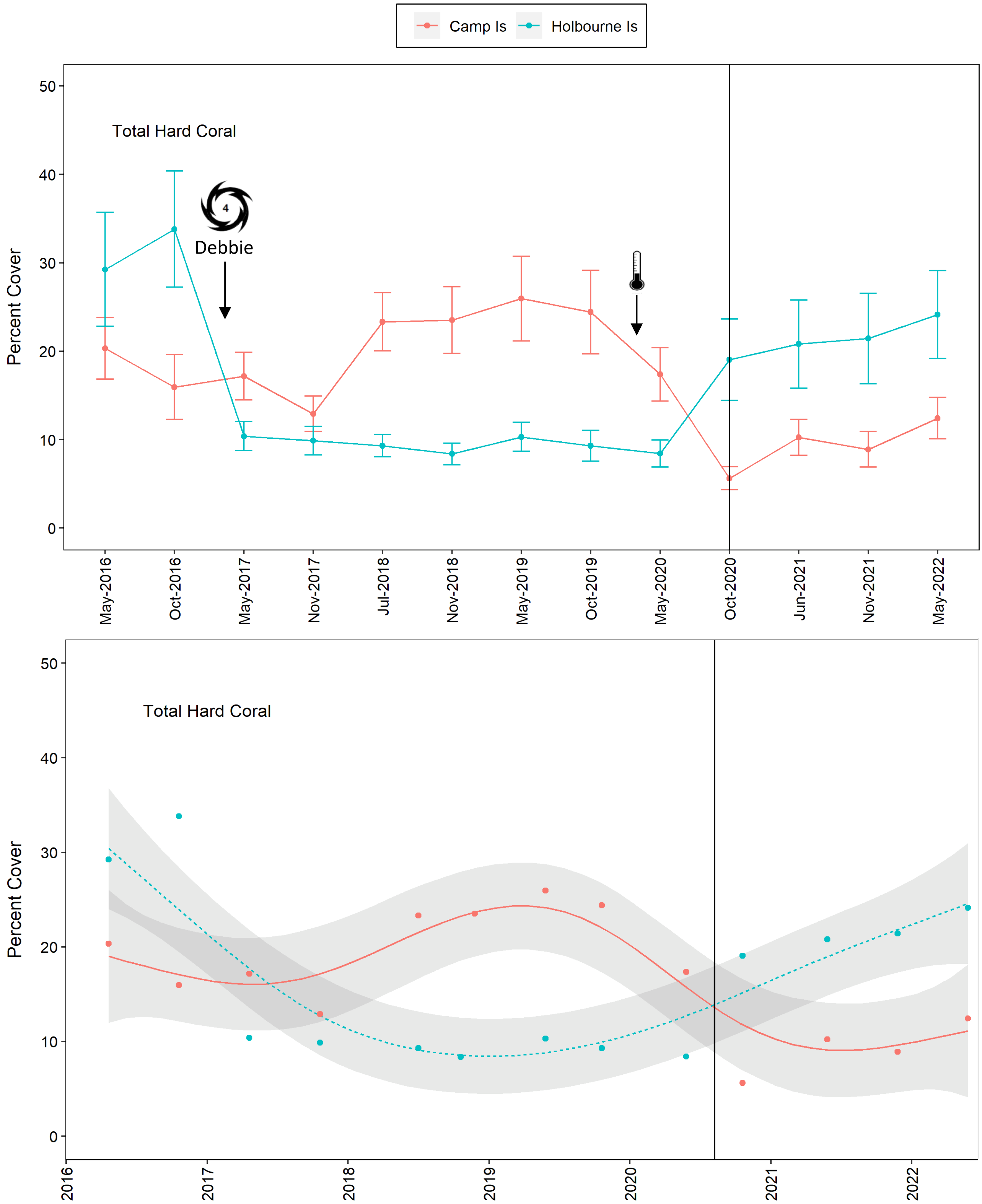


Figure 9. Changes in percentage cover of total hard coral.
Graphs show A) grand mean percentage macroalgal cover ± SE from the 2021/22 ambient surveys and from all previous surveys at each island location (five 20m line intersect transects surveyed at four sites for each location). The black line indicates change to photoquadrat methodology and new Holbourne sites established. B) Generalised additive model of trends in mean coral cover. Significant differences among locations are apparent where 95% confidence bands do not overlap.

Hard coral community composition is somewhat similar between locations with the new Holbourne sites and the bleaching impacts at Camp (Figure 10). Coral communities at both are dominated by *Acropora* (39% at Camp and 43% at Holbourne) followed by *Montipora* spp. (36% at Camp and 21% at Holbourne of total coral cover) and faviid corals (5% Camp Island, 10% Holbourne Island). In the Holbourne sites poritids were still prevalent with 15% of total hard coral compared to 2.5% at Camp. Agariciid corals are also still prevalent on Camp Island, but only at one of the four sites, with large colonies of *Pavona decussata* accounting for almost 20% of coral cover at site W1. Mussids, siderastreids, dendrophyllids and merulinids all made up a smaller composition at both locations (Figure 10).

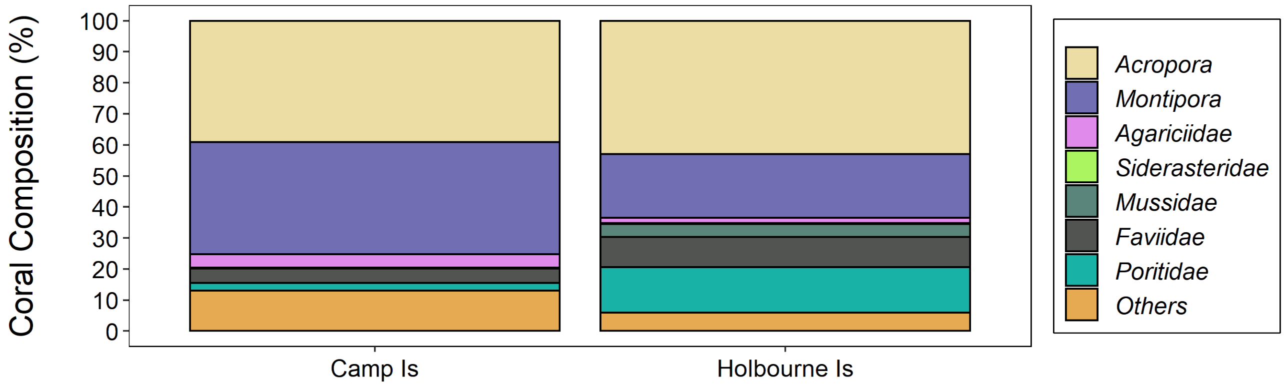


Figure 10. Coral community composition at the two locations for the latest May 2022 ambient survey.

Only *Acropora* corals showed significant site, time and site x time differences during the last four ambient surveys at Camp Island (Table 3). *Acropora* significantly increased at Camp Island driving the biggest increase in hard coral at this location from 4.0% in October 2020 to 5.9% in May 2022 (Figure 11, Table 3). Overall, both west sites having higher *Acropora* than the east sites.

Acropora at Holbourne Island is significantly higher at the new SE site but overall sites were stable with no time effect over the last four surveys with 14% cover on average despite a positive trend in *Acropora* cover since October 2020 (Figure 11, Table 3). The generalised additive model results for *Acropora* do show an overall difference between the two locations in May 2022 when considered against the long term site history (Figure 11B).

Montipora cover did not change at either location over the last four surveys and is at similar levels at both locations (Figure 12, Table 3). *Montipora* at Camp Island declined significantly in October 2020 following the bleaching stress event while Holbourne Island recorded an increase in October 2020 solely from the new site configuration. As of May 2022, *Montipora* at Camp Island was 3.7% cover and 4.8% at Holbourne Island.

Since monitoring began, Holbourne Island has had overall greater abundance of favids, poritids and soft corals while Camp has a larger coverage of agariciids (Figures 13-17). Siderastreids have both been a relatively small proportion of the benthos at both locations (Figure 16). In general, both locations have had relatively stable assemblages of coral families except for the loss of soft corals from Holbourne following Cyclone Debbie with no overall shift in the latest surveys outside of the significant shifts in *Acropora* and *Montipora* due to bleaching and site changes in October 2020 (Figures 13-17).

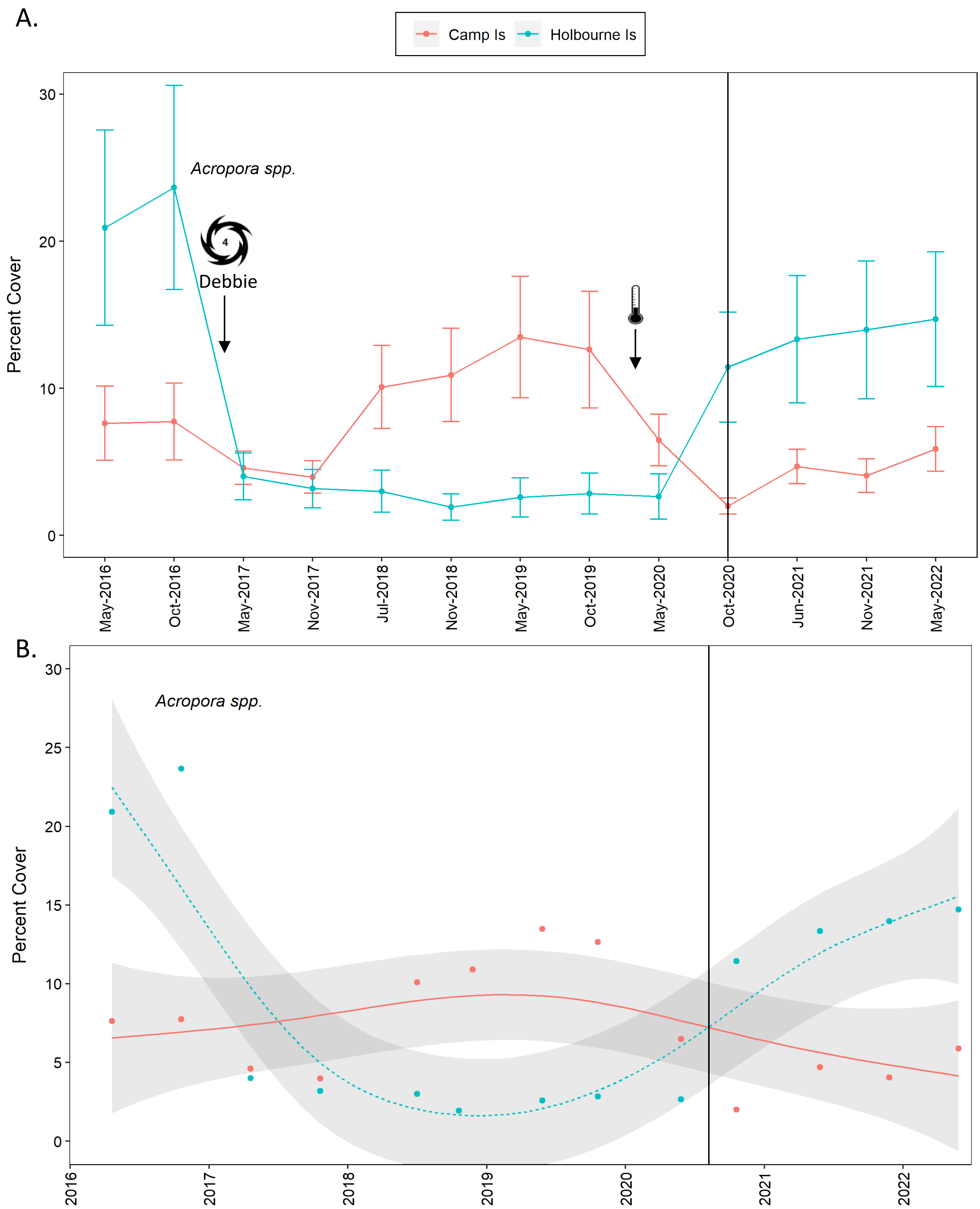


Figure 11. Changes in the cover of *Acropora* corals.
Graphs show A) grand mean percentage benthic cover ± SE from the 2021/22 ambient surveys and from all previous surveys at each island location (five 20m line intersect transects surveyed at four sites for each location). The black line indicates change to photoquadrat methodology and new Holbourne sites established. B) Generalised additive model of trends in mean coral cover. Significant differences among locations are apparent where 95% confidence bands do not overlap.

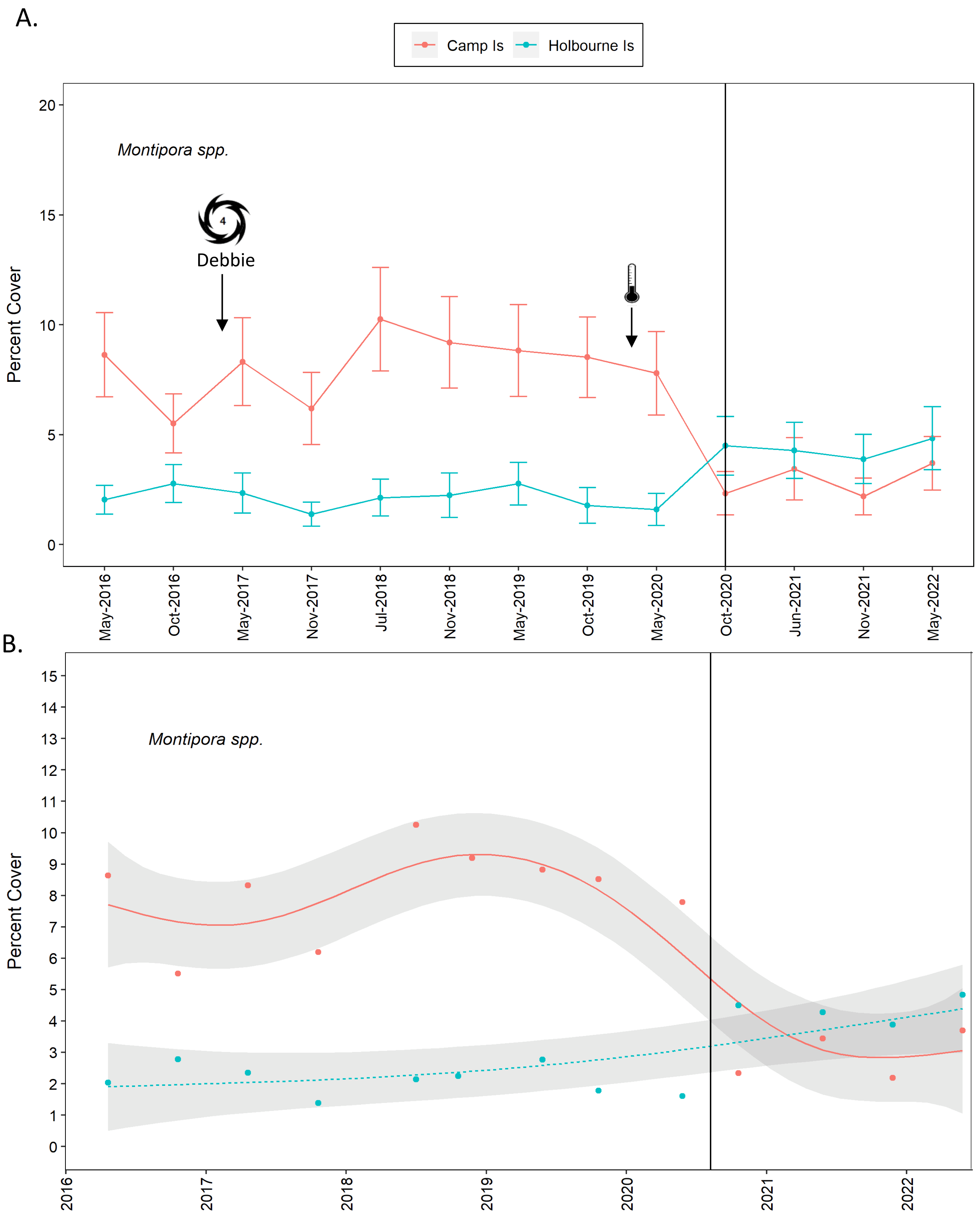


Figure 12. Changes in the cover of *Montipora* corals.
Graphs show A) grand mean percentage benthic cover ± SE from the 2021/22 ambient surveys and from all previous surveys at each island location (five 20m line intersect transects surveyed at four sites for each location). The black line indicates change to photoquadrat methodology and new Holbourne sites established. B) Generalised additive model of trends in mean coral cover. Significant differences among locations are apparent where 95% confidence bands do not overlap.

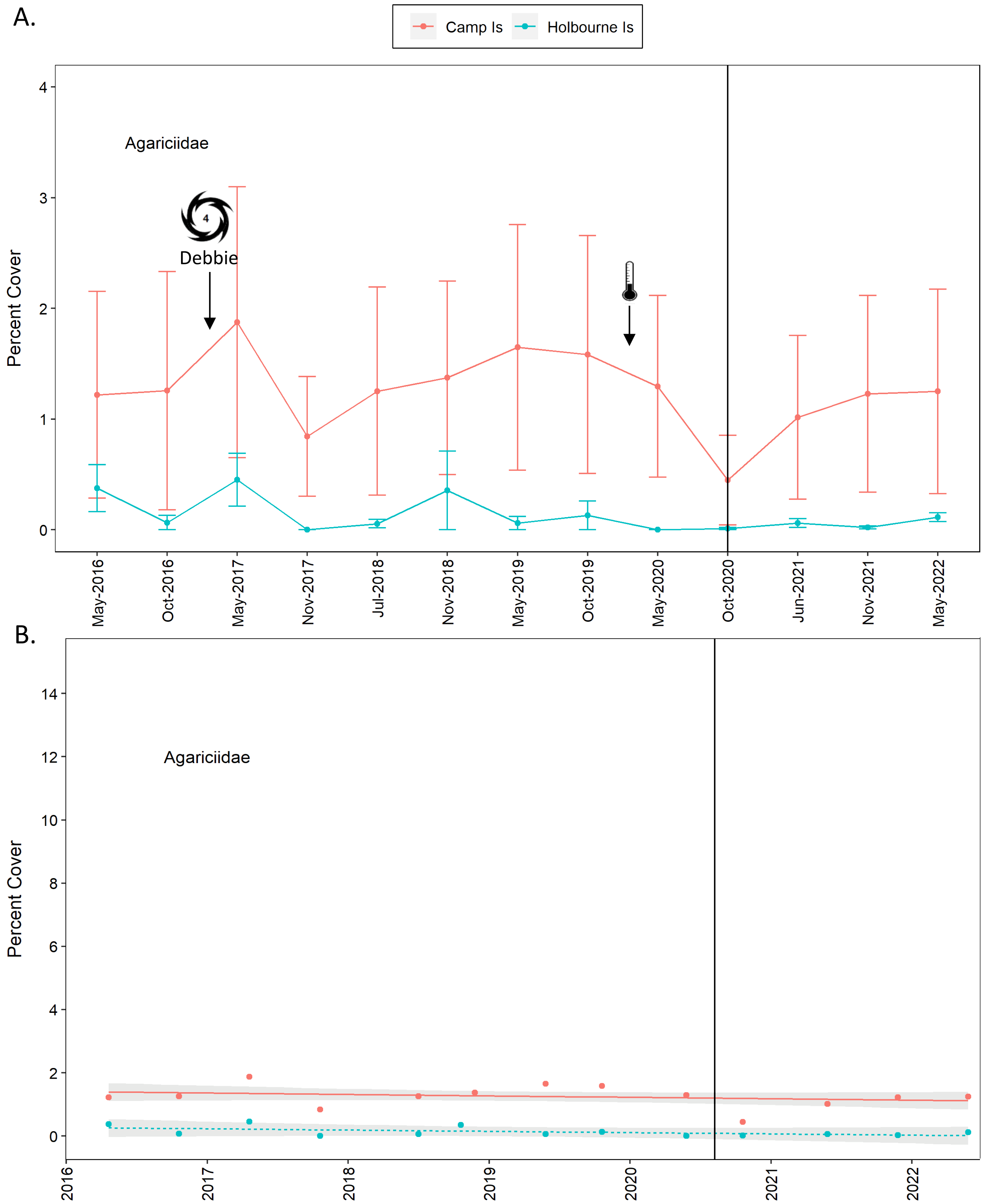


Figure 13. Changes in the cover of Agariciid corals.

Graphs show A) grand mean percentage benthic cover ± SE from the 2021/22 ambient surveys and from all previous surveys at each island location (five 20m line intersect transects surveyed at four sites for each location). The black line indicates change to photoquadrat methodology and new Holbourne sites established. B) Generalised additive model of trends in mean coral cover. Significant differences among locations are apparent where 95% confidence bands do not overlap.

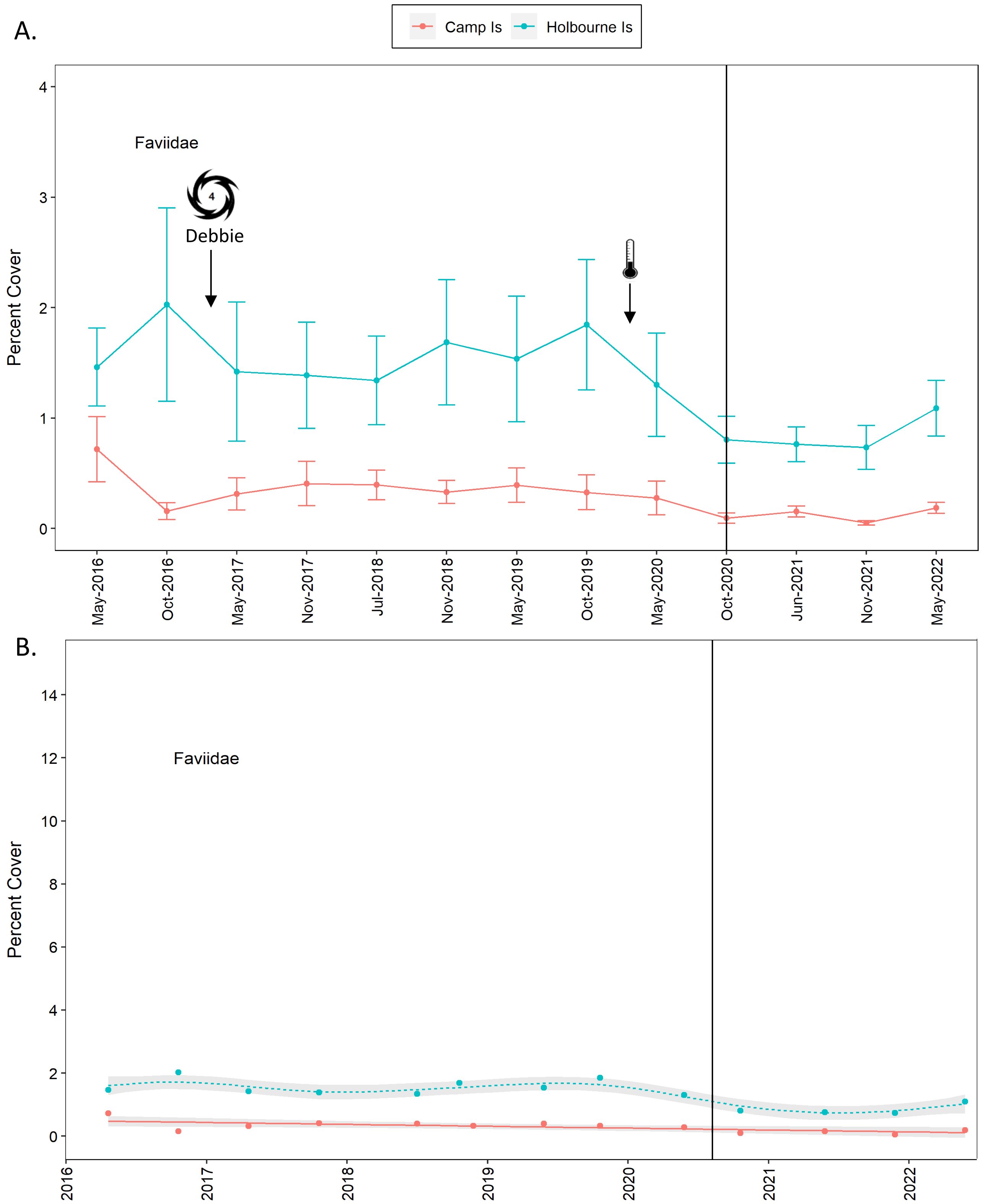


Figure 14. Changes in the cover of Favid corals.

Graphs show A) grand mean percentage benthic cover ± SE from the 2021/22 ambient surveys and from all previous surveys at each island location (five 20m line intersect transects surveyed at four sites for each location). The black line indicates change to photoquadrat methodology and new Holbourne sites established. B) Generalised additive model of trends in mean coral cover. Significant differences among locations are apparent where 95% confidence bands do not overlap.

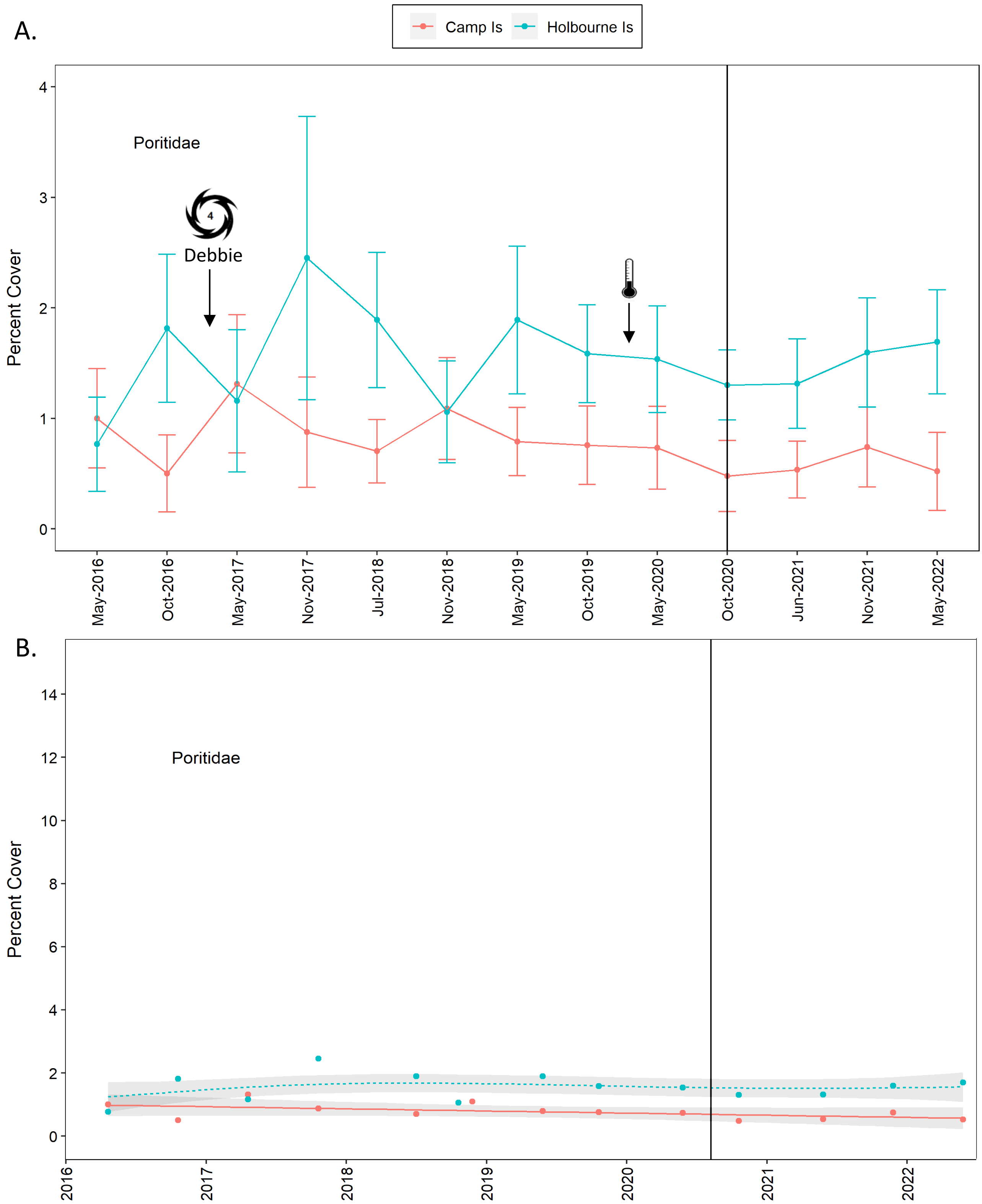


Figure 15. Changes in the cover of Poritid corals.

Graphs show A) grand mean percentage benthic cover ± SE from the 2021/22 ambient surveys and from all previous surveys at each island location (five 20m line intersect transects surveyed at four sites for each location). The black line indicates change to photoquadrat methodology and new Holbourne sites established. B) Generalised additive model of trends in mean coral cover. Significant differences among locations are apparent where 95% confidence bands do not overlap.

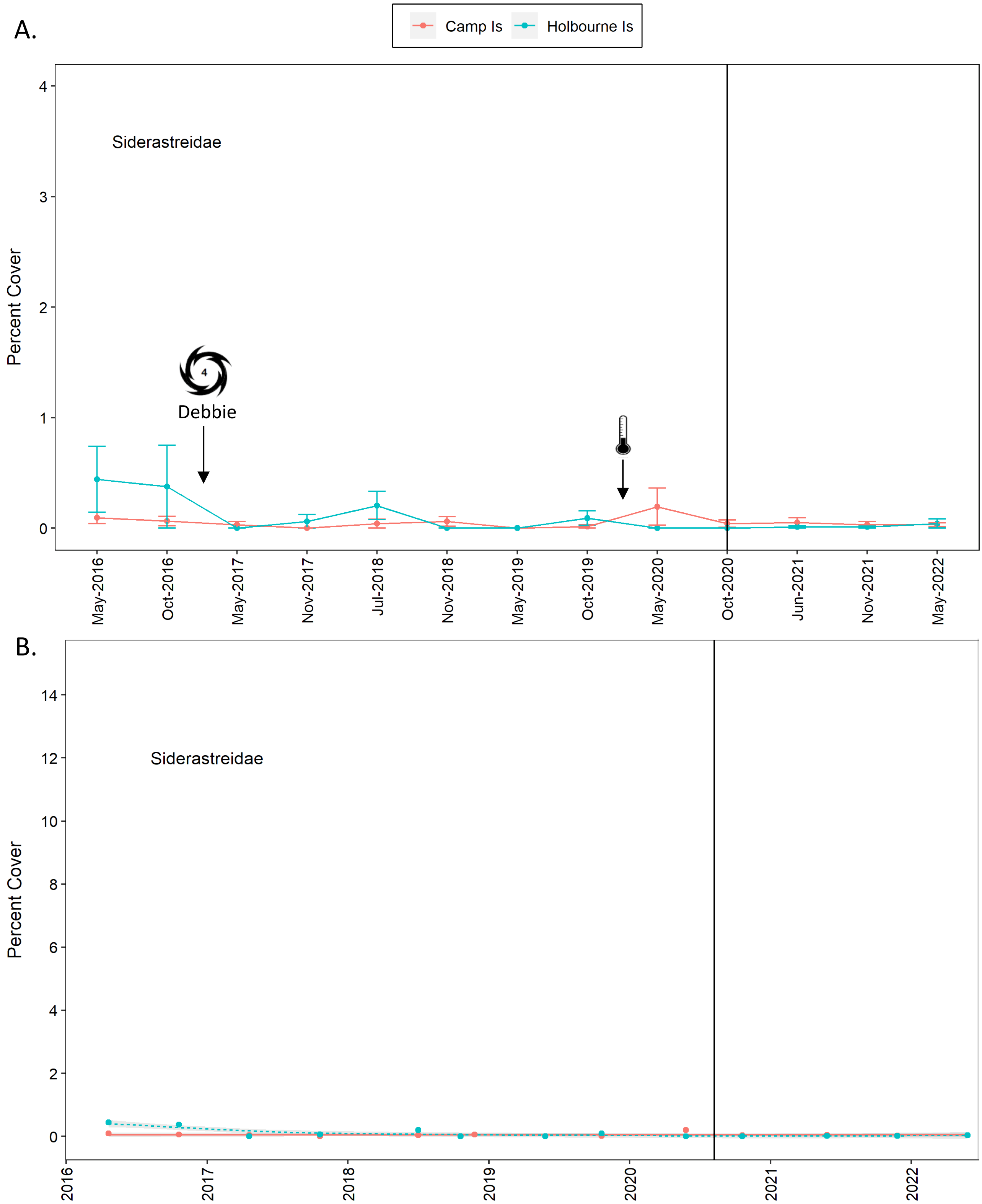


Figure 16. Changes in the cover of Siderastreid corals.

Graphs show A) grand mean percentage benthic cover ± SE from the 2021/22 ambient surveys and from all previous surveys at each island location (five 20m line intersect transects surveyed at four sites for each location). The black line indicates change to photoquadrat methodology and new Holbourne sites established. B) Generalised additive model of trends in mean coral cover. Significant differences among locations are apparent where 95% confidence bands do not overlap.

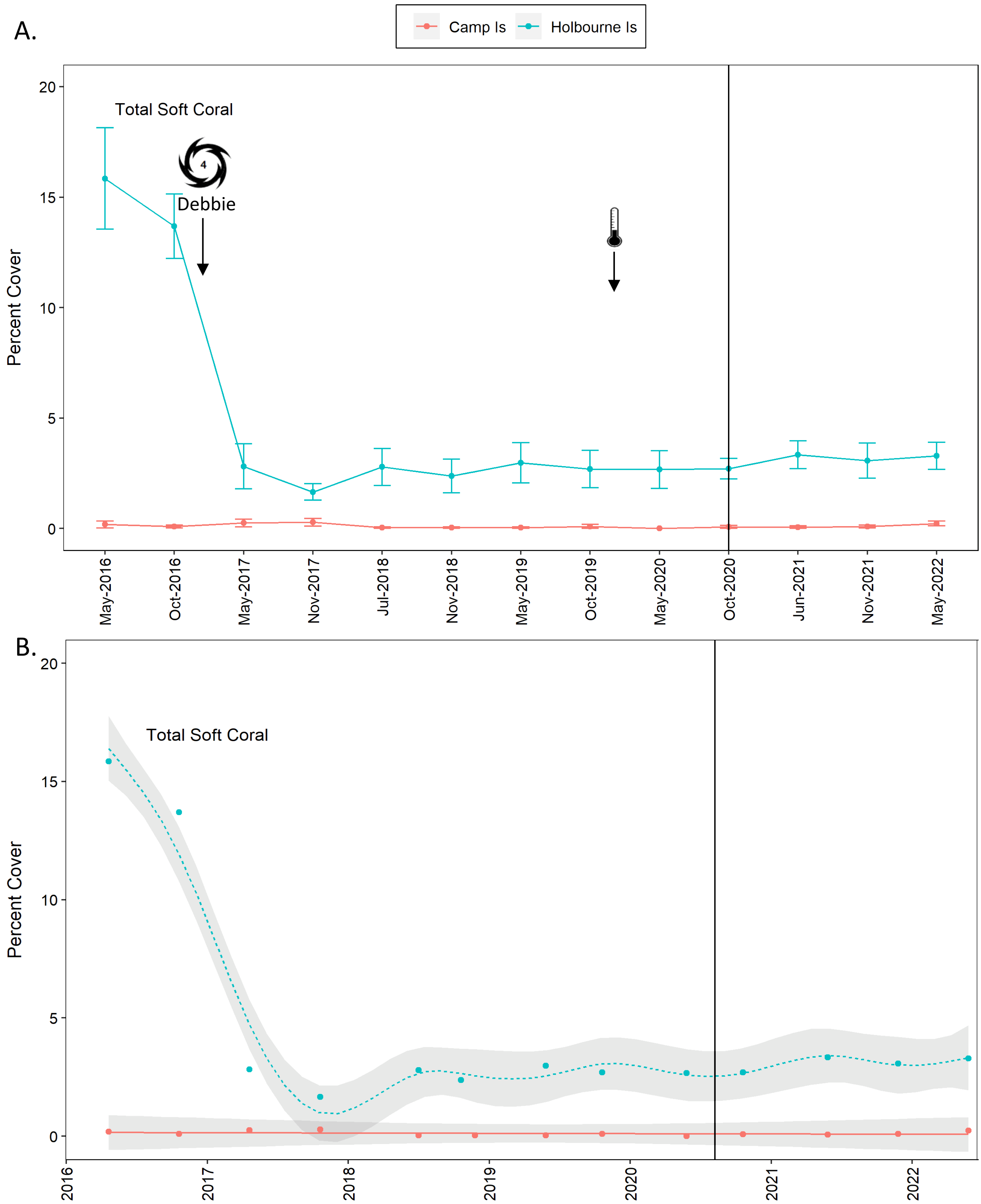


Figure 17. Changes in the cover of soft corals.

Graphs show A) grand mean percentage benthic cover ± SE from the 2021/22 ambient surveys and from all previous surveys at each island location (five 20m line intersect transects surveyed at four sites for each location). The black line indicates change to photoquadrat methodology and new Holbourne sites established. B) Generalised additive model of trends in mean coral cover. Significant differences among locations are apparent where 95% confidence bands do not overlap.

3.4 Coral Bleaching

A severe temperature anomaly during the early months of 2022 was recorded on water quality loggers deployed as part of the ambient monitoring program at Abbot Point and also suggested through the NOAA sea surface virtual station for mass bleaching alerts (see Section 3.1.3, Figure 6). At Camp Island, no significant increase in bleaching was observed at the location scale in May 2022 (Figure 19, Table 5). There was a site effect with collectively higher bleaching across the last four surveys at E2 compared to no bleaching at E1 and W2 (Table 5). The prevalence of bleaching at E2 was still incredibly low, albeit greater than zero thus driving the significance at this site (Figure 18). At Holbourne Island, some mild or partial bleaching was observed away from transect surveys around some sites (Figure 19). This low level of bleaching did drive an overall time effect with greater bleaching in May 2022 compared to June 2021 or October 2020 (Table 4 and 5). As with Camp Island, the overall level of bleaching in May 2022, while significant was still incredibly small compared to the effects of the warming event in early 2020 (Figure 19).

Table 4. Average coral colony health status during the last four ambient surveys by location.

Location	Oct 2020		June 2021		Nov 2021		May 2022	
	mean	*se*	mean	*se*	mean	*se*	mean	*se*
HOLBOURNE								
Partially bleached colonies	0.0	*0.0*	0.0	*0.0*	0.2	*0.1*	0.6	*0.2*
Sediment damaged colonies	0.0	*0.0*	0.1	*0.1*	0.1	*0.1*	0.0	*0.0*
Disease damaged colonies	0.0	*0.0*	0.1	*0.1*	0.1	*0.1*	0.2	*0.1*
COT damaged colonies	0.4	*0.2*	0.3	*0.1*	0.0	*0.0*	0.2	*0.1*
CAMP								
Partially bleached colonies	0.1	*0.1*	0.2	*0.1*	0.3	*0.1*	0.2	*0.1*
Sediment damaged colonies	0.1	*0.1*	0.5	*0.2*	1.1	*0.5*	0.1	*0.1*
Disease damaged colonies	0.1	*0.1*	0.1	*0.1*	0.2	*0.1*	0.1	*0.1*
COT damaged colonies	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*

Damaged corals are recorded as mean number per 40 sq m transect. COT=crown-of-thorns.

Table 5. Abbot Point fringing reefs: changes in the density of partially bleached, diseased, sediment damaged and CoTS damaged corals between the four most recent surveys (Oct 2020, June 2021, November 2021 and May 2022) from the site level data of the two locations of the ambient monitoring project. Results are the anova summary results of a generalised linear mixed effects model output with transect as the random effect.

	CAMP ISLAND			HOLBOURNE ISLAND		
Factor	**Site**	**Time**	**S x T**	**Site**	**Time**	**S x T**
Partial bleaching changes	***	NS	NS	NS	**	NS
Sediment damage changes	*	**	*	NS	NS	NS
Coral disease changes	NS	NS	NS	NS	NS	NS
COT damage changes	NS	NS	NS	**	*	NS

NS = not significant; * = 0.05>p>0.01, ** = 0.01>p>0.001; *** = p<0.001

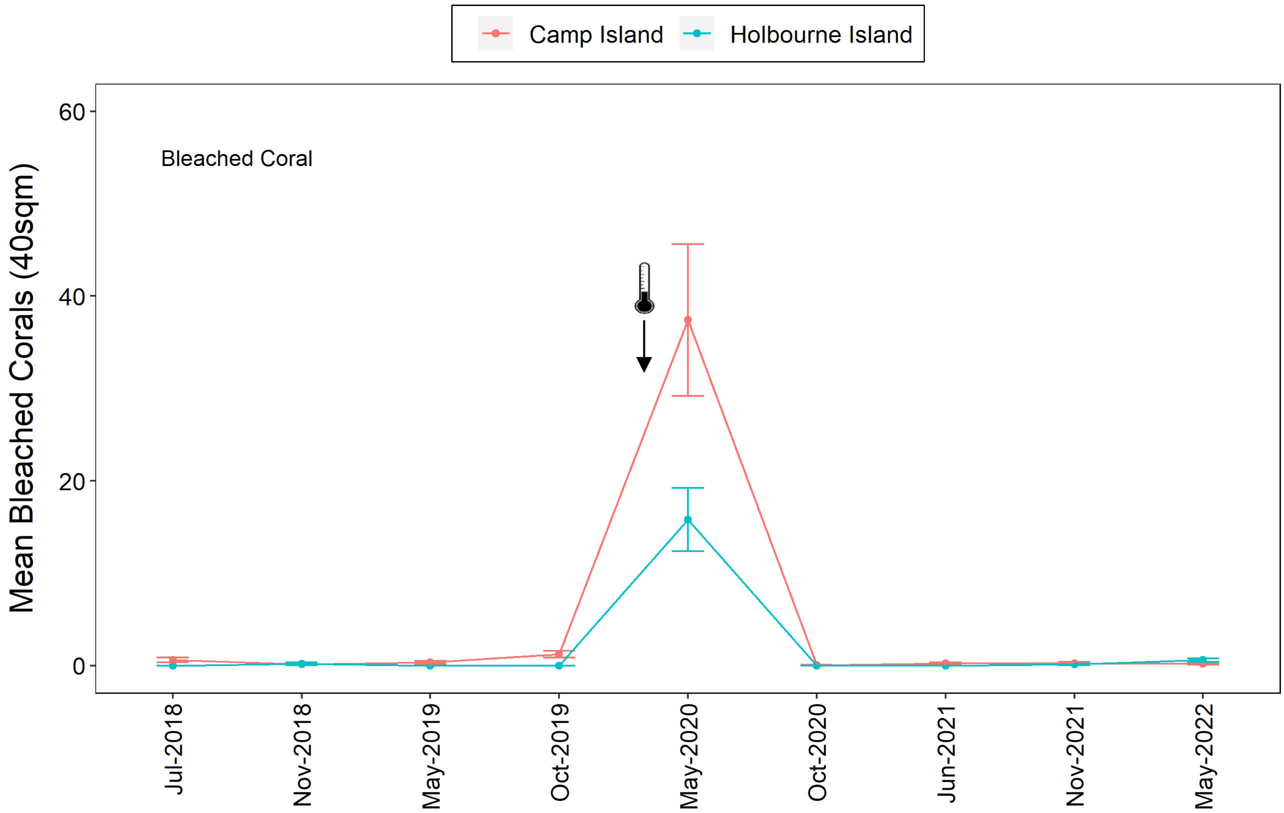


Figure 18. Changes in density of bleached and partially bleached hard coral colonies. Graphs show grand mean density of bleached and partially bleached corals ± SE per 40m^2 from four sites of five 20 x 2m transects in each location from the 2021/22 ambient surveys and all previous surveys.

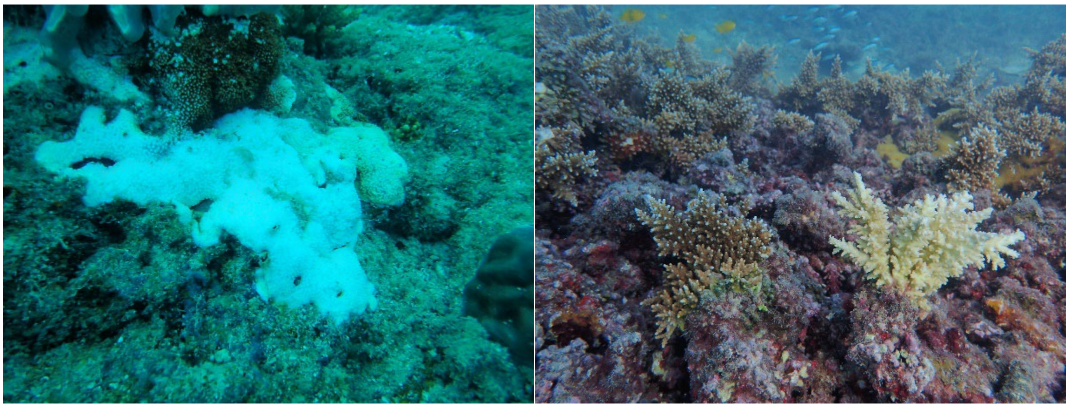


Figure 19. Some mild bleaching was observed on colonies away from the transect line at Holbourne Island in May 2022 at sites A) NE and B) E2 however not widespread across any site.

3.5 Sediment Deposition on Coral Colonies

Many corals on fringing reefs have some sediment on their surface as a result of natural sediment resuspension and movement during strong winds and/or spring tides. Port related activities such as dredging also have the potential to contribute to sediment in the water column but no port related activities of this sort occurred during the period covered by these ambient surveys.

The percentage of corals with sediment load increased in May 2022 to the highest prevalence since monitoring began and included a significant increase in sediment depth at both locations (Figure 20, Table 6 and 7). Despite these significant increases, the amount of sediment is still relatively low at 0.4mm depth at Camp and 0.237 mm at Holbourne Island in May 2022 at the peak. May 2022 surveys did take place soon after the unseasonably large rainfall event earlier in May that may have contributed to overall sediment at both locations, especially at Camp island near the mouth of the Elliot River system (Figures 4 and 5). Sediment levels, as would be expected, were lower on the more offshore Holbourne Island sites than in the more coastal Camp Island location (Figure 20, Table 6).

Table 6. Changes in frequency and depth of sediment load on corals over the four most recent ambient survey events.

Location:	**Holbourne**		**Camp Is.**	
PERCENT OF TOTAL COLONIES WITH SEDIMENT LOAD				
Oct 2020	5.0%		19.0%	
June 2021	6.0%		26.2%	
November 2021	11.2%		20.2%	
May 2022	37.2%		46.7%	
MEAN MAXIMUM SEDIMENT DEPTH (mm)				
Oct 2020	0.03	*0.01*	0.13	*0.02*
June 2021	0.04	*0.01*	0.30	*0.04*
November 2021	0.08	*0.02*	0.15	*0.03*
May 2022	0.27	*0.03*	0.40	*0.05*

Figures are grand mean sediment depth in mm with standard errors in italics where appropriate.

Table 7. Abbot Point Fringing Reefs: Changes in sediment depth on corals between the last four ambient surveys: Anova Results

	CAMP ISLAND			**HOLBOURNE ISLAND**		
Factor:	**Site**	**Time**	**S x T**	**Site**	**Time**	**S x T**
Coral sediment depth changes	NS	***	NS	***	***	***

NS = not significant; * = 0.05>p>0.01, ** = 0.01>p>0.001; *** = p<0.001

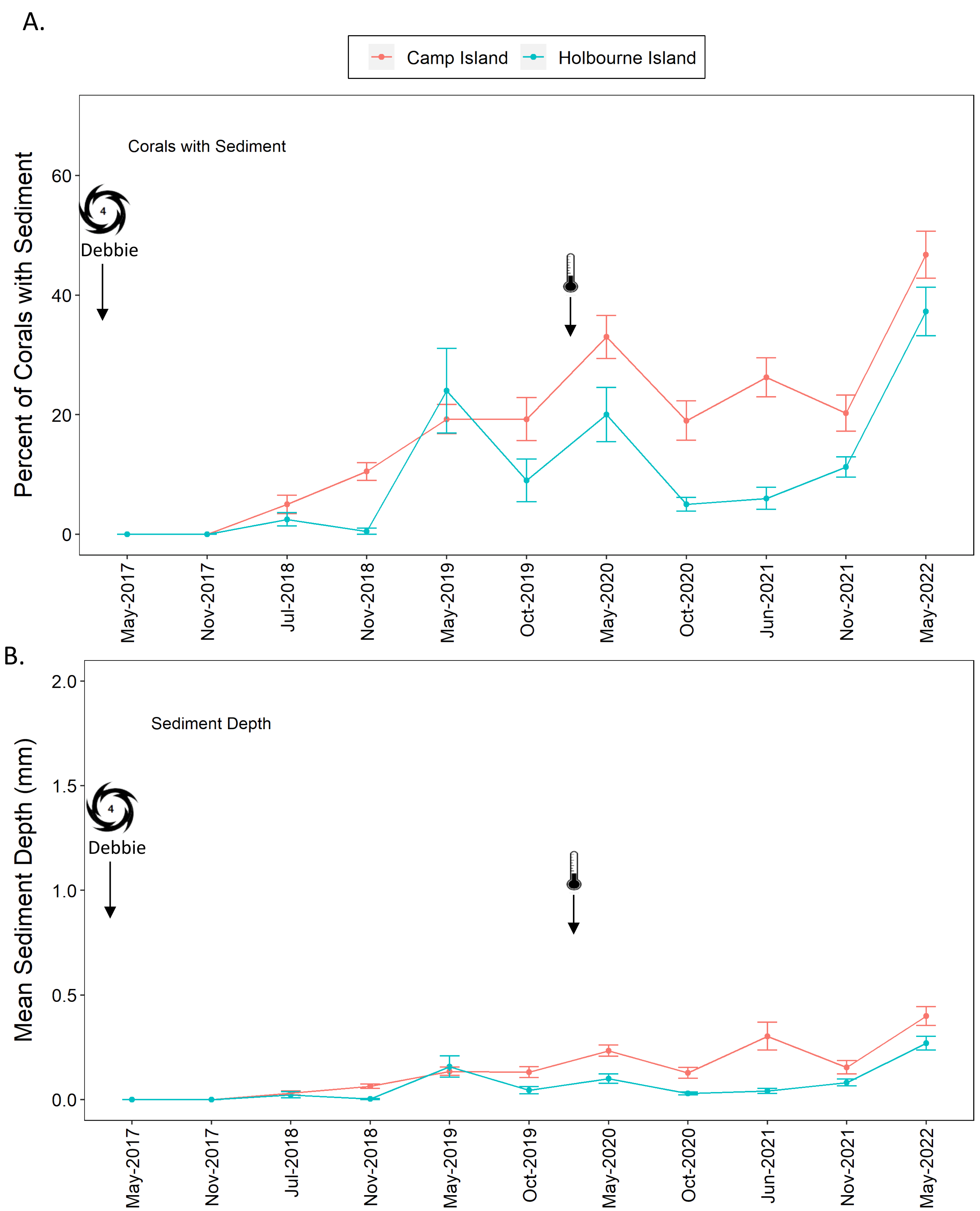


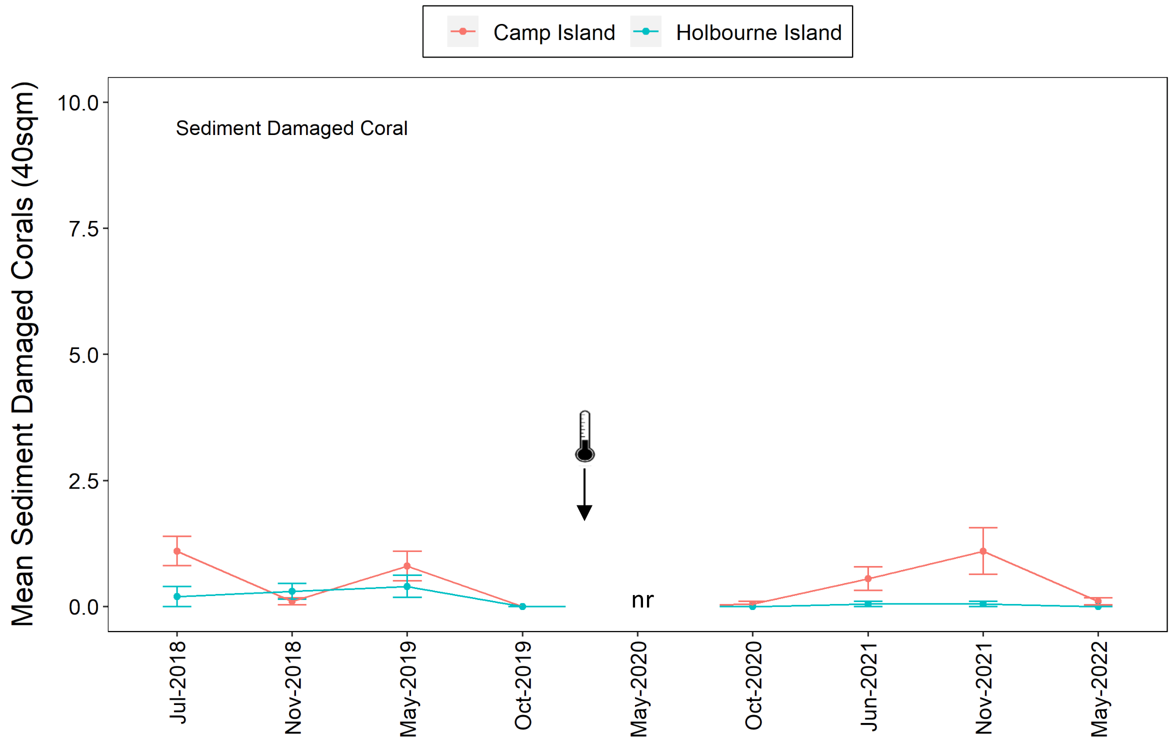
Figure 20. Changes in number of corals with sediment load and sediment depth. Graphs show percentage ± SE of the 400 coral colonies examined in each location that had measurable sediment on part of the surface during each survey and the mean depth ± SE of that sediment for the 2021/22 ambient surveys and for all previous surveys.

2.6 Sediment Damage and Disease in Coral Colonies

Heavy sediment deposition on living coral can cause patches of mortality on the coral surface. At Camp Island, sediment damage was significantly higher than previous surveys in November 2021 (Figure 21A, Tables 4 and 5). This increase in damage follows higher sediment depth and sediment prevalence (30% of colonies) at this location in the previous June 2021 surveys (Figure 20, Table 6). The increase in sediment prevalence and depth in May 2022 did not equate to high sediment damage at this post-wet survey. As with the previous delayed response, pre-wet 2022 surveys may be a better indication of any enduring effect of the higher May 2022 sediment loads. At the site level, a small significant site effect did not translate to any post-hoc significance among Camp Island sites (Table 5). No sediment damage was recorded at Holbourne sites over the four survey period assessed.

A small number of diseased corals are present in most coral reef communities. Disease levels were low during the 2021/22 ambient surveys with a grand mean of 0.15 diseased corals per 40 sq m in May 2022 and November 2021 (Figure 21, Table 4 and 5).

A.



B.

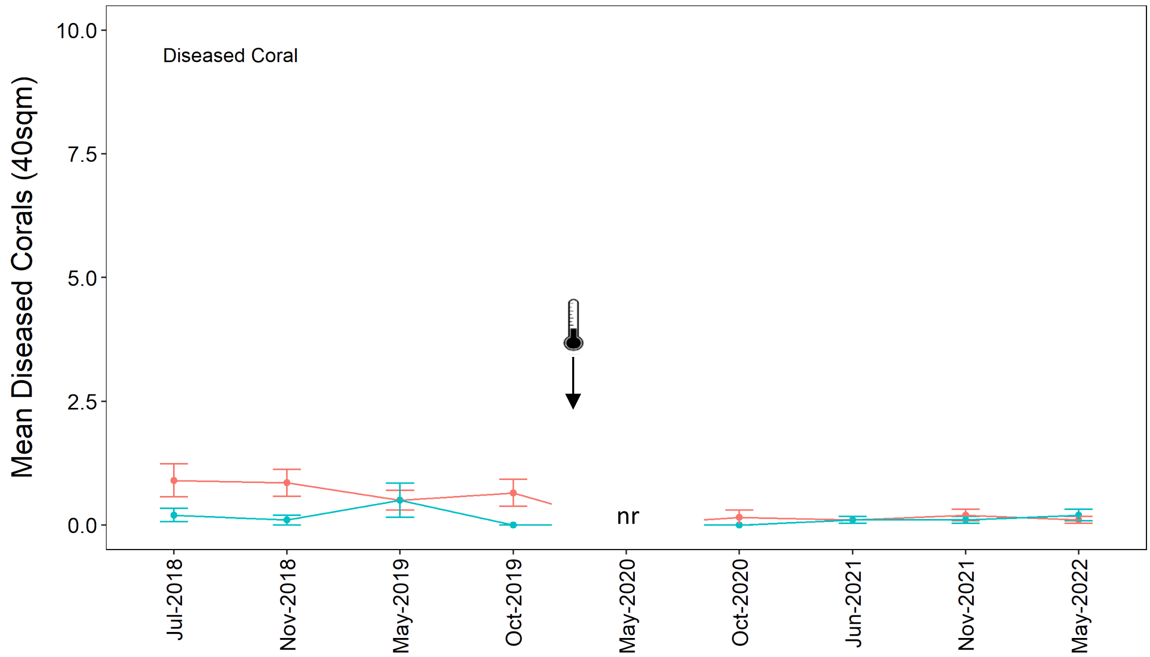


Figure 21. Changes in density of sediment damaged and diseased coral colonies. Graphs show grand mean density ± SE of sediment damaged corals (A) and diseased coral colonies (B) per 40 m^2 from four sites of five 20 x 2m transects in each location from the 2021/22 ambient surveys and all previous surveys. Error bars are standard errors.

2.7 Other Coral Health Issues

Other coral health issues are also recorded during these ambient surveys (Figure 22). Previously, a small number of coral colonies were recorded as damaged due to grazing by the coralivorous *Drupella* snails on several occasions at Holbourne but no evidence of this was observed in 2021/22 surveys along transects (Figure 22). This is in contrast to the large numbers recorded during the October 2017 post-Debbie survey at the original Holbourne East sites where 113 *Drupella* snails were recorded in three corals.

Physical damage was also recorded at one of the Camp Island east sites (East 2) which is shallow and exposed to the SE winds. There are usually some broken branching coral colonies and turned over *Montipora* colonies at this location during each survey (Figure 22). The broken branches are still living and eventually regrow into new colonies or fuse with the parent colonies.

No CoTS have been detected at Camp Island sites since monitoring began while there is an ongoing low level of CoTS at Holbourne Island. Animals were observed on transects at both NE and SE sites on *Acropora* colonies in May 2022 and on a nearby bommie at W1D.

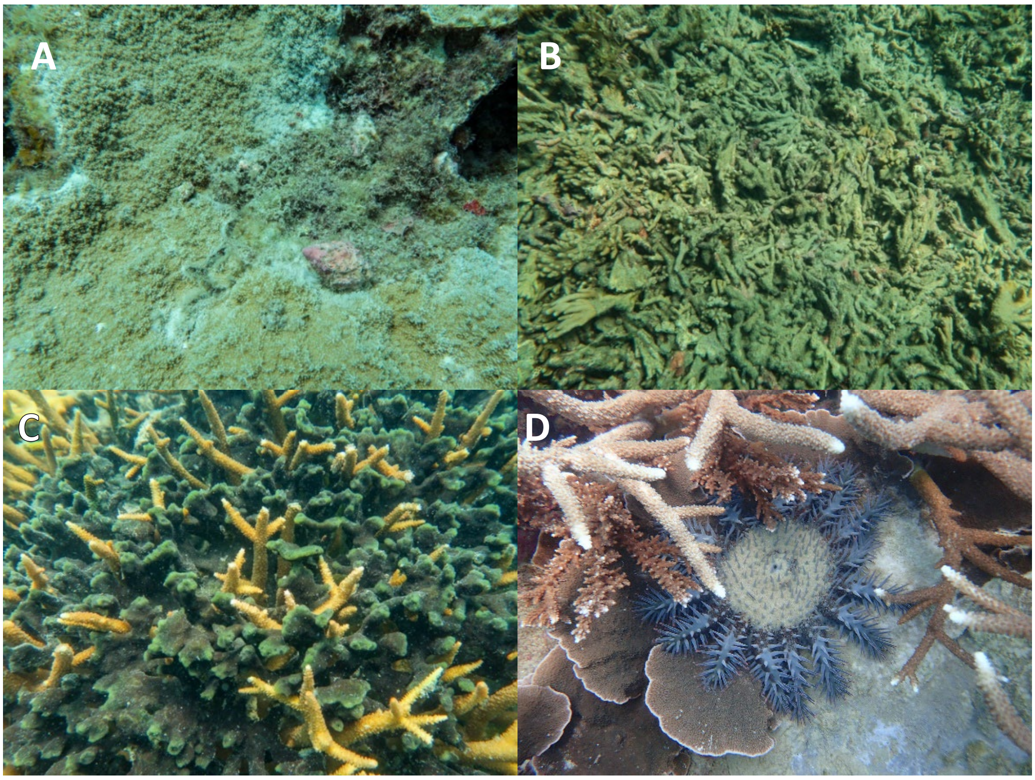


Figure 22. Coral health issues: A) *Drupella* snails grazing on an encrusting *Montipora* coral at the Holbourne deep location in previous years. B) Rubble and broken coral fragments caused by wave action in the Camp Island East 2 site. C) The sponge *Haliclona* growing amongst an *Acropora* colony in the Camp Island location. D) A small number of *Acanthaster* sea stars were still damaging corals in the new Holbourne SE site in May 2022.

2.8 Coral Recruitment Patterns

Numbers of hard coral recruits less than 5 cm in diameter were not significantly different among or within locations at either of the November 2021 and May 2022 surveys (Figure 23, Table 8). Grand mean recruit density was 0.51 m^{-2} in November 2021 and 1.3 m^{-2} in May 2022 at Camp Island, within the expected range at the respective times of year for this location (Figure 23). Recruits were significantly greater in June 2021 at 2.8 m^{-2} for Camp Island compared to surveys before and after in October 2020 and November 2021 with 0.3 m^{-2} and 0.5 m^{-2} recruits respectively (Table 8, Figure 23). At Holbourne Island, recruit density in November 2021 was 1.6 m^{-2}, little change for the time of year from October 2020 at 1.0 m^{-2}. Recruit density at Holbourne in May 2022 was similar at 1.3 m^{-2} with little change from June 2021 estimates of 2.2 m^{-2} recruits (Figure 23). Overall, Holbourne and Camp Island have relatively low recruitment from surveys of other GBR fringing reef areas using the same method (Thompson et al. 2023, A.M. Ayling unpublished data).

The dominant coral group represented in the recruit population for Camp Island was *Acropora* accounting for 40-50% of total recruit numbers (Figure 24). In June 2021, a decline in the proportion of *Turbinaria* recruits to 18% led to a greater proportion of *Fungia* recruits accounting for total recruitment at Camp Island. This compares to approximately 33% and 27% of *Acropora* and *Montipora* respectively during the two previous post-Debbie surveys conducted by AIMS (AIMS 2018). On Holbourne Island, *Acropora* and faviids were the dominant recruits with most coral groups represented to varying extent (Figure 24). *Turbinaria* recruits were present in May 2022 for the first time at a significant level comprising 13% of all recruits (Figure 24).

Table 8. Abbot Point fringing reefs: patterns in the density of hard coral recruits between the last four ambient surveys: ANOVA Results

	CAMP ISLAND			HOLBOURNE ISLAND		
Factor:	**Site**	**Time**	**S x T**	**Site**	**Time**	**S x T**
Hard coral recruits	NS	***	NS	NS	NS	NS

NS = not significant; * = 0.05>p>0.01, ** = 0.01>p>0.001; *** = p<0.001

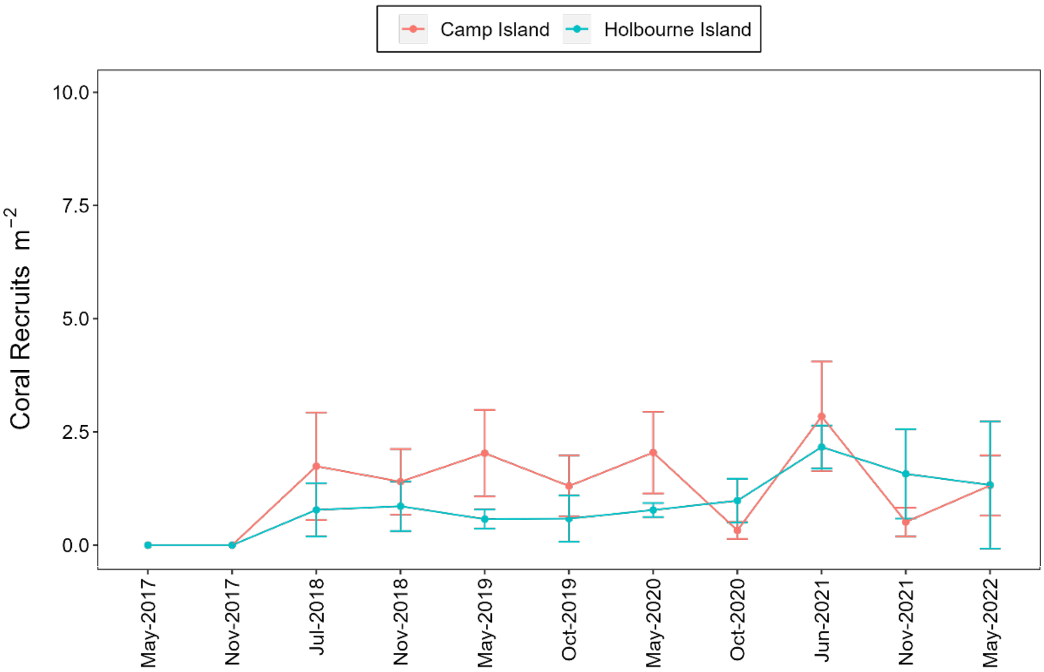


Figure 23. Changes in density of hard coral recruits ± SE over the 2017-2022 ambient surveys. Graphs show mean density of hard coral recruits per m^{-2} from four sites in each location since 2017.

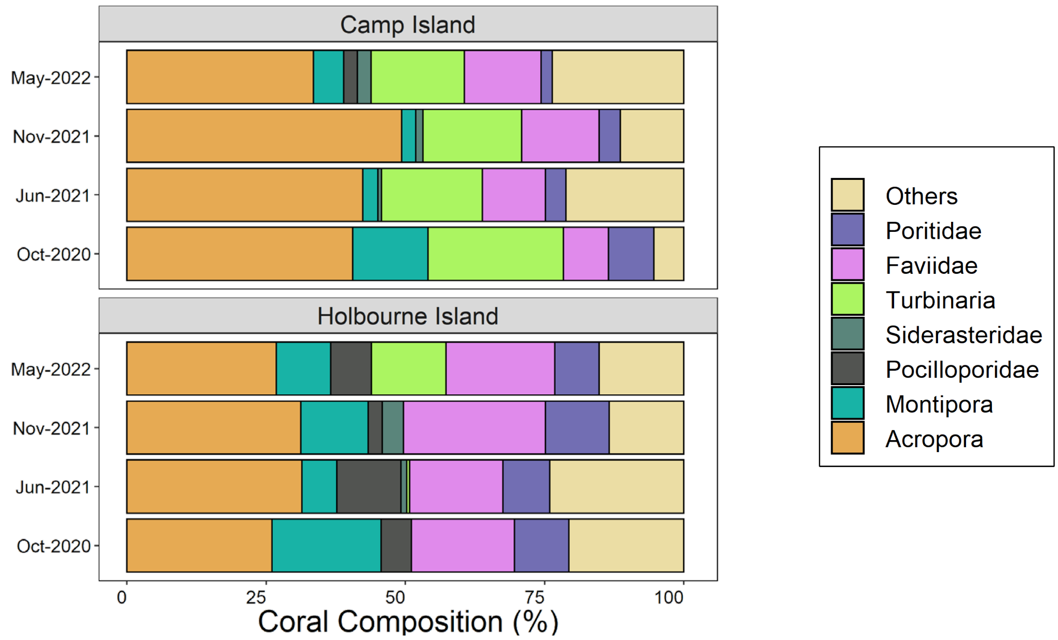


Figure 24. Composition of the hard coral recruit population in the two locations over the last four ambient surveys.

2.9 Coral Community Indicators

The Reef Report Card uses a series of indicators to provide an unbiased scale of overall reef condition and resilience. The full reef report card uses five indicators to derive report card scores (Thompson et al. 2023) but two of these require multiple annual observations or periods without acute disturbances like the 2020 mass bleaching event. This follows the precedent set by AIMS in their report on the first four Abbot Point ambient surveys (AIMS 2018). The three indicators used were: Coral Cover; Juvenile Density and Macroalgae Proportion. For details of methods for these indicators see AIMS (2018) and Thompson et al. 2023).

At the time of the May 2022 survey the Holbourne Island sites were unchanged from June 2021 with an overall score of 'moderate' (Table 9). Overall, juvenile recruitment was down in 2022 leading to lower scores for both locations generating a regional score of 'very poor' down from 'poor' in 2021.The absence of macroalgae cover counteracts the 'very 'poor' score for juvenile density at this location with an unchanged coral cover score of 'poor'. The Camp Island reefs were rated 'very poor' in June 2021 and again in May 2022 due to the low coral cover, high macroalgae and low recruitment. The overall report card score for the Northern Inshore based on these two locations was 'poor'; unchanged from 2021.

Table 9. Reef condition and indicator values during the post-wet 2022 ambient surveys.

Location	Survey	Coral cover	Juvenile density	Macroalgae proportion	Coral cover score	Juvenile score	Macro-algae score	Overall Index
Holbourne Island	May 2022	24.1%	1.3	0.0%	0.32	0.12	1	0.48
Camp Island	May 2022	12.4%	1.3	37.6%	0.17	0.11	0	0.09
Regional Mean	May 2022	18.2%	1.3	18.8%	0.24	0.12	0.50	0.29

Cover score range: ■ Very Poor = 0 to ≤ 0.2 | ■ Poor = > 0.2 ≤ 0.4 | ■ Moderate = > 0.4 ≤ 0.6 | ■ Good = > 0.6 ≤ 0.8 | ■ Very Good = > 0.8 | ■ No score/data gap | ■ Not applicable † Holbourne only has a 2 year record with the current sites instead of 4 to aggregate and determine the coral change score

2.10 Benthic Community Images

Examples of the benthic community structure at each location and examples of coral health impacts are provided in Figure 25 to Figure 34.

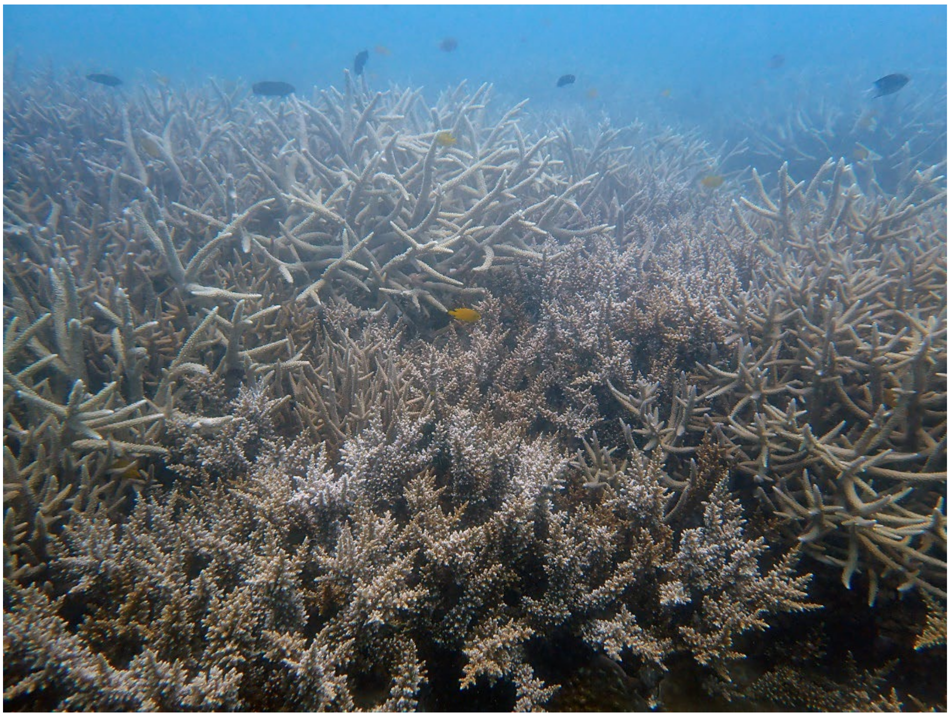


Figure 25. Health *Acropora* branching and bottlebrush corals at Holbourne Island Southeast (SE) location during the November 2021 ambient survey.

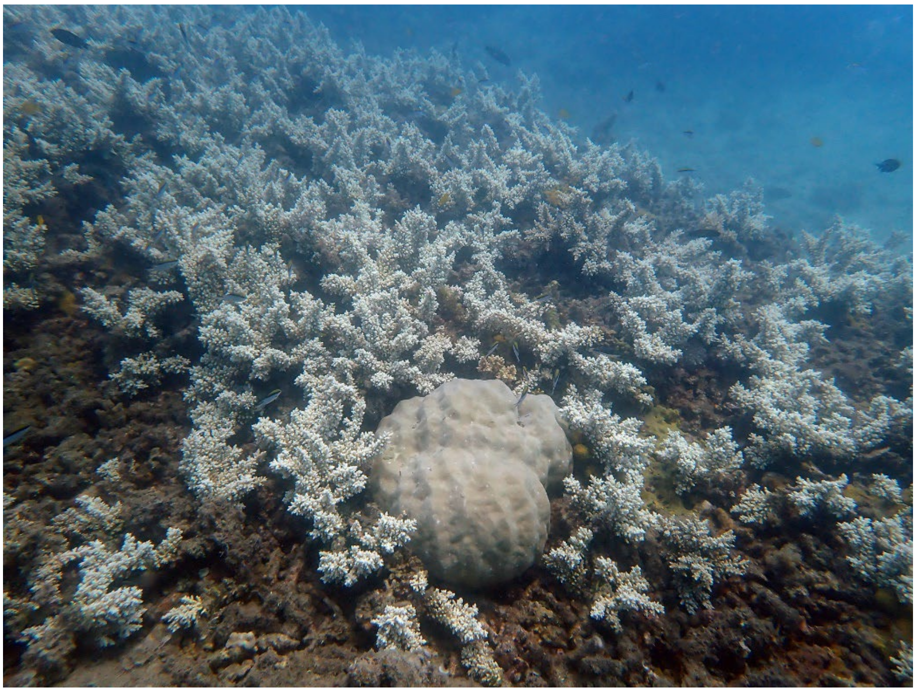


Figure 26. A bottlebrush coral, *Acropora elseyi,* continues to spread over rubble beds created by Cyclone Debbie at Holbourne E2D.

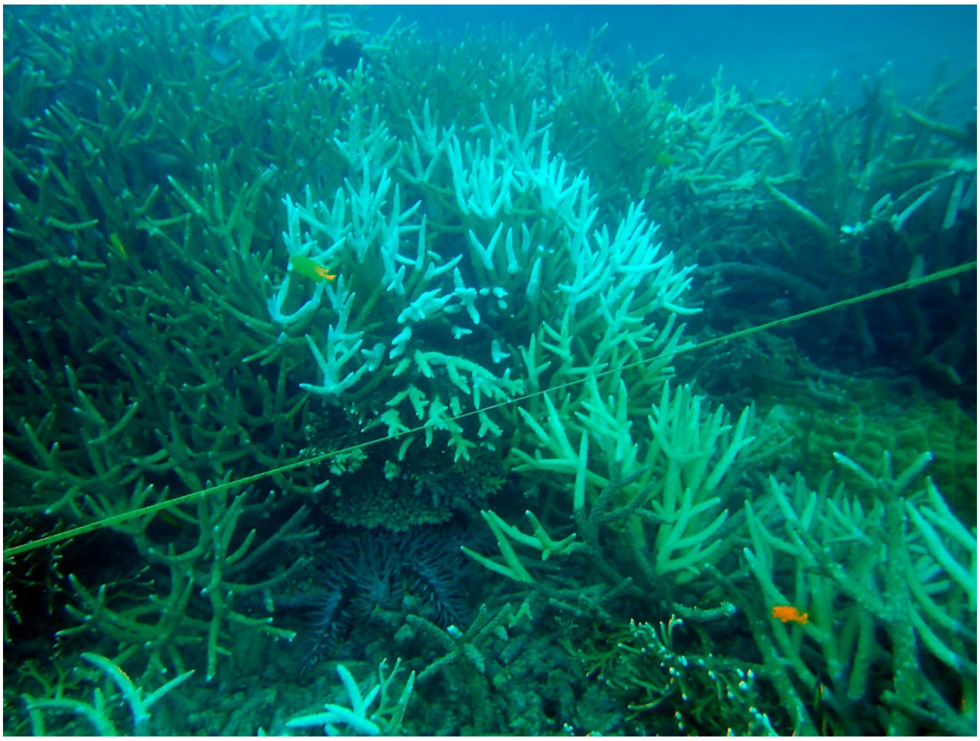


Figure 27. Crown of thorn starfish (CoTS) and associated feeding scars on branching *Acropora* spp. at the Northeast (NE) Holbourne site.

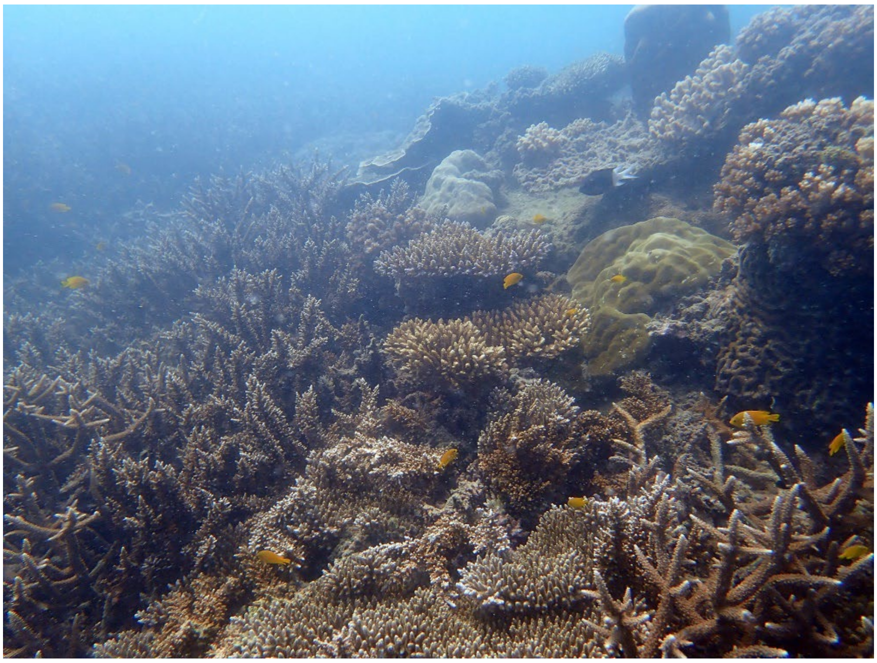


Figure 28. Good coral cover and diversity at Southeast (SE) Holbourne site in May 2022 following summer warm temperatures.

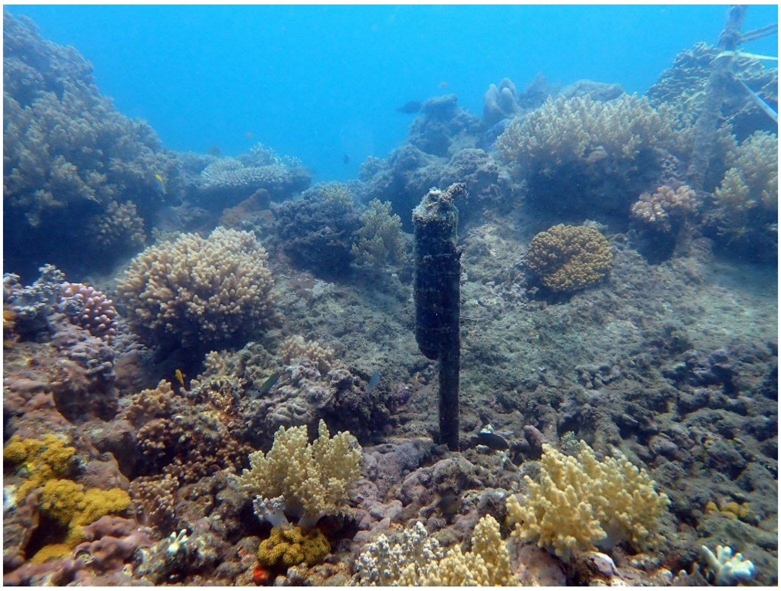


Figure 29. Acoustic receiver placed at E2D to collect data on megafauna using the area in collaboration with Dr. Adam Barnett (JCU). In future, we hope to tag manta rays visiting the local cleaning station which will then track movements using this and other receivers as part of a regional network system to understand population movements.

Figure 30. Despite regular wave exposure at the East 2 site, some healthy *Acropora* plate colonies remain upright amongst rubble and macroalgae stands (in background) typical at this Camp Island site.

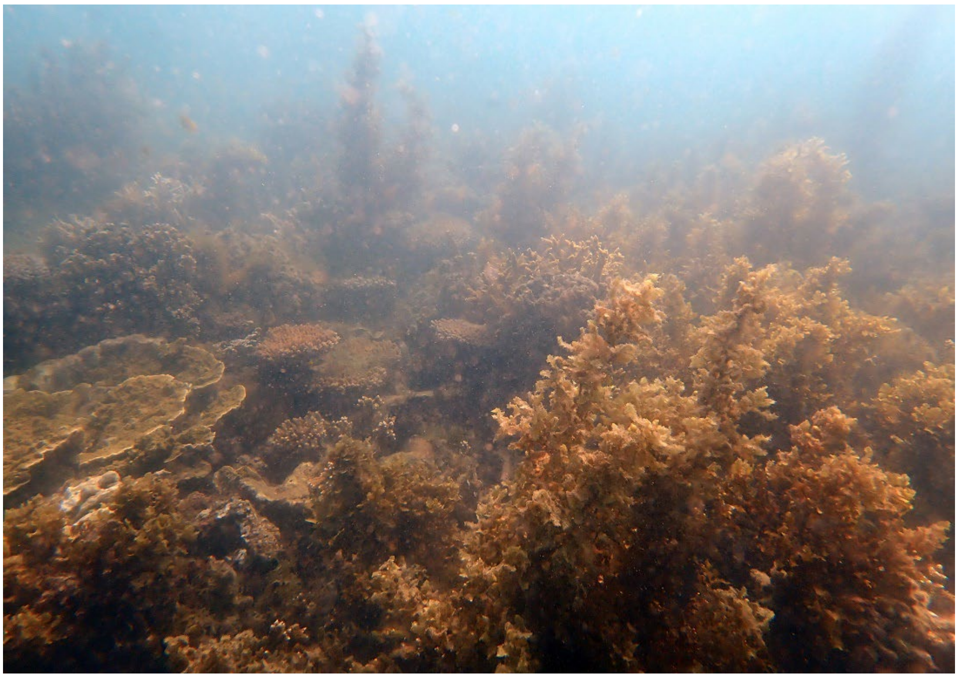


Figure 31. A mixture of macroalgae, *Montipora* and *Acropora* dominate West Site 2 at Camp Island.

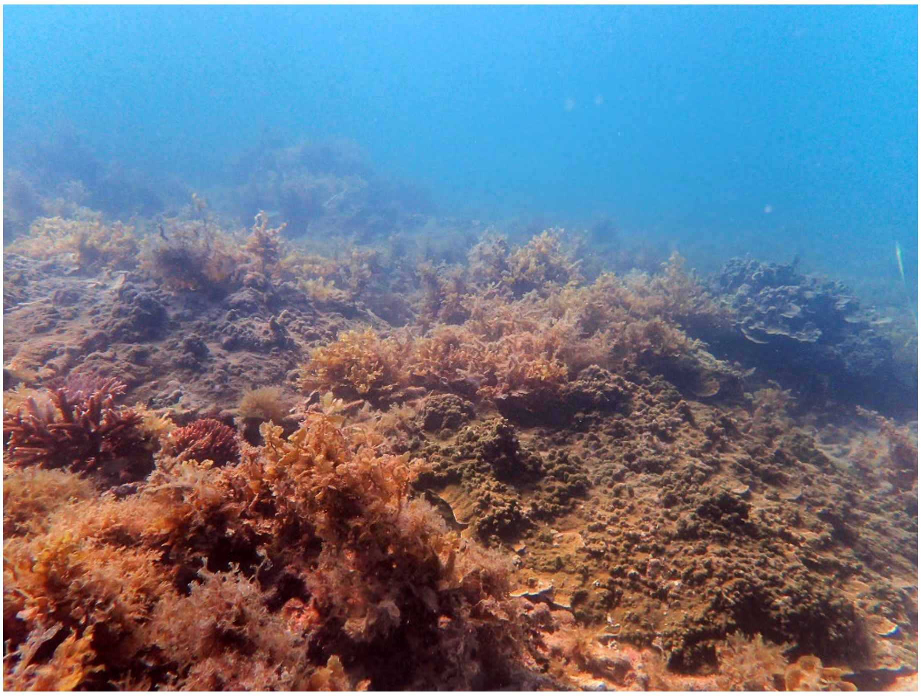


Figure 32. Encrusting *Montipora* corals amongst lower macroalgae levels than observed in the last two years at Camp Island East Site 2 in May 2022.

Figure 33. Large *Galaxea* colonies present at West 1 Camp Island.

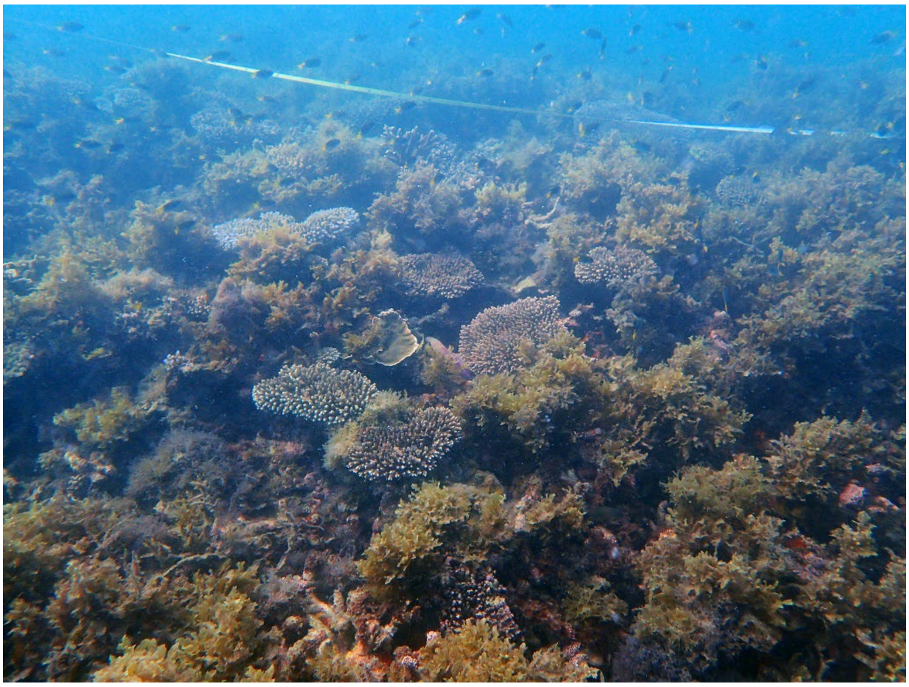


Figure 34. Lower macroalgae levels were also encouraging at Camp Island West Site 2 where substantial blooms have been present over the last few years.

4 DISCUSSION

4.1 Benthic Cover during the 2021/22 Ambient Surveys

Overall, the 2021/22 ambient coral surveys at Abbot Point found 1) small but significant recovery in hard coral cover at Camp Island following the significant declines in October 2020 due to the mass bleaching event earlier that year, and 2) overall stable coral cover at Holbourne Island monitoring sites.

The coral cover at the four sites at Camp Island had all significantly increased in May 2022 following the mass bleaching event which drove a significant mortality of corals in the following months. Coral cover ranged from 1.8% at East 1 to a high of 23.7% at West 1 with the majority of gains from *Acropora* colony growth resulting in a grand mean of 12% coral at this location. Macroalgal cover of 49% in November 2021 was also back down to more typical levels seen prior to the spike in cover that occurred in October 2020. This higher than normal macroalgal cover was hypothesised to be in part fuelled by the release of nutrients on top of typical levels due to localised coral necrosis following bleaching stress feeding a larger than normal *Sargassum* bloom. Further declines in macroalgae in May 2022 to 38% is a good sign for this location, providing greater open substrate for new coral recruits and less competition for light for corals in the understorey of the algal canopy.

Original site selection at Camp Island also is a factor that affects the location level coral cover estimates. Sites were selected by AIMS haphazardly from the surface on areas of substrate suitable for corals (AIMS 2018) but a slight repositioning of several of the sites would have given more consistency and increased the grand mean coral cover significantly. Although the present site selection does cover a good range of possible reef types from algal dominated (e.g. site East 1 and West 2) to hard coral dominated (site West 1), it is future trajectories of coral dominated sites that most aligns with the objectives of this ambient program.

Coral communities at Holbourne Island have remained stable with an overall 24% hard coral cover since the adjusted design was put in place in October 2020 which initially increased coral cover estimates. Holbourne sites, NE and SE, increased the overall coral cover by about 10% for this location compared to assessing the old sites alone. The coral assemblage is also more diverse and representative of this mid-shelf location and provides a better baseline from which further impacts or recovery can be measured at the appropriate depth stratum. Old monitoring sites removed from the program in more shallow depths were decimated by Cyclone Debbie (AIMS 2018) and no signs of recovery were found over three years of biannual surveys. The deeper sites that remain in the program as well as the two new sites on the eastern side of the island provide a better representation of coral communities in order to measure their trajectories at this location. At the original sites still monitored, surviving corals have been slow to re-grow and recruitment of new coral colonies has been unusually slow despite ample open substrate for colonisation. Similar slow recovery was noted by AIMS during the decade after CoTS outbreaks damaged coral communities around Holbourne Island in 1987 (AIMS 2018). The isolation of this reef in the middle of the shipping channel may be partly responsible: it is at least 40 km inside the band of mid-shelf reefs in this region of the GBR and about 30 km from the inner fringing reefs. Recruitment at the new sites also appears to be relatively low despite relatively high coral cover with 20% and 54% cover at NE and SE sites in May 2022. If coral is impacted by an acute event such as a mass bleaching or cyclone, coral recovery may also struggle at these currently better off sites.

In comparison to trends observed at these Abbot Point monitoring locations, the Port of Mackay and Hay Point ambient coral monitoring program also recorded stable or increasing hard coral cover at the three inshore locations over this same period (Chartrand et al. 2022). Both port programs help put trends in coral and the broader benthic community composition in perspective with potential regional scale impacts and potential for recovery.

The severe temperature anomaly during the early months of 2022 had the potential to affect Camp Island and Holbourne Island coral communities by generating a significant coral bleaching event caused by high temperature stress (Figure 6B). Despite similar warm water recorded in early 2020 that resulted in a documented bleaching and subsequent dieback of corals on these reefs, no substantial bleaching was recorded in May 2022; only two months following the warm water event. The period of extreme temperatures and associated alert level in 2022 by NOAA was slightly shorter and broken by a period in which temperatures briefly dropped in February before increasing further. In comparison, the warm water was elevated for a consistent and longer period in 2020 which may explain the difference in significant bleaching in early 2022 at these locations. In addition, there is some evidence that corals exposed to repetitive warm water events may build up some tolerance to more extreme water temperatures or that those corals that survived previous extreme events may be more adapted to withstand warm water stress and therefore surviving corals do not show the same visible impacts (DeCarlo et al. 2019).

4.2 Sedimentation and Coral Damage

Corals on inshore fringing reefs must deal with heavy sedimentation as part of normal environmental conditions. Inshore waters become very turbid from resuspended sediment during any strong wind event and this sediment settles on all fringing reef corals. These corals are able to actively remove surface sediment unless rates remain very high for long periods or corals are under stress and have reduced sediment removal capacity (e.g. during bleaching). It takes extreme events like cyclones or prolonged rough weather to overwhelm coral colonies natural sediment removal mechanisms. In these cases sediment may accumulate in depressions on the surface of vulnerable coral colonies and eventually cause small patches of mortality. Such dead patches occur naturally on most fringing reefs and are usually repaired, once sediment levels decrease, by regrowth from the edges of the damaged patch.

The Holbourne locations, being further offshore, in a generally less turbid water mass and with lower levels of silt in the bottom sediment (AIMS 2018) have much lower rates of sedimentation and sediment damage to corals than most fringing reefs. Camp Island, although only 2 km from the coast and the Elliot River mouth, appears to be in an unusually clear water mass most of the time and has historically during the monitoring program had relatively low rates of sedimentation and sediment damage. AIMS reported that they experienced 5m+ underwater visibility during their surveys and Sea Research has recorded 5-10m underwater visibility on all visits to the location.

Over the monitoring program, the sediment found on colonies and sediment depth appears to be increasing in frequency at Camp Island and at Holbourne Island as of May 2022. A continued loss of live coral cover and increasing macroalgae at Camp Island may enable further retention of fine particles and sediment, creating further burdens to the surviving coral community. The bleaching stress over the 2020 period may have interfered with the ability of corals to remove sediment from their surface, leading to an unusual number of corals with recorded surface sediment over the latest monitoring surveys. Additional sediment loads from the Elliot River may also be driving localised increases around Camp Island. Timing of surveys may also contribute to patterns recorded during surveys. Just prior to the May 2022 surveys, the Abbot Point region received substantial rainfall and subsequent river discharge from the Don and Elliot River systems. Storm activity can temporarily increase sediment on coral surfaces that may not translate to sediment damage or colony mortality. One-off measures of sediment depth are useful but do not give an indication of the temporal extent of sediment load which sediment damage may more accurately represent. Despite the increased depth and frequency of corals observed with sediment, damage was absent from Holbourne Island sites and extremely low at Camp Island. Further monitoring will help to understand if the prevalence of sediment in the system is a short- or long-term trend at these locations.

4.3 Other Sources of Coral Mortality

Levels of coral disease during these ambient surveys was quite low with only 0.1 or 0.2 diseased colonies per 40 sqm at Camp Island and Holbourne Island in November 2021 and May 2022, respectively. Corals usually affected by disease during these surveys were acroporids and a small number of pocilloporids. Disease of

Montipora colonies, atramentous necrosis, on Camp Island had been regularly found by both Sea Research and AIMS during previous surveys but has not been present following the dieback of *Montipora* from the 2020 bleaching event. The lower proportion of *Montipora* may in part explain the lack of this disease following the bleaching-related mortality. Coral disease is usually more prevalent when water temperatures and nutrient levels are higher (AIMS 2018). Monitoring of disease long term will help to explain whether this disease returns as the corals at this location stabilise following bleaching stress and the dieback events. In general, a small number of corals are affected by disease on most fringing reef locations at any one time and this rarely causes significant coral mortality (Ayling and Ayling 2005). Black band disease in *Turbinaria* and *Psammocora* corals was responsible for a small but significant reduction in overall coral cover in the Hay Point region during the summer of 2006 (GHD 2006) and the atramentous necrosis mentioned above caused a slight reduction in *Montipora* cover at Camp Island over the four surveys between July 2018 and October 2019 but has not been noted as a concern since.

The ongoing presence of *Acanthaster* starfish (CoTS) at Holbourne Island could further damage coral communities that are struggling to recover from Cyclone Debbie damage and now the latest bleaching event further slowing recovery. The presence of CoTS at the new Holbourne Island monitoring sites has the potential to negatively affect the higher coral cover areas on the NE and SE face of the island. However, the scale of the outbreak to date has not led to widespread losses in recent surveys but may be stunting recovery rates.

Large numbers of coral grazing *Drupella* snails were recorded by AIMS in the Holbourne East deep sites in October 2017 but no snails have been recorded in significant numbers since this time including during the 2021/22 surveys. Cyclone Debbie reduced coral cover markedly on Holbourne and this has the effect of concentrating low densities of *Drupella* into the few remaining corals. This can lead to a pulse of coral damage but the *Drupella* reduce in numbers as they destroy the corals they have retreated into (A.M. Ayling personal observations).

4.4 Implications of Coral Assessment

Coral cover at Camp Island increased significantly in May 2022 for the first time from October 2020 levels during which 54% of corals were lost from pre-bleaching estimates. The overall increase was from the low of 5.4% in October 2020 to 12.4% in May 2022. *Acropora* colonies are largely driving the measurable change at all sites, with some increases in the *Montipora* community which was also was heavily impacted by bleaching at this location. Until the 2020 coral bleaching episode, coral communities on Camp Island appeared to be healthy and growing well although smothered by algal growth as a seasonal challenge at this location. There has been little evidence that macroalgae are increasing on Camp Island reefs at the expense of coral cover. It is probable that the algal communities recorded during these surveys have been present on this island for many decades. The return to more typical macroalgal levels in 2021/22 may further assist with recovery as corals have space to grow and available substrate is more available to recruits. Strong recruitment, relatively good water quality and open substrate will be important for these reefs to recover. The unique macroalgae community and increasing pattern in sediment load on corals at Camp Island, however, are factors known to hinder recruitment success and survivorship and therefore could affect rates of recovery.

Cyclonic impacts more than acute effects of the recent bleaching event has reduced coral cover significantly at Holbourne Island. The slow rate of recovery of hard coral communities on these fringing reefs in the greater than four years since Cyclone Debbie is a cause for concern but is in line with the decadal long recovery times reported by AIMS following CoTS grazing damage to Holbourne coral communities in 1987. Further damage caused by CoTS grazing and coral bleaching is now exacerbating this slow recovery. The established Holbourne Island survey sites are all on the continuous fringing reef that sweeps in a crescent around the south and west faces of the island. The sites commissioned on the eastern face of the island in late 2020 based on recommendations by A.M. and A.L. Ayling show that corals were not as badly impacted by Cyclone Debbie on these reefs and have provided more balanced view of coral recovery on Holbourne as a whole to better understand the bigger picture of recovery and trend at this location.

Overall, 2021/22 surveys at Camp Island and Holbourne Island found similar stable patterns with some stronger recovery of coral cover at Camp Island compared to Holbourne Island. While cyclones have driven declines at Holbourne Island, Camp Island has been largely affected by the mass bleaching event. Despite different acute impacts, both are in need of further recovery to return to levels first recorded when sites were established in 2017. Recovery will likely take a decade or more based on studies of similar reef systems with a real risk that further climate-related impacts such as bleaching and cyclones may hinder any recovery that occurs. In addition, ongoing CoTS outbreaks on the GBR and the presence of these animals at Holbourne Island create further potential to drive long-term declines in in coral assemblages, adding to the cause for concern for these local reef systems. In summary, the stability in coral cover at both locations in 2021/22 and lower macroalgae at Camp Island are favourable for potential recovery if no significant disturbances affect this trajectory.

5 REFERENCES

Ayling, A. M. and Ayling, A. L. 1995. A preliminary survey of benthic communities on fringing reefs in the middle Cairns Section. Unpublished report submitted to the Great Barrier Reef Marine Park Authority.

Ayling, A. M. and Ayling, A. L. 2002. Long term monitoring program for marine benthos in the vicinity of Keswick Island development (Whitsunday Island Group): baseline survey, Unpublished report to the Great Barrier Reef Marine Park Authority. 18 pp.

Ayling, A. M. and Ayling, A. L. 2005. The Dynamics of Cairns and Central Section Fringing Reefs, Unpublished report to the Great Barrier Reef Marine Park Authority. 81

BOM. 2017. Daily rainfall measured at the Mackay Airport (Station number 033045).

DeCarlo, T. M., Harrison, H. B., Gajdzik, L., Alaguarda, D., Rodolfo-Metalpa, R., D'Olivo, J., Liu, G., Patalwala, D. and McCulloch, M. T. 2019. Acclimatization of massive reef-building corals to consecutive heatwaves. Proceedings of the Royal Society B: Biological Sciences, **286**: 20190235

Jonker, M. J., Bray, P. E., Johns, K. A. and Osborne, K. O. 2020. Surveys of benthic reef communities using underwater digital photography and counts of juvenile corals. Long Term Monitoring of the Great Barrier Reef - Standard Operational Procedure Number 10, 2nd ed. . Townsville, Australia, https://doi.org/10.25845/jjzj-0v14, 36 pp.

Jonker, M. M., Johns, K. K. and Osborne, K. K. 2008. Australian Institute of Marine Science Standard Operational Procedure Number 10 - Surveys of benthic reef communities using underwater digital photography and counts of juvenile corals. AIMS.

Mapstone, D. D., Choat, J. H. and Cumming, R. L. 1989. The fringing reefs of Magnetic Island: Benthic biota and sedimentation – a baseline survey. Unpublished report to the Great Barrier Reef Marine Park Authority, 88 pp.

Sea Research. 2017. Ports of Mackay and Hay Point Ambient Coral Monitoring Surveys: 2016-2017. Unpublished report to North Queensland Bulk Ports Corporation.

Thompson, A., Davidson, J., Logan, M. and Thompson, C. 2023. Marine Monitoring Program Annual Report for Inshore Coral Reef Monitoring: 2021–22. Report for the Great Barrier Reef Marine Park Authority. Great Barrier Reef Marine Park Authority, Townsville, 143 pp.

WIMP. 2016. Queensland Government Water Monitoring Information Portal for The Pioneer River at Dumbelton Weir (Station Id: 125016A)

6 APPENDIX

Figure A1. Changes in the cover of macroalgae by site for each location.
Graphs show grand mean percentage benthic cover from the 2021/22 ambient surveys for each location in bold with simple lines indicating mean cover at the site level. Black line indicate the change to photoquadrat methodology in October 2020.

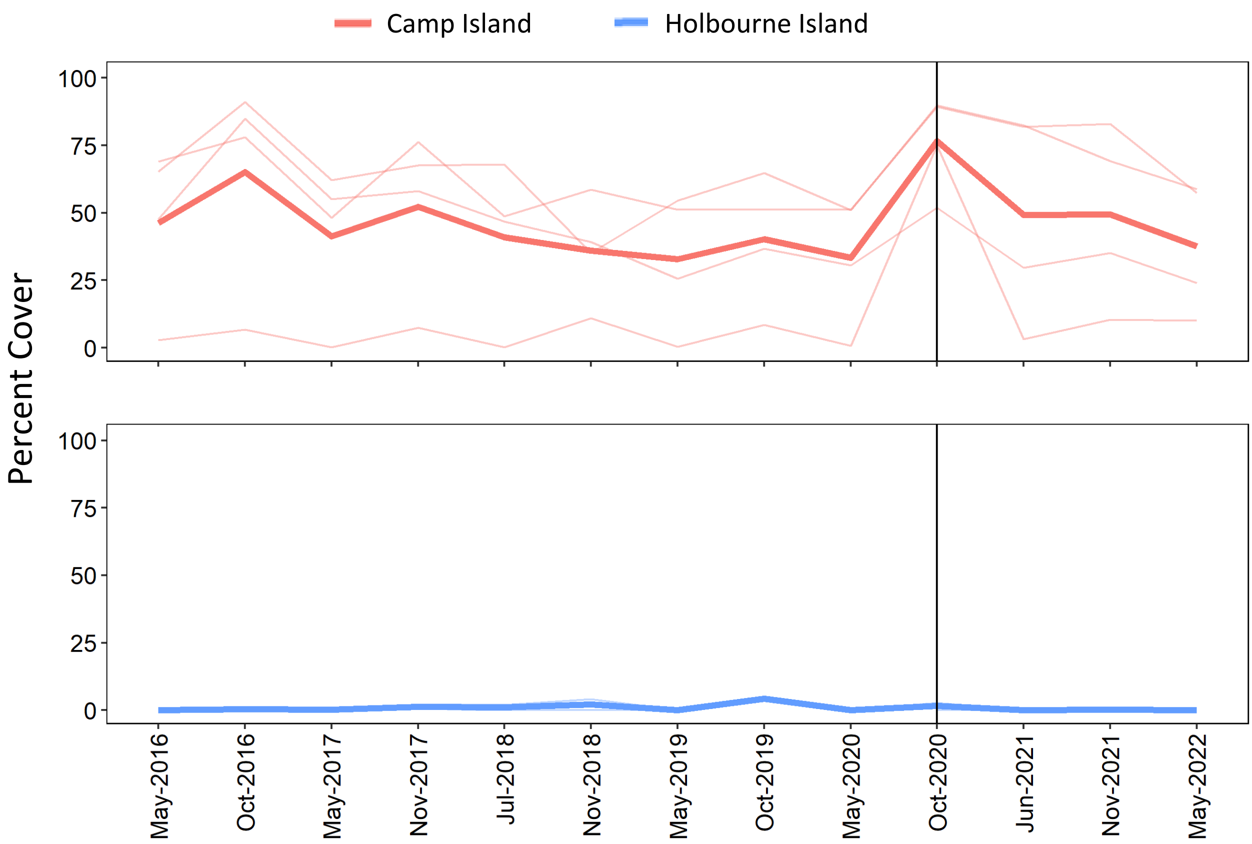


Figure A2. Changes in the cover of total hard coral by site for each location.
Graphs show grand mean percentage benthic cover from the 2021/22 ambient surveys for each location in bold with simple lines indicating mean cover at the site level. Black line indicate the change to photoquadrat methodology in October 2020.

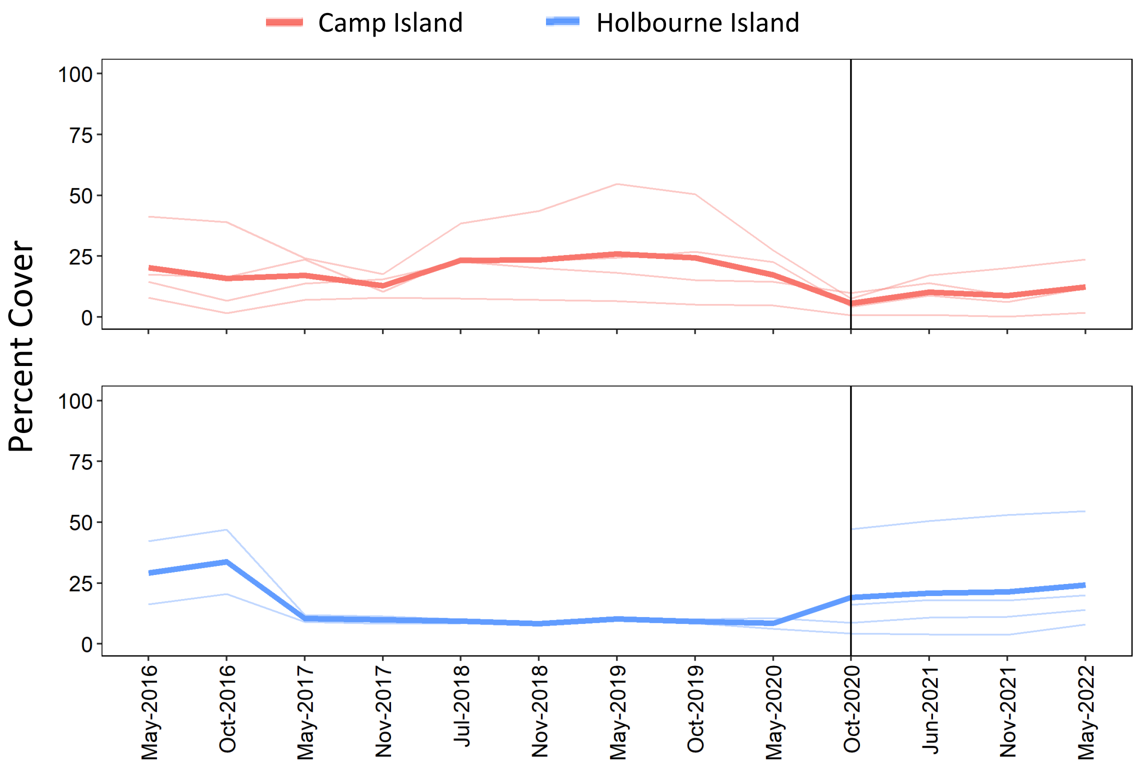


Figure A3. Changes in the cover of sponges by site for Camp Island.
Graphs show grand mean percentage benthic cover from the 2021/22 ambient surveys for each location in bold with simple lines indicating mean cover at the site level. Black line indicate the change to photoquadrat methodology in October 2020. Camp Island