Magnetic Island Long-Term Coral Monitoring:

February 2022 Fringing Reef Resurvey and Comparison with all Previous Surveys

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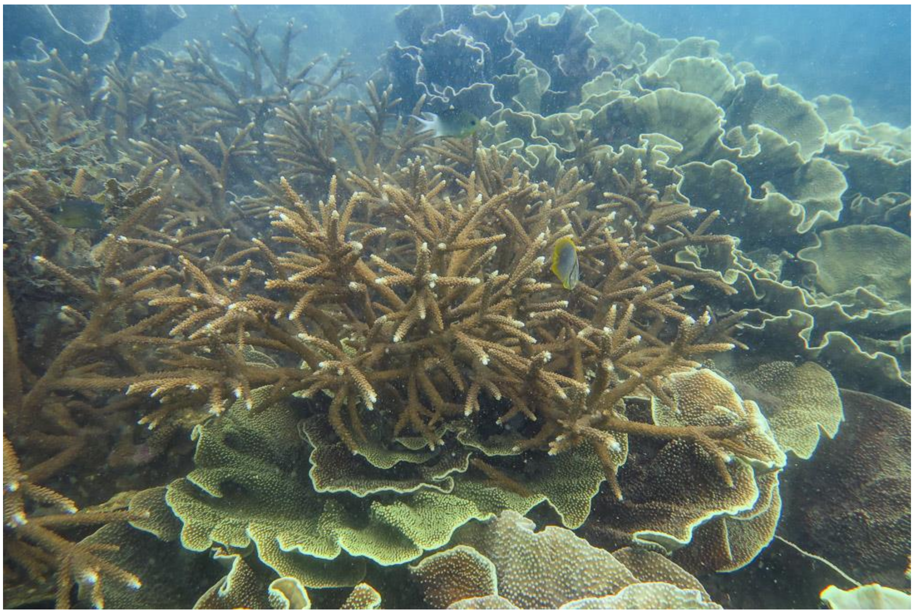
For

Magnetic Island Community Development Association

February 2022



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1. SUMMARY

Sea Research first surveyed Magnetic Island fringing reefs in late 1988/early 1989 as part of a baseline monitoring program for the proposed Magnetic Quays marina in Nelly Bay. A number of reef slope sites were set up and surveyed using four permanently marked 20m transects at each site. Permanent transects give a more powerful measure of benthic cover than randomly placed transects in highly variable reef communities. These sites were also used for subsequent monitoring programs and were surveyed a total of sixteen times between 1989 and 2006. The Magnetic Island Community Development Association commissioned a resurvey of these sites in 2022 to get some indication of changes in Magnetic Island fringing reefs over the past 33 years.

Percentage coral cover was measured by running a fiberglass tape along the original transects and using line intercept techniques to record the intercept length in centimetres of each benthic organism immediately beneath the tape. The intercepts for each benthic group were summed and converted to a percentage cover. A photographic record was made of the coral community along each transect by taking a series of 20 images along the landward side of the tape. The transects had not been maintained for sixteen years and it was not possible to run the tapes along exactly the original path but a few marker stakes remained and every effort was made to keep the transects as close to the original positions as possible.

In early February 2022 a total of 27 of the original sites were resurveyed. Tony Ayling of Sea Research, who carried out most of the previous surveys of these sites, conducted the line intercept measurements for this resurvey. Twelve sites were surveyed in Nelly Bay, six in Geoffrey Bay and three each in Arthur, Florence and Picnic Bays.

Macroalgae, mainly *Sargassum* and *Lobophora*, are often common on fringing reefs and this group covered a grand mean of 19.6% of the reef substratum during the 2022 survey. Macroalgal cover had fluctuated by almost an order of magnitude over the 33 year span of these surveys but was similar to present levels in March 2000 and only a little lower during the original 1989 baseline.

Grand mean hard coral cover was 42% on Magnetic Island fringing reefs during the 1989 baseline. Coral cover reduced to a low of 31% following the three major impacts of coral bleaching in 1998 and 2002 and TC Tessi in March 2000. In the absence of further impacts coral cover increased to almost 43% by late 2006. Grand mean coral cover from the 2022 resurvey was 37%, well above the 2003 lows and only slightly lower than the baseline and 2006 levels.

Coral abundance was different in the different Magnetic Island bays, being on average lower in Geoffrey Bay and highest in Florence and Arthur Bays. Grand mean coral cover from the 16 surveys between 1989 and 2006 was 36% in Nelly Bay, 31% in Geoffrey Bay and 42% in Florence and Arthur Bays. This compares well with coral cover measured in the 2022 resurvey: 35.7% in Nelly; 34.8% in Geoffrey and 41.3% in Florence/Arthur.

Magnetic Island fringing reefs have different coral composition in the different bay locations. Although there have been fluctuations in this composition over the past 33 years

major changes have only occurred in Geoffrey Bay where the previously dominant acroporid corals have declined markedly and been replaced by a variety of other coral groups.

The four shallow sites closest to the Nelly Bay marina are the only sites to show major coral cover reductions since they were first set up in March 2000. Coral cover has reduced from 77% to 15% in these sites while macroalgae increased from 15% to 41%. Although these shallow sites may be being impacted by marina operations most of this coral cover reduction is probably due to natural cyclone and bleaching impacts over the past 22 years. Recovery has not kept pace with these impacts, which may be influenced by chronic marina effects.

A short video documenting the condition of the Magnetic Island reefs and the results from the 2022 and all previous surveys is available on YouTube: https://youtu.be/d5YVBRM6rac.

Acknowledgements:

Our thanks to Dani Ceccarelli for suggesting this fringing reef resurvey, for providing wonderful assistance and discussion during the field work program and providing input to this report. Gemma Wickens, the Reef Community Action Plan leader for the Magnetic Island Community Development Association, for organising volunteers and scuba tank fills for the field work. Thanks also to Gemma, Maeve and Hayley for providing valuable help with the field work. Pleasure Divers Magnetic Island provided invaluable scuba tank hire and fill support for the diving field work. Thanks also to Andy Lewis for his information on recent Magnetic Island weather and bleaching impacts.

2. INTRODUCTION

2.1 Magnetic Island monitoring history

The Nelly Bay marina on Magnetic Island was initiated in 1988 as part of the Magnetic Quays project. As part of this project a comprehensive monitoring program was established by JCU. Sea Research was asked to organise the field benthic surveys required for this monitoring program. A number of survey sites were set up on the fringing reefs in each of five bays along the east and south coasts of Magnetic Island. A total of 26 reef slope sites were established and surveyed three times during 1988-1990. Although the Magnetic Quays project stalled and was mothballed these monitoring sites were re-activated as part of another monitoring program for the 1.5 million cubic metre Townsville Port Authority (TPA) dredging in 1993. Sea Research again carried out the field surveys for this new monitoring program although the survey methods used video transects rather than the original line intercept methods. Three surveys were carried out for this project during 1992 and 1993.

In early 1998 the GBRMPA funded Sea Research to carry out maintenance on these permanently marked sites and resurvey them using both previous methods to enable comparison of the results. The marina project was resurrected as Nelly Bay Harbour in 2000 (Figure 1) and GHD was appointed to carry out the overall environmental monitoring program. Sea Research was again contracted to carry out the benthic component of this monitoring program using the same sites as previously but with a few additions and deletions. The modified program used 26 reef slope sites and four reef flat sites in four bays. These sites were resurveyed seven times between March 2000 and June 2003. The GBRMPA funded a further resurvey of the reef slope sites in 2005, while the TPA funded a partial resurvey in late 2006.

2.2 Fringing reef resurvey 2022

The Magnetic Island Community Development Association instigated a Reef Community Action Plan in 2021 and approached Sea Research to resurvey all the old monitoring sites that had been surveyed sixteen times between 1989 and 2006. It was envisaged that this would give some indication of the long-term changes experienced by Magnetic Island fringing reefs over a 33 year period.

This document presents the data from the February 2022 resurvey and compares the benthic community with the results from all previous surveys of the same sites.

Figure 1. The completed Nelly Bay marina on Magnetic Island.

3. METHODS

3.1 Survey Design

A pilot study determined that the most appropriate monitoring design incorporated a number of sites with four 20 m survey transects at each site. For the Magnetic Quays program 26 reef slope sites were set up: ten in Nelly Bay; eight in Geoffrey Bay; two on Bright Point; two in each of Arthur, Florence and Picnic Bays (Figure 2). The bulk of the sampling was in Nelly and Geoffrey Bays because they were the most likely impact sites from the marina construction. In subsequent monitoring programs a third site was set up in both Arthur and Florence Bays and the Bright Point and Picnic Bay sites were dropped as well as the two northern-most Geoffrey Bay sites. As part of the 2000 Nelly Harbour program four new sites were set up on the shallow reefs immediately adjacent to the marina breakwater and the marina entrance channel (Figure 3). For the 2022 resurvey we included 27 reef slope sites: twelve in Nelly Bay, six in Geoffrey Bay and three each in Arthur, Florence and Picnic Bays.

3.2 Benthic survey methods

The four survey transects at each site were arranged parallel to the reef edge within an area of reef about 50 x 10 m in size. The transects were originally permanently marked with reinforcing rod stakes driven into the bottom at 5m intervals. Fixed transects are a better way to measure change in reef benthic communities than haphazardly placed transects because of the extreme patchiness that is a characteristic of coral reefs. However, in 2022 the transects had not been maintained for more than 15 years and many stakes had either rusted away, been covered by growing corals or dislodged during strong wind episodes. Although some stakes still survived, for this survey the transect marker tapes were run in approximately the original positions from the GPS position in the middle of the site. This ensured that most of the benthic variability was accounted for and that any changes would be genuine temporal shifts rather than just measuring different sections of the community.

Each transect was marked by running out a 20m fibreglass tape. Benthic cover was assessed using line intersect techniques by recorded the intercept in centimetres of each coral or other benthic organism immediately under the tape. The following benthic categories were recorded: all macroalgae; all sponges; all hard corals to genus or genus and growth form where appropriate, and all soft corals to genus level. The recorded intercepts were summed for each category and converted to a percentage cover. Similar techniques were used for most previous Magnetic Island reef surveys (Mapstone et al. 1989, Kaly et al. 1993, Ayling and Ayling 2005). Tony Ayling carried out most of the previous surveys and also recorded the line intercepts for this survey, ensuring that there was minimal observer bias in the data.

A photographic record was made of the reef community along each transect by recording a series of 20 images of a one metre wide strip along the landward side of each tape.

Figure 2. Magnetic Island east coast showing the position of the survey reefs and the marina. Darker tinted areas in the figure show fringing reef areas in each indicated bay.

Figure 3. Nelly Bay marina showing the position of the four sites close to the marina and entrance channel that were added to the monitoring program in March 2000.

4. RESULTS

4.1 Macroalgal cover changes

Brown macroalgae, mainly *Sargassum* and *Lobophora,* form a dense band on Magnetic Island fringing reefs on the outer reef flat and shallow reef slope. This band was present when the reefs were first surveyed in 1988 and although the height and density of the algae fluctuated seasonally and annually it has been present ever since. There has been concern that nutrient enrichment would lead to an increase in macroalgal cover but there is limited evidence for this from these surveys. Overall macroalgal cover was 11.6% in 1989, 20.7% for the same sites in 2000 and 19.6% in 2022.

In the eight original Nelly Bay sites macroalgal cover has fluctuated from 4% to 21% cover during previous surveys and was 20.6% in 2022 (Figure 4). This is at the high end of the range recorded previously and almost double the previous grand mean of 10.5% but only a third higher than mean cover recorded for surveys made during the same season. In Geoffrey Bay macroalgal cover fluctuated between 4% and 32% previously and was 25% in 2022 (Figure 5). The present level was more than double the mean macroalgal cover during the first six surveys between 1989 and 1993 but the same as the mean from the seven surveys between 2000 and 2003. In the combined Florence and Arthur Bay sites macroalgal cover fluctuated between 7% and 26% previously and was 13.2% in 2022 (Figure 6). This is the same as the long-term mean of 13.7% macroalgal cover in these two bays.

Figure 4. Long-term changes in the cover of macroalgae on Nelly Bay fringing reefs.
Graph shows grand mean percentage cover from eight sites of four 20m transects; error bars are standard errors.

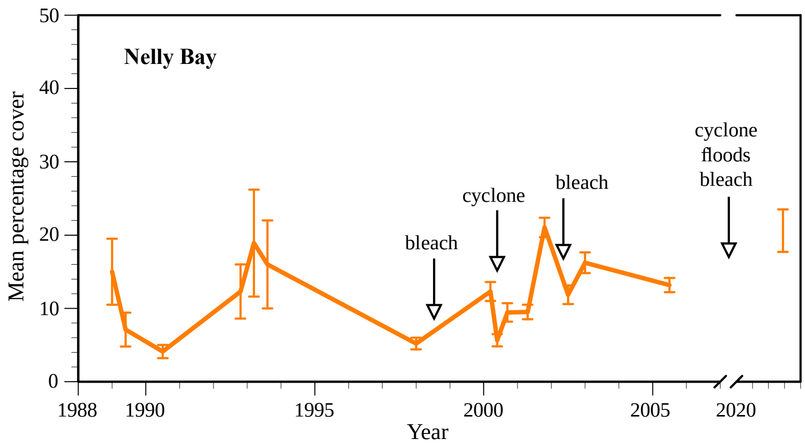


Figure 5. Long-term changes in the cover of macroalgae on Geoffrey Bay fringing reefs.
Graph shows grand mean percentage cover from six sites of four 20m transects; error bars are standard errors.

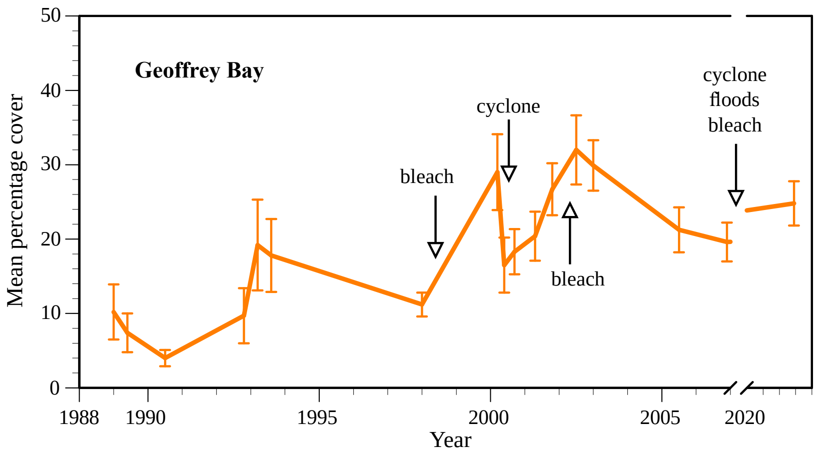


Figure 6. Long-term changes in the cover of macroalgae on Florence/Arthur Bay fringing reefs.

Graph shows grand mean percentage cover from six sites of four 20m transects; error bars are standard errors.

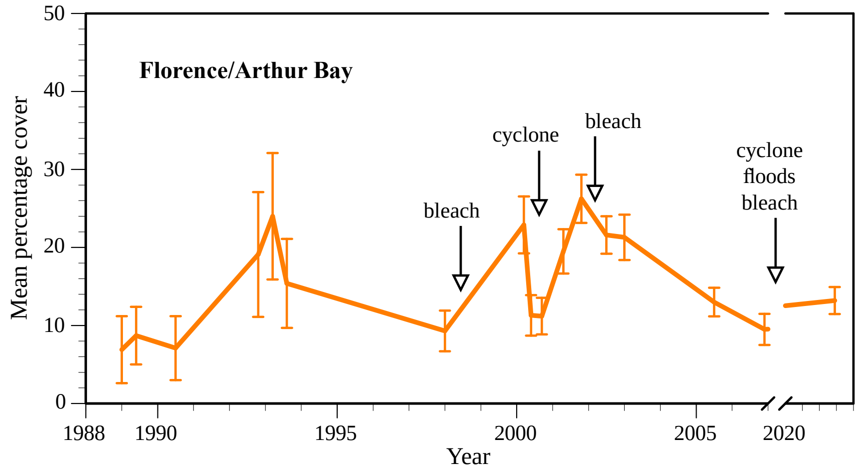
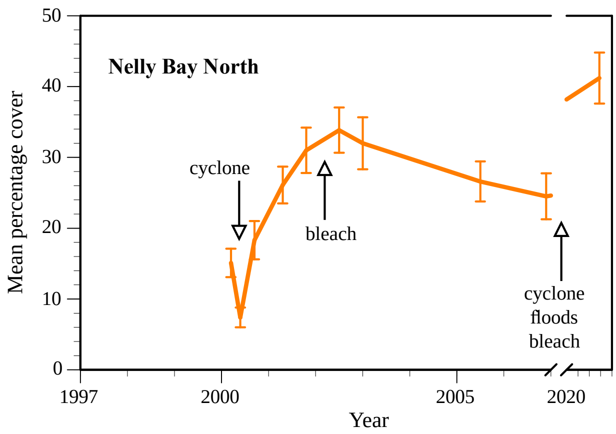


Figure 7. Long-term changes in the cover of macroalgae on Nelly Bay north fringing reefs.

Graph shows grand mean percentage cover from four sites of four 20m transects; error bars are standard errors.



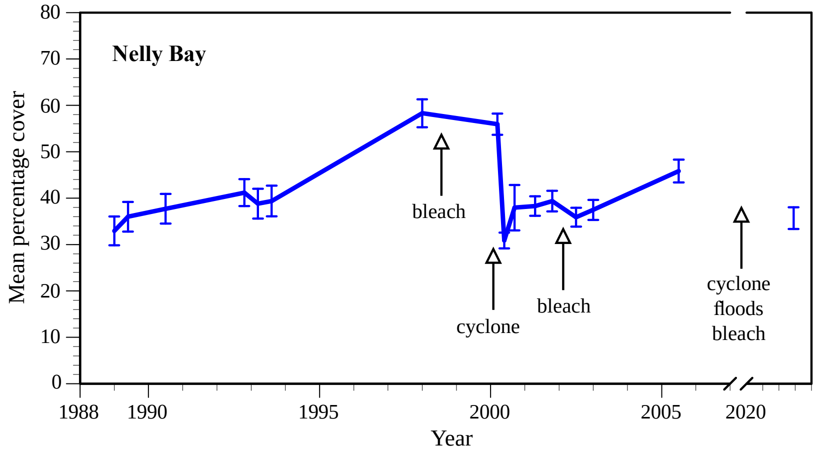
The four sites established at the north end of Nelly Bay close to the marina in March 2000 initially recorded a grand mean of 15% macroalgal cover but this had increased to almost 35% by mid 2002 following cyclone and bleaching events. Macroalgal cover had further increased to over 41% by the time of the 2022 survey (Figure 7).

4.2 Hard coral cover changes

Overall coral cover in the eight original Nelly Bay sites increased slightly from 33% to 40% cover between 1989 and 1993 and then increased at a greater rate to reach 58% cover by early 1998 (Figure 8). The 1998 bleaching event reduced coral cover slightly in Nelly Bay but TC Tessi in March 2000 reduced coral cover by a further 45%, down to only 31% cover. Recovery from this severe event was set back by a further slight coral cover reduction during the 2002 bleaching event but coral cover was back up to 46% at the time of the mid 2005 survey. Between 2005 and the latest 2022 survey coral cover in Nelly Bay had again reduced to 36%. Note that this was still higher than the cover first recorded in early 1989. The present coral cover in Nelly Bay is the same as the overall mean from all sixteen previous surveys of 36% cover.

Figure 8. Long-term changes in the cover of hard corals on Nelly Bay fringing reefs.

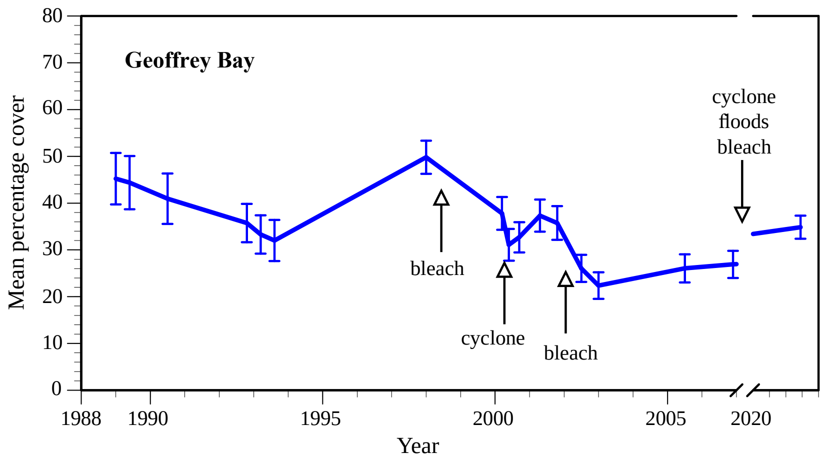
Graph shows grand mean percentage cover from eight sites of four 20m transects; error bars are standard errors.



Hard coral cover in Geoffrey Bay was 45% in 1989 but decreased to 32% by 1993 (Figure 9). Strong recovery over the next five years saw coral cover at 50% by 1998 but this was down again to 38% by the year 2000 due to the 1998 bleaching event. This bleaching impact was mainly due to mortality of *Acropora* corals, down from 14% cover to only 3% cover. TC Tessi further reduced coral cover to only 31% and coral cover reached a low of 22% cover after the 2002 bleaching event. Coral cover recovered slightly in Geoffrey Bay by 2006 to 27% and was up to a grand mean of 35% by 2022. Although 2022 coral cover was 10% lower than that originally measured in 1989 it was higher than the overall mean of 31% from all previous surveys.

Figure 9. Long-term changes in the cover of hard corals on Geoffrey Bay fringing reefs.

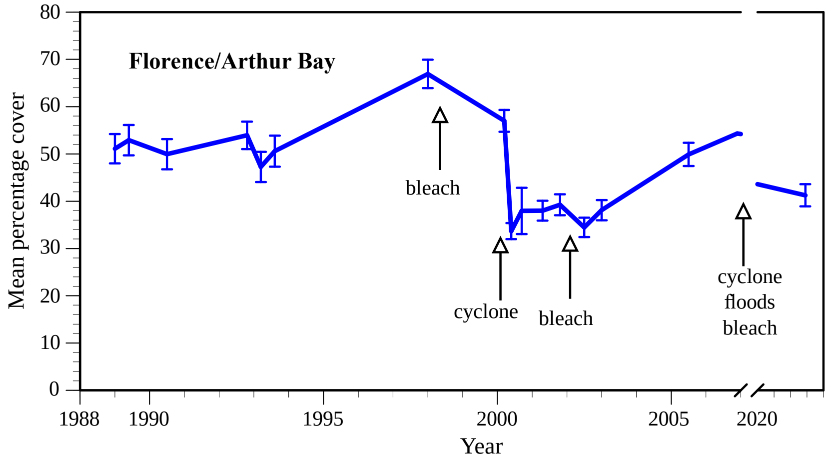
Graph shows grand mean percentage cover from six sites of four 20m transects; error bars are standard errors.



Hard coral cover on the combined Florence and Arthur Bay reefs was 51% during the 1989 baseline survey and remained the same up till mid 1993 (Figure 10). Coral cover then increased strongly to reach 67% by 1998 but was down to 57% following the 1998 bleaching event. TC Tessi caused a more than 40% fall in coral cover in these bays down to only 34% coral cover. The 2002 bleaching event stalled recovery in these bays but overall coral cover was up strongly to 54% by late 2006. Overall coral cover was down to 41% at the time of the latest 2022 survey but this was very similar to the overall mean from all previous surveys of 42% coral cover.

Figure 10. Long-term changes in the cover of hard corals on Florence/Arthur Bay fringing reefs.

Graph shows grand mean percentage cover from six sites of four 20m transects; error bars are standard errors.



Looking at the long-term changes in overall hard coral cover is revealing. When this monitoring program was initiated in early 1989 overall coral cover on the reef slope at Magnetic Island was 42%. At the time of this latest survey of the same sites in 2022 overall coral cover was only slightly lower at 37.3%.

The four sites that were established at the northern end of Nelly Bay adjacent to the new marina in March 2000 had very high coral cover of 77% when they were initially surveyed (Figure 11). Two thirds of this coral cover was accounted for by large colonies of whorl-forming *Montipora* corals (Figure 12). These shallow sites were badly affected by TC Tessi in March 2000 and coral cover was reduced down to only 44% by this event. Recovery of these sites was set back by the 2002 bleaching event and coral cover had only increased to 50% by late 2006. Coral cover had reduced substantially at these sites by the time of the 2022 resurvey when grand mean coral cover was only 15%.

Figure 11. Long-term changes in the cover of hard corals on Nelly Bay north fringing reefs.

Graph shows grand mean percentage cover from four sites of four 20m transects; error bars are standard errors.

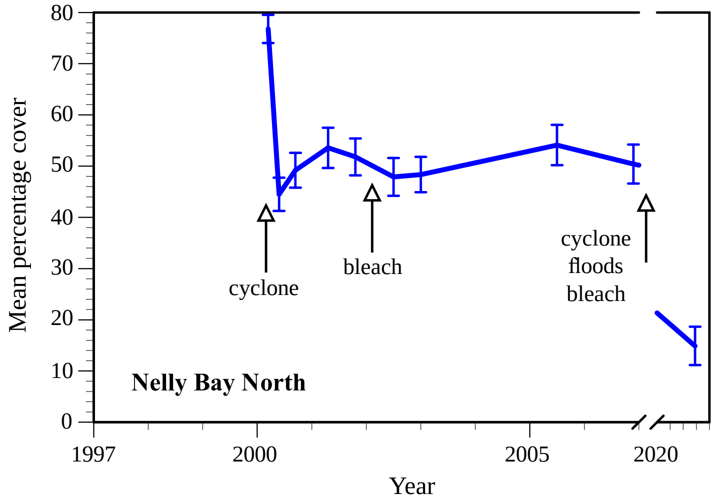


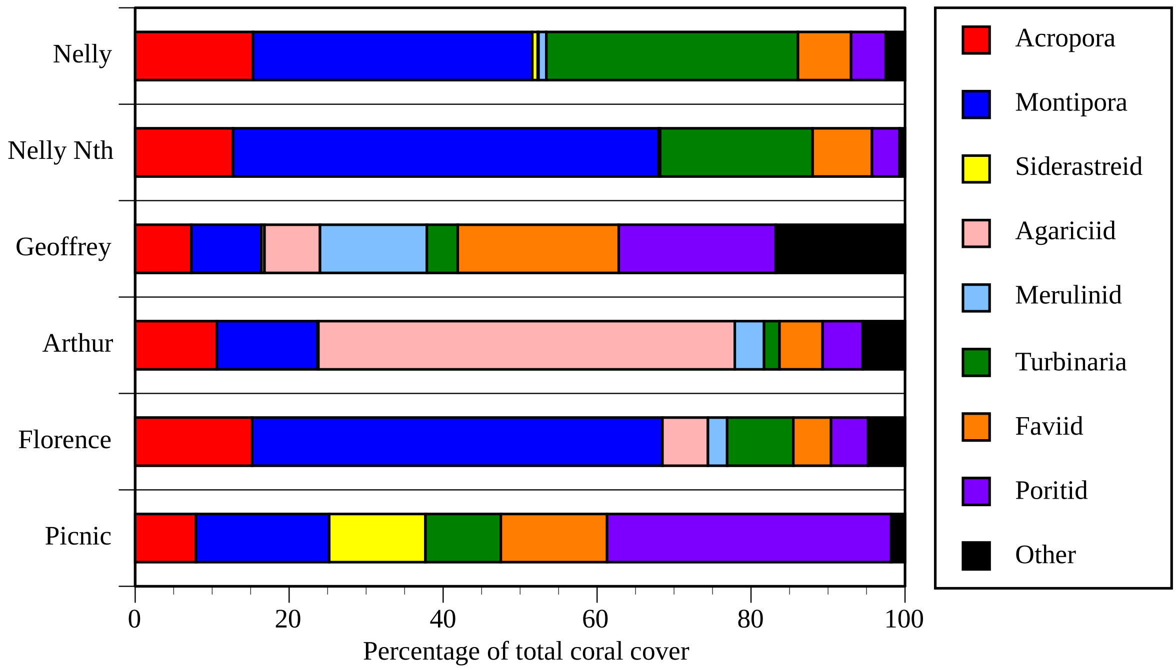
Figure 12. Extensive stands of *Montipora* corals in the Nelly Bay north sites in March 2000.

Although two reef slope sites were surveyed in Picnic Bay in 1989 data from this survey are not available. Three sites were surveyed in a similar location in 2006 and these sites were resurveyed in 2022. overall coral cover was 38% in 2006 but had reduced significantly to only 15% in 2022 due mainly to large reductions in the cover of both *Turbinaria* and *Acropora* corals, probably due to flooding and freshwater inundation of these reefs during the 2019 wet season Townsville floods.

4.3 Hard coral community composition

Although the Magnetic Island fringing reefs surveyed are all on the same eastern face of the island and subject to similar environmental influences the coral communities in the different bays all have markedly different coral composition (Figure 13).

Figure 13. Coral community composition in the survey locations during the 2022 survey.



In Nelly Bay coral communities were dominated by *Montipora* and *Turbinaria* corals and these two groups combined accounted for almost 70% of total coral cover. *Acropora* corals were also important in this bay at 15% of total coral cover. In the new sites at the north end of Nelly Bay *Montipora* corals accounted for over 55% of coral cover with *Turbinaria* and *Acropora* corals also important. No single coral group dominated Geoffrey Bay coral communities in 2022. Poritids and faviids each accounted for about 20% of total coral cover with meruliniids, *Montipora*, *Acropora* and agariciids (*Pachyseris*) also important. A variety of other corals, including *Galaxea*, fungiids and *Lobophyllia* were also common in Geoffrey Bay accounting for a combined 17% of total coral cover. Arthur Bay coral communities were dominated by agariciid corals (mainly *Pachyseris speciosa*) that formed huge colonies along the deeper parts of the reef slope. Although these colonies have been badly damaged by cyclones and were heavily bleached in 2002 they have survived and managed to recover between impacts. *Acropora* and *Montipora* corals were also important in Arthur Bay. Florence Bay coral communities were dominated by *Montipora* corals (53% of total corals) with *Acropora* corals also important. In Picnic Bay coral communities are presently dominated by poritid corals with faviids, *Montipora* and siderastreid corals also important.

Coral composition has changed significantly in some of the bays over the past 33 years. In Nelly Bay the percentage of *Acropora* corals increased over the first 15 years. Since that time *Acropora* corals have decreased again, along with the cover of *Turbinaria* corals, while the cover of *Montipora* corals has increased (Figure 14A).

Geoffrey Bay has experienced the greatest change in coral composition over the past 33 years (Figure 14B). In 1989 *Acropora* corals accounted for almost 40% of total coral cover in this bay. The 1998 and 2002 bleaching events killed most of this *Acropora* and in 2022 this group only accounted for 7% of coral cover. The contribution of *Montipora* corals also decreased while that of poritids, agaricids and merulinids increased. In contrast coral composition only fluctuated slightly in Florence and Arthur Bays over the past three decades (Figure 14C).

Figure 14A. Changes in Nelly Bay coral composition 1989-2022.

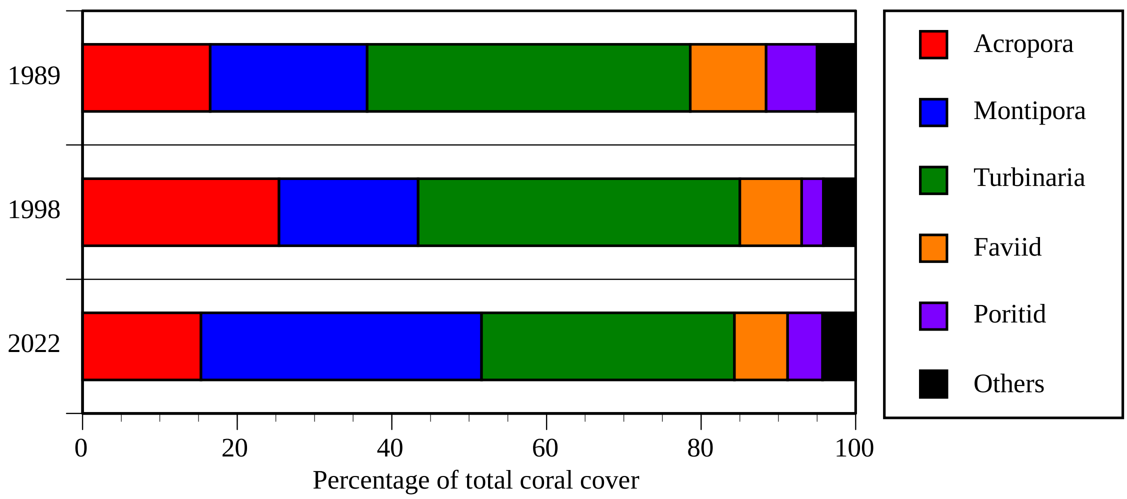


Figure 14B. Changes in Geoffrey Bay coral composition 1989-2022.

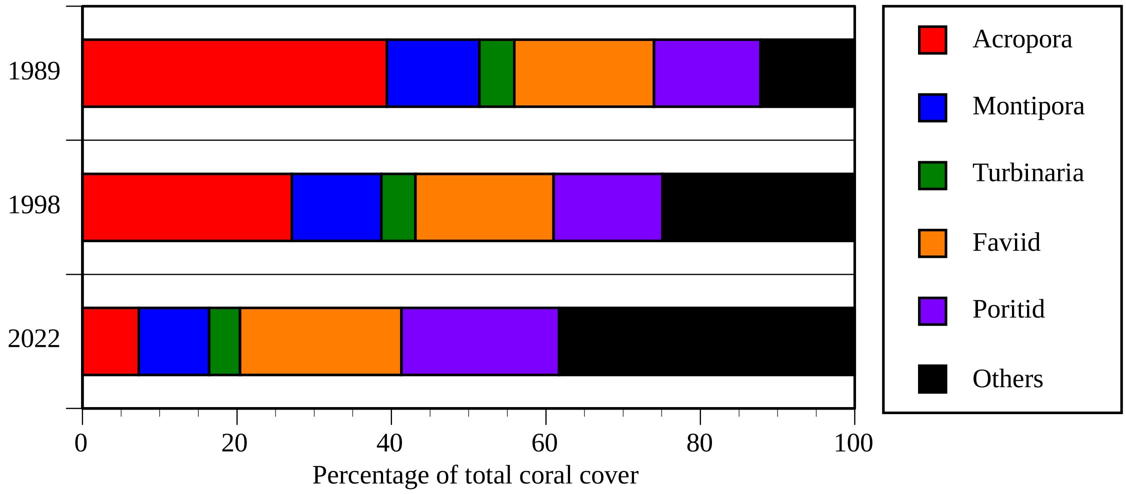
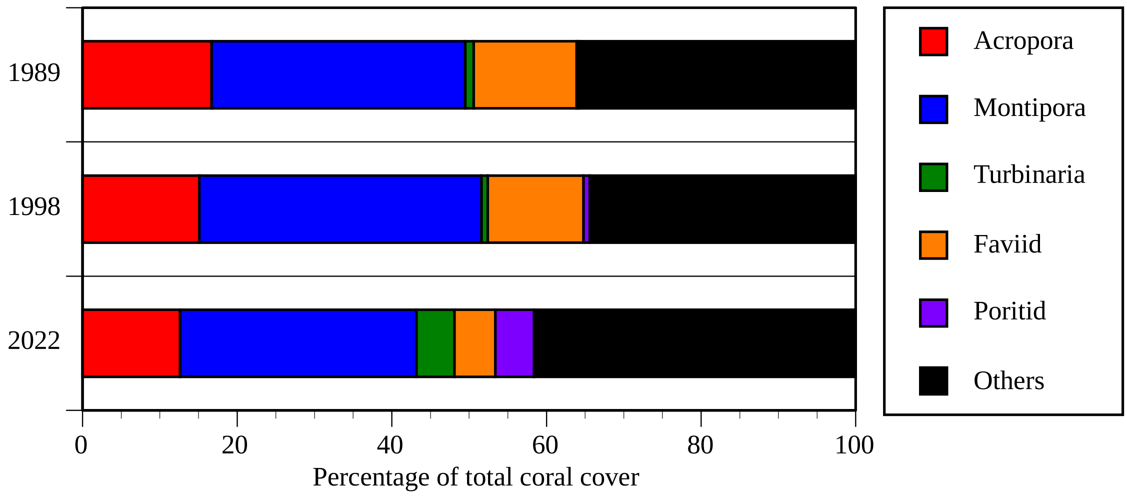


Figure 14C. Changes in Florence and Arthur Bays coral composition 1989-2022.



4.4 Coral bleaching during the 2022 survey

Water temperatures around the Magnetic Island fringing reefs ranged from 29° to 31°C during the 2022 surveys. This is at the high end of what corals can cope with before expelling their zooxanthellae and bleaching. Some corals were partially bleached during this survey especially in Geoffrey Bay. In Nelly Bay less than 10% of corals were partially bleached and there were no corals showing obvious signs of bleaching induced mortality. Florence, Arthur and Picnic Bays also showed low levels of partial bleaching during the 2022 survey. Many corals in Geoffrey Bay were partially bleached, however, with more than 50% of colonies much paler than normal. A small number of coral colonies in this bay were totally bleached and some were showing partial mortality from bleaching.

Although *Acropora* and *Montipora* corals have been severely impacted by some previous bleaching events, eg Geoffrey Bay in 1998, they were mostly healthy during these surveys. A few other corals were also completely healthy, including *Podabacia* and *Echinopora*.

Some soft corals were partially bleached during this survey, especially in Geoffrey Bay, but no partial mortality was observed in this benthic group.

There were signs that many of the corals in Geoffrey Bay were recovering from a previous event that had caused partial mortality of many colonies (Figure 26, Figure 29). This event was probably the

2020 mass bleaching event that affected reefs over wide areas of the central and southern GBR, including Magnetic Island (Thompson et al. 2021).

4.5 Changes in other benthic groups

Benthic groups apart from hard corals and macroalgae are not common on Magnetic Island fringing reefs. Sponges covered an overall mean of only about 0.5% of the substratum and were most abundant in Florence Bay where mean cover was about 2%. The green symbiotic sponge species *Haliclona cymaeformis* was the most abundant sponge on these Florence Bay reefs. Soft corals were also uncommon with an overall mean of only 2% cover. This group was most abundant in Nelly Bay (3% cover) where the encrusting soft coral *Briareum* was the most common soft coral genus. All other benthic groups were rare and not recorded in these surveys.

5. DISCUSSION

5.1 Has macroalgal cover increased on Magnetic Island reefs?

Most GBR region fringing reefs have a band of macroalgae in shallow water. This band has been present since at least the late 1970s. Throughout the GBR, the distribution of macroalgae shows a strong positive relationship to high nutrient availability from river runoff, adequate light (hence its prevalence in shallower areas of the reef flat and slope) and sufficient water movement to flush fine sediments from the water column (De'ath and Fabricius 2010; Thompson et al. 2017). Inshore reefs of the GBR also have naturally low densities of grazing fish that typically suppress the growth of macroalgae (Wismer et al. 2009; Cheal et al. 2012). On Magnetic Island reefs, macroalgae covered a mean of 11% of the substratum on the reef slope when these surveys were initiated in 1988. Fringing reef macroalgal cover fluctuates markedly with the annual seawater nutrient cycle and may vary by up to an order of magnitude (Martin-Smith 1993). In Geoffrey Bay, for example, percentage cover of macroalgae ranged from 4% to 32% during these surveys which were carried out in a range of seasons.

There has been concern that nutrient enrichment resulting from human activities is causing a long-term increase in macroalgal cover; regular monitoring of the inshore GBR shows that Chlorophyll *a* levels, a measure of nutrient enrichment, are often above the threshold levels recommended for reef ecosystem health (Thompson et al. 2021). There is a distinct gradient in turbidity and nutrient concentrations from the coastal reefs to those further offshore, with evidence that pollutants and nutrients derived from runoff were historically lower (Belperio and Searle 1988). These surveys found that mean macroalgal cover apparently increased between the 1989 baseline survey and the March 2000 survey, from an overall mean of 11% to 20.5%, but that this cover was down to 10.6% in April 2000 following TC Tessi impacts. During the latest 2022 survey overall mean macroalgal cover from the original survey sites was 19.6%, marginally less than in March 2000. Although macroalgal cover increased markedly at the shallow Nelly Bay north sites where coral cover decreased substantially, there is no strong evidence that there has been a continuing upward trend in macroalgal cover on Magnetic Island fringing reefs over the past 33 years. Other studies, using slightly different sites and methods, have found cover of brown macroalgae to be higher in recent years. Thompson et al. (2021) recorded brown macroalgae of around 23% on the reef slope (similar to the present mean of almost 20%) and 53% on the shallow reef flat in 2020. Ceccarelli et al. (2020) reported approximately 40% total macroalgal cover across eight sites on the eastern side of Magnetic Island in 2016. This is an indication of both the seasonality and the variability of macroalgal density across different zones and bays of the Magnetic Island reefs. Nevertheless, there is concern that where high densities of large macroalgae persist, such as in the shallower parts of the reef, the cover is above the threshold where the settlement of juvenile corals is inhibited (Johns et al. 2018; Thompson et al. 2021; Smith et al. 2022).

5.2 Impacts on Magnetic Island fringing reef corals

There have been at least seven major impacts on Magnetic Island fringing reefs over the 33 years spanned by these surveys (see also Thompson et al. 2021). In early 1998 the first severe global coral bleaching event affected these reefs (Berkelmans et al. 2004), in combination with a severe rain/flood event that saw 600mm of rain in only a few days. The next major impact was TC Tessi that passed directly over Magnetic Island in March 2000, reducing grand mean coral cover by more than 30%. Early 2002 saw the second widespread coral bleaching event also impact these reefs (Berkelmans et al. 2004).

Between the 2006 and 2022 surveys at least four more major impacts affected these reefs. During the 2008-2009 wet season two tropical lows passed over Townsville generating 30-40 knot winds around Magnetic Island and dumping lots of rain that sat in a warm lens over these reefs causing extensive mortality of acroporid corals. This was followed in 2011 by severe TC Yasi that hit Magnetic Island at low tide with winds of 85 knots and huge seas, causing major breakage and mortality of reef corals. The big floods of 2019 in the Townsville region pushed freshwater out around Magnetic Island causing lots of coral mortality along the Picnic Bay/Cockle Bay reef but limited damage on the other east coast reefs. The widespread 2016 and 2017 bleaching events had little impact on Magnetic

Island reefs but the 2020 event badly affected Geoffrey Bay reefs (Thompson et al. 2021), with a more limited effect elsewhere.

Other minor impacts have probably caused damage to these reefs over this time period, including the current bleaching event that is also having the most impact on Geoffrey Bay corals.

This indicates that Magnetic Island fringing reefs are being damaged by severe impacts on average about every five years. Globally, the frequency of high-intensity disturbance events has been increasing, and is predicted to increase further if current climate change trajectories are maintained (Hughes et al. 2018). Best case recovery rates between these major impacts have averaged about 4% coral cover increase per year suggesting that average recovery between impacts is about 20% absolute hard coral cover increase. The three impacts covered during the first seventeen years covered by these surveys caused a mean absolute reduction in coral cover of just over 11%, well below the mean rate of five-year recovery. The effects of these impacts ranged from only 2.4% reduction in coral cover in Nelly Bay during the 1998 bleaching event to a huge 25% reduction in Nelly Bay due to TC Tessi. This suggests that the Magnetic Island fringing reefs are able to cope with the current level of major reef impacts and still maintain, or even increase, healthy coral cover. This mirrors the most recent findings of coral cover across the GBR reported by the Australian Institute of Marine Science's Long Term Monitoring Program. In the relatively disturbance-free year of 2021, coral cover increased between 26% on the central GBR to 39% in the southern GBR.

However, this does not take account of the many other minor impacts on fringing reef corals such as less severe strong wind episodes, coral disease, overgrowth by other corals or other benthic organisms, *Drupella* snail grazing and sediment smothering amongst others. During the first seventeen years covered by these surveys there was a 1% reduction in overall hard coral cover in the combined survey sites and a further 4% coral cover reduction between the 2006 and 2022 surveys. This is a relative coral cover reduction of 11.4% over 1989 levels. This small change was probably not significant given the huge fluctuations that have occurred over the past 33 years.

In the real world both impact and recovery are very patchy. Some areas of reef have maintained or increased coral cover over the past 33 years eg the southern, deeper part of Nelly Bay, while others have been severely impacted eg the shallow northern sites of Nelly Bay where coral cover has reduced from 77% down to 15% in the past 22 years.

This survey used large numbers of sites in each bay with a total of 27 sites. With the large variation in coral cover between the sites in each bay choosing a smaller number of sites could change the picture we have presented. In Nelly Bay site means ranged from 22% up to 49% coral cover. In Geoffrey the range was 22% to 54% while in Florence and Arthur the range was a huge 26% to 75%. Ceccarelli et al. 2020 also found that trajectories and drivers of coral cover change varied both for site and location, indicating that caution is advised when making statements about reef condition based on a few selected locations.

It's interesting to note that, because of the large fluctuations in overall coral cover that have been experienced, choosing different start and end points for coral cover change can paint very different pictures. From the coral cover high of 59.8% in 1998 there has been a dramatic relative coral cover reduction of 38% over 24 years but if we choose an April 2000 start point there has actually been a 17.3% increase in overall coral cover on Magnetic Island over the past 22 years. Ceccarelli et al 2020 reported a 45% reduction in Magnetic Island coral cover between 2004 and 2016 using eight sites scattered through these survey bays but using our, more comprehensive, survey coral cover over the period 2003 to 2022 increased nominally from 33.1% to 37.3%.

It is also interesting to compare overall coral cover from the latest survey (37.3%) with an overall mean from all sixteen surveys between 1988 and 2006 (36.2%). Although there have been large fluctuations in coral cover on these reefs, taken over the long term there has been no significant change. It is clear that to make useful statements about coral cover impacts and changes on Magnetic Island fringing reefs we need many fixed sites, regular surveys and as long a time scale as possible, such as this survey provides.

5.3 Has coral composition changed on Magnetic Island fringing reefs?

Although the percent cover of all corals is a globally useful measure of how reef condition changes through time, it can mask changes in which species make up the coral community, and how this may also change over time. Magnetic Island fringing reefs are unusual in that coral community composition is markedly different in the different bays. Additionally, the high turbidity has resulted in a compressed depth stratification, where species usually found on deeper reef slopes are present at shallower depths (Morgan et al. 2020). Different coral groups are affected differently by the various impacts experienced by coral reefs, and coral composition often changes following repeated impacts (Van Woesik et al. 2011). For example, acroporid corals are more fragile than other groups and usually suffer higher mortality during cyclonic episodes, and Poritid and *Turbinaria* corals are better able to cope with bleaching without suffering mortality than most other corals. However, acroporid corals are also the fastest-growing, and can quickly cover broad areas during the recovery phase, driving coral cover increases but not the recovery of the diversity of different species of corals (McWilliam et al. 2020).

In spite of frequent impacts, coral composition has only changed markedly in Geoffrey Bay. This location was strongly dominated by *Acropora* and *Montipora* corals in 1989 with these two groups accounting for 52% of total coral cover. Geoffrey Bay seems to be more severely affected by bleaching episodes than the other Magnetic Island bays and these repeated episodes have dramatically reduced cover of acroporid corals so that they now account for only 16% of coral cover. Three other groups that are more bleach tolerant have taken over the coral community and merulinids, faviids and poritids between them now make up 55% of total coral cover in Geoffrey Bay.

It is not known why the Geoffrey Bay fringing reefs are more severely affected by bleaching episodes than other Magnetic Island bays but it may be due to slight differences in flushing tidal currents through the bay that let warmed surface water inundate the edge of the reef for longer periods.

5.4 Is the marina affecting Nelly Bay north sites?

The only long-term sites that have shown a strong long-term downward trend are the four that were established close to the Nelly Bay marina in March 2000 (referred to as the Nelly Bay north sites in this report). Hard coral cover decreased from 77% down to 15% while macroalgae increased from 15% to 41% over the past 22 years. It might be expected that this has resulted from impacts from the operation of the marina. Tidal flushing of the marina brings silty and possibly polluted water out over this reef during each tidal cycle, especially during spring tides. However, underwater visibility was similar at these sites during the 2022 survey to that in the other Nelly Bay sites and better than that experienced in Geoffrey, Arthur and Florence Bays. When the wind blew up to 20 knots the day after these surveys wave action generated similarly turbid water along the whole length of the Nelly Bay reef (Tony Ayling, personal observations).

These sites are also close to the marina entrance channel where large fast-moving passenger and car ferries make many trips every day that may stir up bottom sediments from both wake and prop-wash. Passage of ferries during surveys at these sites did not stir up sediments on the reef, however, and there was no evidence that silt was accumulating on corals or on the substratum at these sites.

Although most of the changes at these sites may have been due to natural impacts, the proximity of the marina may be limiting their ability to recover. These sites are only a few metres deep at low tide and the reef community was strongly dominated by more fragile acroporid corals. Wave action generated by TC Tessi reduced coral cover at these sites from 77% down to 45% in March 2000. Both the 2008/2009 wet season winds and floods and the large waves generated by TC Yasi in 2011 probably caused equally large coral cover reductions at these sites. Both these impacts would have caused extensive coral mortality that has not been able to recover due to both the lower than normal surviving coral cover and the increase in macroalgal cover.

5.5 Does dredging affect Magnetic Island reefs?

The original 1988/1990 coral monitoring program was set up to detect any effects from the marina entrance and basin dredging operations. The reef slope sites were used again in 1992/1993 to monitor any possible impacts from the Platypus Channel extension that required 1.5 million cubic metres of dredging. There was no discernible increase in sediment on corals on the survey reefs and no significant decrease in coral cover that might have been due to the dredging. However, dredging around Townsville Port, and the dumping of dredge spoil in various locations around Cleveland Bay, began in 1883, and developed from a small operation in the 1880s to an annual maximum of over 2 million tonnes in the mid 1970s (Pringle 1992). It is therefore highly likely that even by 1988, we were already surveying a coral community where species had either already disappeared or developed a tolerance to the high and variable levels of turbidity and sediment deposition.

Sea Research has helped monitor the likely impacts of a 9 million cubic metre capital dredging program on fringing reefs around Mackay and Hay Point. Although there were significant increases in sediment on living corals and a slight amount of partial coral mortality from this program there was no measurable change in coral cover (GHD 2006). This dredging did, however, have a slight long-term effect on sediment levels in the two sites (out of 18) closest to the dredge site (Ayling and Ayling 2017). These sites were about five kilometres from the dredge operations whereas Magnetic Island reefs are about 3 kilometres at their closest to any dredging operations in Platypus Channel.

On most fringing reefs there is chronic accumulation of sediment on living corals (Ayling and Ayling 2005, GHD 2006). Corals can usually quickly remove this sediment but during extended periods of strong winds, or during large, extended dredging programs, the corals' sediment removal mechanism may be overwhelmed and sediment may cause small patches of mortality on some corals (Ayling and Ayling 2017). In our experience normal sediment levels on Magnetic Island reefs are lower than on many other fringing reefs (Tony Ayling, personal observations). This may provide some resilience to sediment damage in the event of a future large dredging program in Platypus Channel.

5.6 Conclusions

The surveys of Magnetic Island fringing reefs reported here span a time period of more than 33 years and cover 27 sites in five different bays. Although there is no strong evidence that the overall cover of macroalgae has increased over that time some reef areas do now support levels of macroalgae that may be inhibiting coral growth and further coral recruitment.

Coral cover has fluctuated significantly over the past 33 years on these reefs but the effects and trajectories have been different in the different sites and bays. Coral cover has increased in some locations and decreased strongly in others. Taken as a whole, the coral cover on these reefs in 2022 (37.3%) was very similar to the overall mean of 36.2% from all sixteen surveys made between 1989 and 2006. We suggest that to make meaningful statements about coral cover changes on Magnetic Island reefs regular surveys of many fixed sites over as long a time period as possible are needed.

Major reef impacts often have different levels of effect on different coral groups and repeated impacts may cause shifts in reef diversity and coral composition. Coral composition has changed significantly at some of the Magnetic Island locations eg Geoffrey Bay, but stayed similar in other areas.

Long-term surveys at other GBR fringing reef locations show similar large fluctuations in coral cover from repeated cycles of impact and recovery but some show strong signs of reductions in coral cover over recent years where recovery between impacts is not sufficient to maintain or increase coral cover (Ayling and Ayling 2017, Tony Ayling, personal observations).

6. REPRESENTATIVE PHOTOS OF MAGNETIC ISLAND REEFS

Figure 15. *Acropora* staghorn and *Turbinaria* corals were typical of Nelly Bay fringing reefs. This photo was taken during the late 2006 survey.

Figure 16. *Acropora* staghorn and *Montipora* corals on the Nelly Bay fringing reefs. Most corals were healthy on these reefs at the time of the 2022 resurvey.

Figure 17. A large colony of *Goniopora* coral on the Nelly Bay fringing reef in 2022 that has some parts completely bleached.

Figure 18. *Sargassum* macroalgae (top), *Montipora* corals (right) and the pink encrusting soft coral *Briareum* (left) on Nelly Bay reefs in 2022.

Figure 19. Two *Drupella* snails (pink and white/red shapes centre right) eating a *Montipora* colony in Nelly Bay during the latest survey.

Figure 20. Bleached colony of *Sinularia* soft coral on the Nelly Bay fringing reefs during the 2022 resurvey.

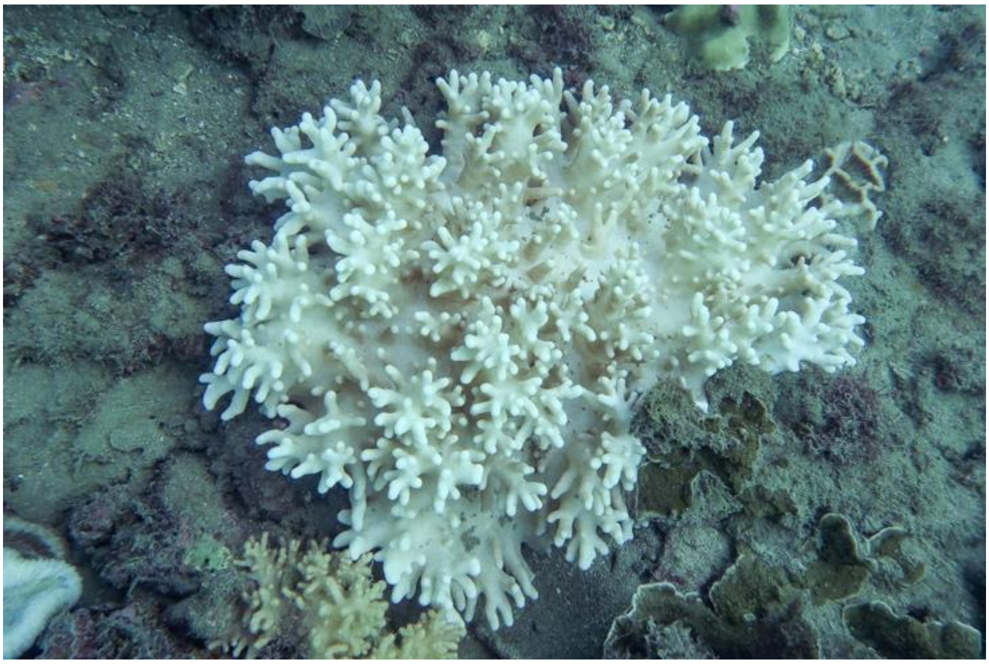


Figure 21. These *Turbinaria* colonies in Nelly Bay during the latest survey have been turned over by wave action but are still alive and recovering strongly.

Figure 22. *Montipora* and *Acropora* corals in Nelly Bay north that have been badly damaged by the March 2000 impact of TC Tessi.

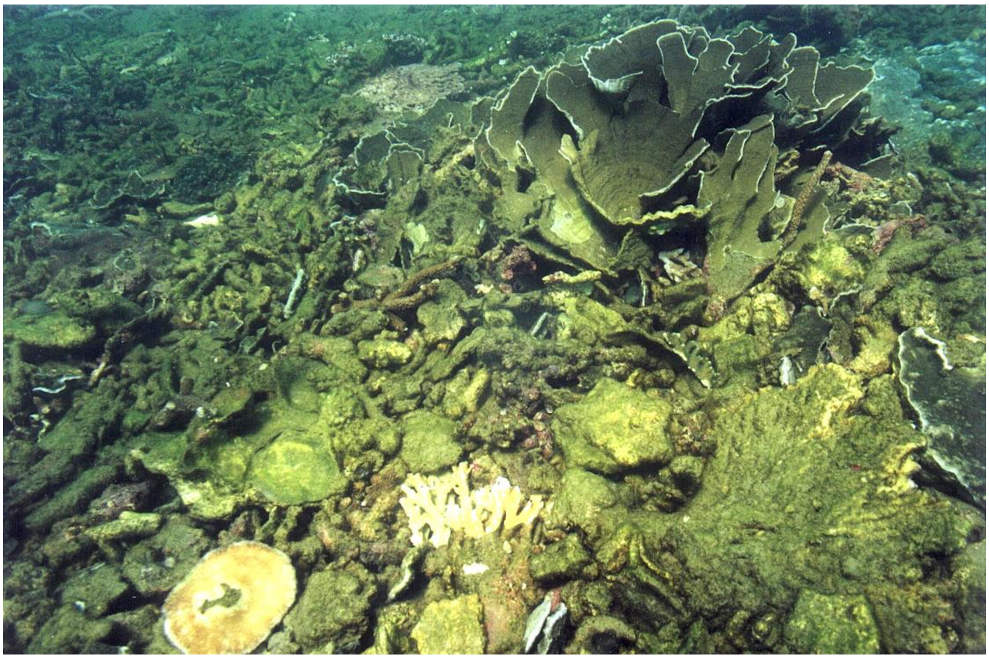


Figure 23. Healthy *Montipora* whorls in Nelly north site 2 at the time of the March 2000 Magnetic Island survey. Hard corals covered 84% of the substratum at this site during this survey.

Figure 24. At the time of the 2022 survey the above site in Nelly Bay north had 55% cover of macroalgae, primarily *Sargassum*, and only 3% coral cover.

Figure 25. An assortment of partially bleached corals in Geoffrey Bay in 2022. Corals include *Fungia* mushroom corals, *Merulina* (middle left and lower right), pink *Lobophyllia* and faviids (top left).

Figure 26. Partially bleached *Pachyseris* colony (left) and a badly bleached *Merulina* coral (right) showing small patches of mortality.

Figure 27. This large *Turbinaria* coral in Geoffrey Bay was more than 10 metres across. A small *Acropora* coral is growing in the middle of the *Turbinaria*.

Figure 28. This huge colony of *Goniopora* coral in Geoffrey Bay is slightly bleached from the current coral bleaching event.

Figure 29. This partially bleached colony of *Pachseris* in Geoffrey Bay is recovering from past partial mortality, probably from the 2020 bleaching event.

Figure 30. Some of the original transect marker stakes were still present at most of the survey sites. This Geoffrey Bay stake is surrounded by healthy *Podabacia* corals and bleached *Merulina* corals.

Figure 31. Huge colonies of *Pachyseris speciosa* covered 25% of the reef substratum in Arthur Bay at the time of the 2022 survey and had been present on this reef since at least 1988.

Figure 32. Some sections of the *Pachyseris* colonies in Arthur Bay had died, probably aa result of bleaching during the 2020 bleaching episode.

Figure 33. *Acropora* and *Montipora* corals on the Florence Bay fringing reefs. These two groups accounted for almost 70% of coral cover in this bay in 2022.

Figure 34. *Acropora* staghorn and whorl-forming *Montipora* corals on Florence Bay fringing reefs in 2006. *Montipora* corals alone covered almost 30% of the substratum in this bay at that time.

Figure 35. The agariciid coral *Pachyseris speciosa* accounted for 6% of corals on Florence Bay reefs at the time of the 2022 survey.

Figure 36. The green symbiotic sponge *Haliclona cymaeformis* was present on the Florence Bay fringing reefs.

Figure 37. *Acropora* corals (foreground) made up 30% of hard coral cover in Picnic Bay during the 2006 survey and along with *Turbinaria* corals (back right) accounted for two thirds of total coral cover.

Figure 38. Most *Acropora* corals were dead on Picnic Bay fringing reefs at the time of the 2022 survey, probably due to the 2019 Townsville flood event.

Figure 39. *Turbinaria* corals were common on the Picnic Bay fringing reef in late 2006. This group accounted for 33% of total coral cover at this time

Figure 40. During the 2022 survey most of the *Turbinaria* colonies had died although some were starting to recover from surviving sections of the colonies.

Figure 41. This large *Coscinarea* coral colony was present on the Picnic Bay reef in 2006 and still healthy during the 2022 survey.

Figure 42. *Porites* corals were the dominant coral group on Picnic Bay fringing reefs at the time of the 2022 survey.

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