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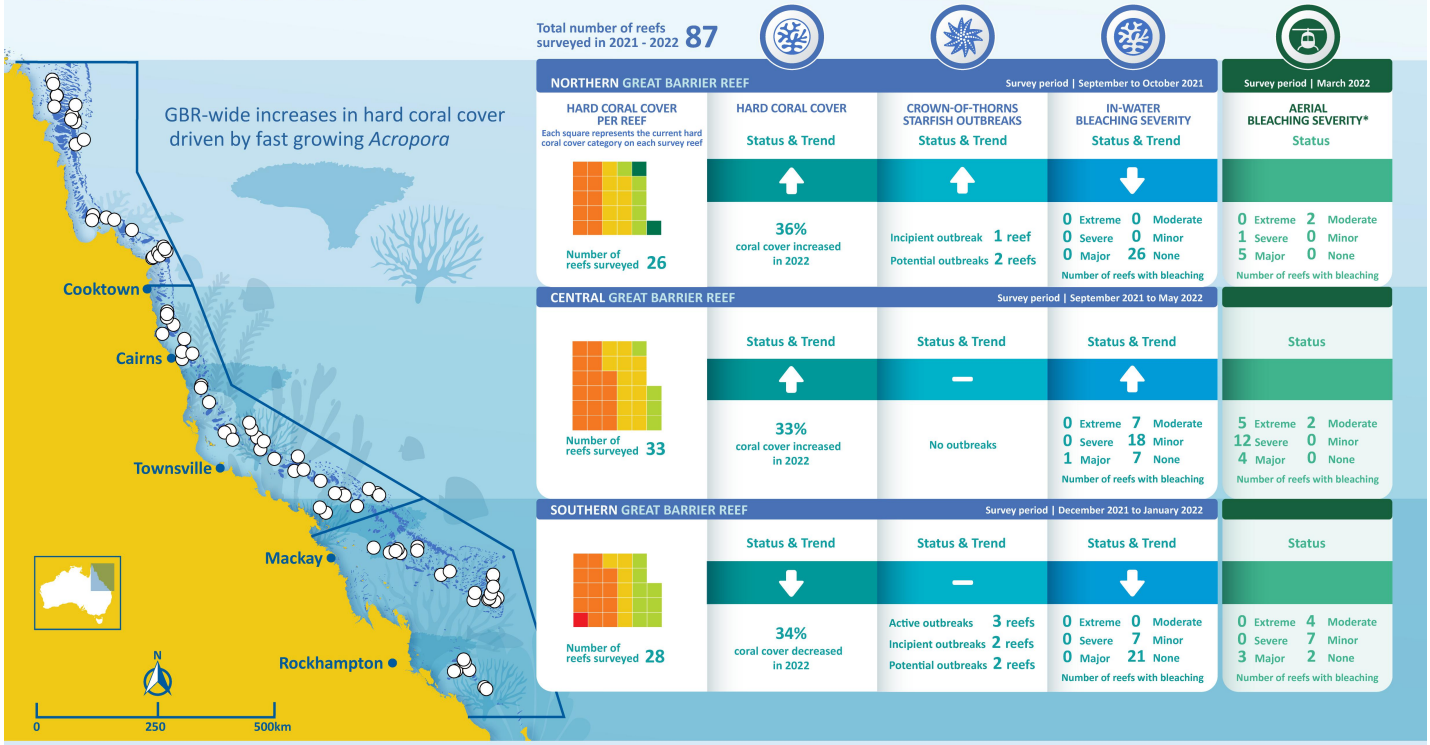
Continued coral recovery leads to 36-year highs across two-thirds of the Great Barrier Reef

AIMS LONG-TERM MONITORING PROGRAM 2021 - 2022 RESULTS



LEGEND

- Survey Site Locations

HARD CORAL COVER: >0% - 10% | >10% - 30% | >30% - 50% | >50% - 75% | >75% - 100%

CROWN-OF-THORNS STARFISH (COTS): **No Outbreak** 0 to 0.1 COTS **Potential Outbreak** 0.1 to 0.22 COTS **Incipient Outbreak** 0.22 to 1 COTS **Active Outbreak** Over 1 COTS (Number of COTS divided by tow numbers)

BLEACHING SEVERITY: **None** =0% **Minor** = >0% - 10% **Moderate** = >10% - 30% **Major** = >30% - 60% **Severe** = >60% - 90% **Extreme** >90%

* Aerial surveys were conducted on 47 of the 87 LTMP survey reefs in 2022

SUMMARY

In 2022, the GBR continues to recover, registering the highest levels of coral cover yet recorded in the Northern and Central regions over the past 36 years of monitoring. While recovery continued on many Southern GBR reefs, regional coral cover declined slightly due to ongoing outbreaks of crown-of-thorns starfish in the Swain reefs. Importantly, the trends of coral cover are highly variable across the GBR, and most reefs had between 10% and 50% hard coral cover.

Above-average water temperatures led to a mass coral bleaching event in 2021/22, the fourth event since 2016 and the first recorded during a La Niña year, when conditions are typically cooler. The peak of this bleaching event was in March, and the accumulated heat stress, measured as Degree Heating Weeks (DHW), reached levels expected to result in widespread bleaching but not extensive mortality. In-water and aerial bleaching surveys recorded widespread bleaching across the GBR, with the most severe bleaching on reefs in the Central GBR.

The recovery of hard coral cover continues to be driven by fast-growing *Acropora* corals, which are vulnerable to the common disturbances affecting the GBR. The GBR remains exposed to the predicted consequences of climate change, including more frequent and intense marine heatwaves, as well as the ongoing risk of outbreaks of the crown-of-thorns starfish, and tropical cyclones. The increasing frequency and extent of mass bleaching events in recent years poses a significant risk to the state of the reefs in the GBR. Any future disturbances can rapidly reverse the observed recovery.

Key Results

- This report summarises the condition of coral reefs of the Great Barrier Reef (GBR) from the Long-Term Monitoring Program (LTMP) surveys of 87 reefs conducted between August 2021 and May 2022 (reported as '2022').
- Over the past 36 years of monitoring by the Australian Institute of Marine Science (AIMS), coral reefs in the GBR have shown an ability to begin recovery after disturbances.
- In 2022, widespread recovery has led to the highest coral cover recorded by the LTMP in the Northern and Central GBR, largely due to increases in the fast-growing *Acropora* corals, which are the dominant group of corals on the GBR and have been largely responsible previous changes in hard coral cover.
- Above-average water temperatures led to a mass coral bleaching event over the austral summer of 2021/22, the fourth event since 2016 and the first recorded during a La Niña year. The peak of this bleaching event was in March, and accumulated heat stress measured as Degree Heating Weeks (DHW)[1] for most of the GBR reached levels expected to result in widespread bleaching but not extensive mortality.
- Survey reefs experienced low levels of other acute stress over the past 12 months, with no severe cyclones impacting the Marine Park. The number of crown-of-thorns starfish outbreaks on survey reefs has generally decreased; however, there remain ongoing outbreaks on some reefs in the Southern GBR.
- The combination of few acute stresses and lower accumulated heat stress in 2020 and 2022 compared to 2016 and 2017 has resulted in low coral mortality and has allowed coral cover to continue to increase in the Northern and Central GBR.
- Nearly half of the surveyed reefs (39 out of 87) had hard coral cover levels between 10% and 30%, while almost a third of the surveyed reefs (28 out of 87) had hard coral cover levels between 30% and 50%.
- On the Central and Northern GBR, region-wide hard coral cover reached 33% and 36%, respectively; the highest level recorded in the past 36 years of monitoring.
- Region-wide hard coral cover on reefs in the Southern GBR was 34% and had decreased from 38% in 2021, largely due to ongoing crown-of-thorns starfish outbreaks.
- In periods free from intense acute disturbances, most GBR coral reefs demonstrate resilience through the ability to begin recovery. However, the reefs of the GBR continue to be exposed to cumulative stressors. The prognosis for the future disturbance regime suggests increasing and longer-lasting marine heatwaves, as well as the ongoing risk of outbreaks of crown-of-thorns starfish and tropical cyclones. Therefore, while the observed recovery offers good news for the overall state of the GBR, there is increasing concern for its ability to maintain this state.

1 DHW expresses the accumulated heat stress over the previous three months by adding up the time when temperature exceeds the bleaching threshold. Significant coral bleaching is predicted above 4 DHW and coral mortality is expected above 8 DHW. Further information available from NOAA.

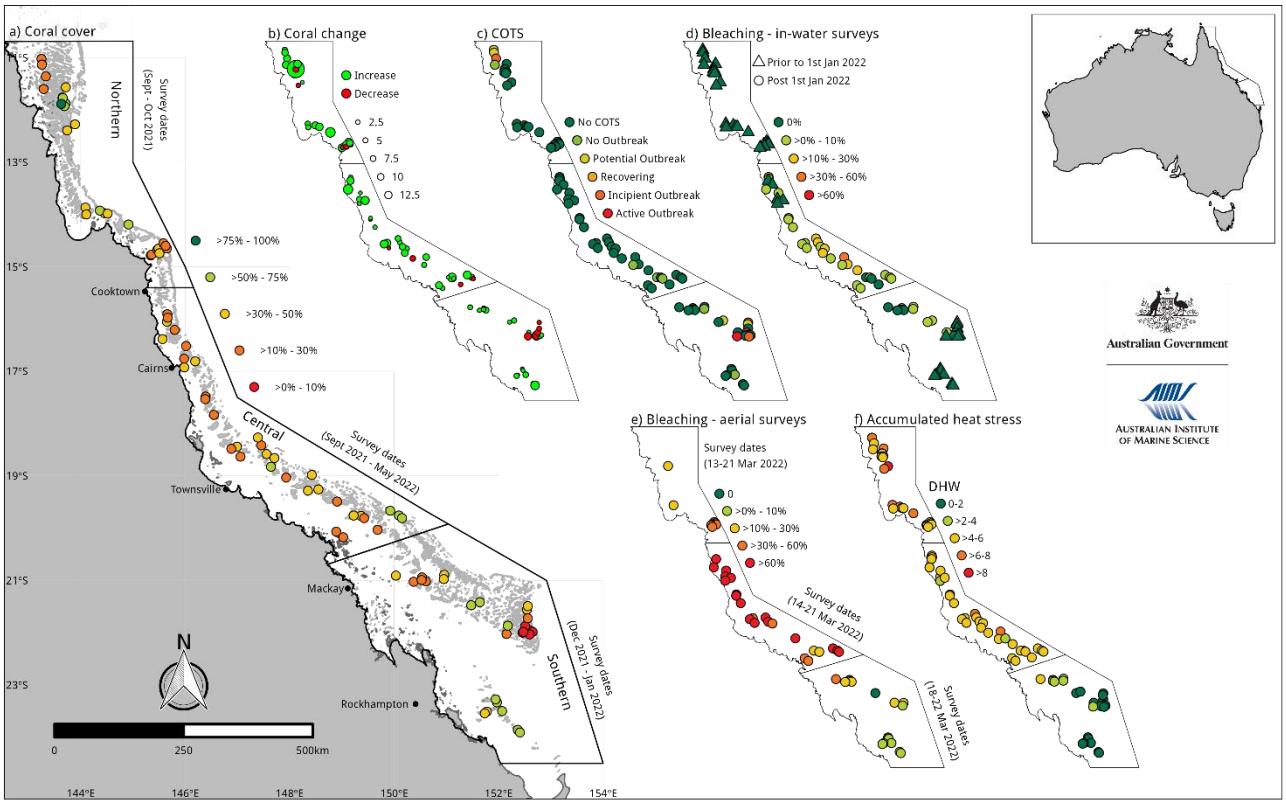


Figure 1: Summary of the results from the 87 reefs surveyed by manta tows between August 2021 and May 2022, along with the boundaries of the Northern, Central and Southern GBR reporting regions (see details of the long-term regional coral cover trends below). a) The status of the surveyed coral reefs is defined by the category of hard coral cover. b) The coral change metric displays the magnitude and direction of the absolute annual change in reef-level percent of hard coral cover between 2022 and the previous survey within the last two years. c) The COTS outbreak status of each reef is defined by the number of COTS per 2-minute manta tow: No COTS (0 COTS), No Outbreak (0 to 0.1 COTS), Potential Outbreak (0.1 to 0.22 COTS), Incipient Outbreak (0.22 to 1 COTS) and Active Outbreak (more than 1 COTS). Reefs are defined as Recovering when they were previously classified with an Incipient or Active Outbreak but currently have COTS numbers below outbreak thresholds. d) The coral bleaching severity recorded during in-water LTMP manta tow surveys. e) The coral bleaching severity recorded as the percent of live coral colonies bleached during aerial surveys conducted by AIMS and the Great Barrier Reef Marine Park Authority (GBRMPA) in March 2022. f) The degree of accumulated heat stress for 85 of the 87 LTMP survey reefs in 2022.

Background

With reef surveys extending over 36 years, the AIMS Long-Term Monitoring Program (LTMP) provides an invaluable record of change by repeatedly surveying coral reef communities over a large area of the Great Barrier Reef (GBR).

This annual summary of the state and trends in hard coral cover is based on manta tow surveys of coral reefs, mainly on the mid- and outer shelf (Figure 1).

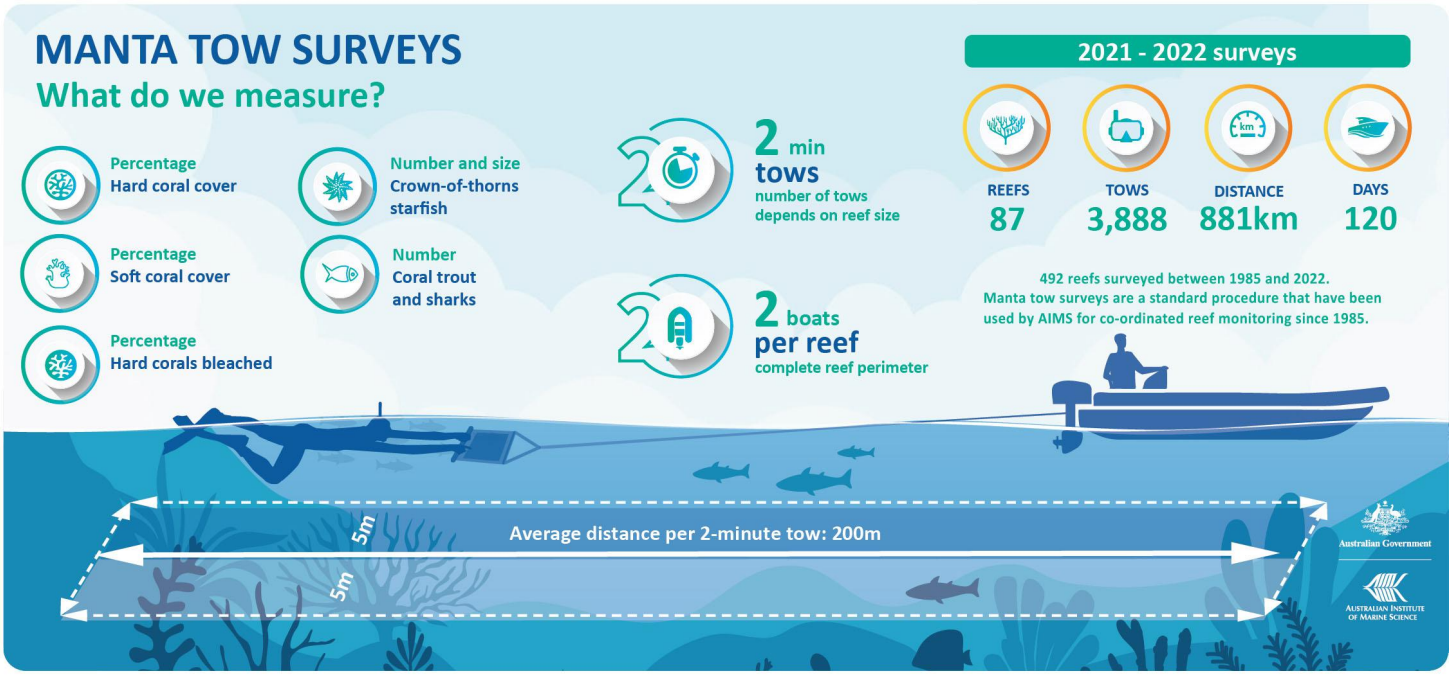
For this annual summary, the GBR Marine Park is divided into three regions (Figure 1), with each showing different trajectories of change in hard coral cover over time, mostly in response to the cumulative impacts of the main disturbances affecting the surveyed reefs, that is, severe tropical cyclones, outbreaks of crown-of-thorns starfish and coral bleaching.

A total of 87 reefs were surveyed from August 2021 to May 2022 (reported as '2022'). Detailed reports on the state and trends of reefs grouped by latitudinal sectors and of individual reefs, including their disturbance history, are available shortly after the completion of each survey trip. Data summaries are available for download.

The dynamic nature of GBR coral reefs and the considerable variation among regions in the decline and recovery rates of hard coral cover in response to disturbances are clear in the long-term record. Understanding the dynamics of the disturbance regime provides a critical context for the interpretation of the long-term monitoring data.

The LTMP provides the longest running, most spatially extensive dataset collected by standard methods on the GBR (see Box 1). The number of reefs able to be surveyed each year is small compared to the number of reefs found on the GBR (~100 vs 3000). However, the LTMP survey reefs provide a representative sample across the length and breadth of the GBR that captures several geographical and ecological gradients (e.g. latitude, position across the continental shelf) and encapsulates many of the bioregions and all the management zones defined in the 2004 rezoning of the Marine Park.

AIMS is committed to continuous improvement in the analysis of LTMP data, and recent statistical advances have permitted a refinement of analytical approaches used to analyse the type of ecological time series data used in this report. A newly developed dashboard now presents a synthesis of all coral reef monitoring data at AIMS across surveyed reefs and at various spatial aggregations (including Natural Resources Management (NRM) regions and latitudinal sectors).



Condition Summary to May 2022
Surveyed September to October 2021

There was substantial variation in the condition of individual reefs in the Northern GBR (Figure 1a, Image 1).

Ten of 26 reefs had coral cover >10% – 30%, nine reefs had >30% – 50%, five had coral cover >50% – 75% and two reefs had coral cover >75% (Figure 1a).

Recovery has continued on the majority of Northern GBR reefs following a period of cumulative disturbances from 2014 to 2020. Only three out of 26 reefs previously surveyed in the last two years had decreased hard coral cover (Figure 1b).

Region-wide hard coral cover continued to increase from the lowest levels recorded by the LTMP in 2017 of 13% to 36% in 2022, the highest levels recorded by the LTMP (Figure 2). Much of the recovery occurred in the Cape Grenville and Princess Charlotte Bay sectors, which were severely impacted by the 2016 mass coral bleaching event.

The fourth mass coral bleaching event since 2016 occurred over the austral summer of 2021/22 and Northern GBR reefs were variously affected.

In 2022, LTMP in-water surveys were conducted during September and October 2021, prior to peak summer temperatures and no bleaching was recorded (Figure 1d). Aerial surveys conducted at the height of the bleaching event in March surveyed eight LTMP reefs. All eight reefs had signs of bleaching; two were moderately bleached (>10% – 30% of colonies bleached), five had major bleaching (>30% – 60% of colonies bleached) and one showed severe bleaching (>60% of colonies bleached; Figure 1e).

The impacts of this event are discussed in more detail below.

Surveys in 2022 found low crown-of-thorns starfish activity in the region (Image 1A), most reefs were classified as *No COTS* and *No Outbreak* and only two reefs with *Potential Outbreaks* and one reef was classified as *Incipient Outbreak* (Figure 1c).

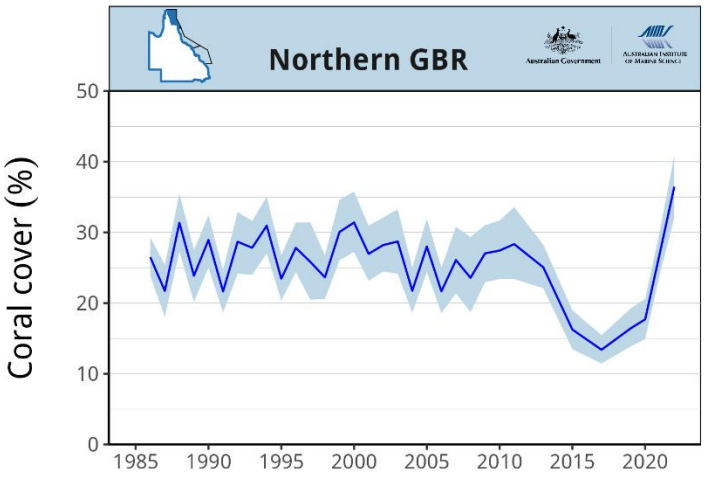


Figure 2: Trends in average hard coral cover (blue line) for the Northern GBR based on manta tow surveys. Survey data from 129 reefs contributed to the 36-year time series; blue shading represents 95% confidence intervals. A total of 26 reefs were surveyed in 2022. Note that many reefs in this region do not have a regular survey history and in recent years fewer inshore reefs have been surveyed due to the risk of crocodile encounters.

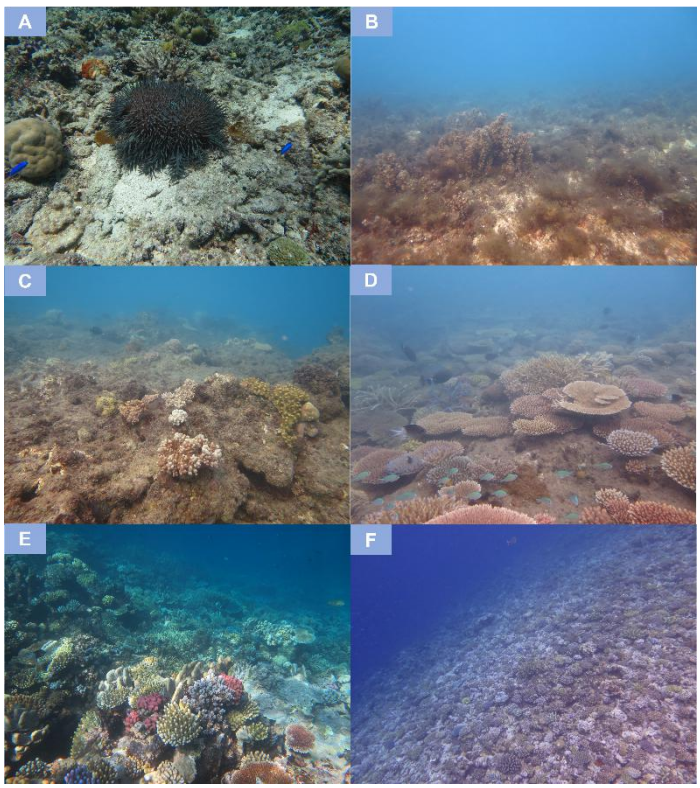


Image 1: Photos showing the variable state of reefs in the Northern GBR in 2022. A. A small cluster of reefs in the far north had populations of crown-of-thorns starfish on them at Potential or Incipient Outbreak levels such as Reef 11-049. B. Some reefs are still yet to begin recovery from the 2016 mass coral bleaching event, such as McSweeney Reef. Other mid-shelf reefs have had substantial recovery of hard coral cover as seen at Linnet Reef near Lizard Island, shown in C. 2017 and D. 2022. E. and F. Outer shelf coral assemblages had moderate to high levels of hard coral cover, such as Lagoon Reef and No Name Reef. More information on individual survey reefs can be found here.

Condition Summary to May 2022
Surveyed September 2021 to May 2022

Since regular surveys by AIMS began in 1985, hard coral cover on reefs in the Central GBR has generally been lower than that in the Northern and Southern GBR.

Region-wide hard coral cover in the Central GBR decreased to the lowest level in LTMP records in 2012, following the impact of Severe Tropical Cyclone Yasi in 2011. Hard coral cover then recovered rapidly to 29% in 2016. From 2016 to 2019, region-wide hard coral cover decreased continuously to 14%, largely due to repeated mass coral bleaching in 2016 and 2017 and outbreaks of crown-of-thorns starfish. In 2022, hard coral cover had increased again to 33%, the highest recorded by the LTMP for this region (Figure 3).

The status of the reefs in the Central GBR was variable in 2022; 16 of the 33 reefs surveyed had hard coral cover >10% – 30% while 13 reefs had coral cover >30% – 50% (Figure 1, Image 2). Four of the surveyed reefs had hard coral cover >50% – 75% (Figure 1a).

A total of 30 of the 33 Central GBR reefs surveyed in 2022 had been previously surveyed within the last two years. Hard coral cover had declined on only four reefs, increasing on most of them (Figure 1b).

Many reefs offshore from Cairns, Innisfail and Townsville have had outbreaks of crown-of-thorns starfish in recent years. However, there were no *Potential*, *Incipient* or *Active Outbreaks* of crown-of-thorns starfish recorded on Central GBR reefs in 2022 (Figure 1c).

The Great Barrier Reef Marine Park Authority's Crown-of-thorns Starfish Control Program has been actively removing substantial numbers of starfish in this area, which has likely contributed to the low numbers of crown-of-thorns starfish recorded during these surveys.

Widespread coral bleaching (minor to major) was observed in the Central GBR during LTMP in-water surveys between January and May 2022, while reefs surveyed in September 2021 (before the summer heat stress) were not bleached (Figure 1d). Aerial surveys conducted at the height of the bleaching event in March surveyed 23 LTMP reefs. Two were moderately bleached (>10% – 30% of colonies bleached), four had major bleaching (>30% – 60% of colonies bleached), 12 showed severe bleaching (>60% – 90% of colonies bleached) and five had extreme bleaching (>90% of colonies bleached; Figure 1e). The impacts of this event are discussed in more detail below.

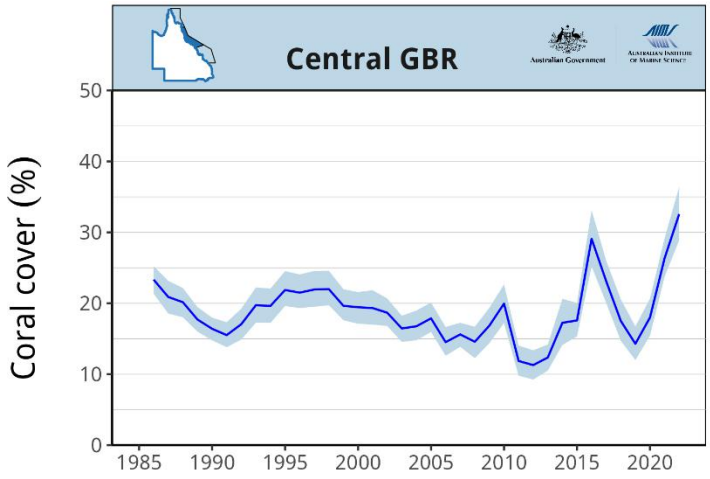


Figure 3: Trends in average hard coral cover (blue line) for the Central GBR based on manta tow surveys. Survey data from 226 reefs contributed to the 35-year time series; blue shading represents 95% confidence intervals. A total of 33 reefs were surveyed in 2022.

Image 2: The Central GBR was most severely affected by the mass coral bleaching event that unfolded over the austral summer, although the severity of the event varied among reefs and survey months. A. In early February, there was differential bleaching among various types of corals at Reef 19-131, whereas B. most corals at Jaguar Reef were bleached at the end of February, as the heatwave intensified. Differential effects of disturbances can lead to differences in the current status among reefs, but also at different parts of the same reef, like C. and D. that show the reef flat habitat in different parts of John Brewer Reef. Some Central GBR reefs had very high coral cover like E. Hyde Reef offshore from the Whitsundays, while other reefs were recovering from previous disturbances like F. Myrmidon Reef. More information on individual survey reefs can be found here.

Condition Summary to May 2022
Surveyed December 2021 and January 2022

The Southern GBR has generally had higher coral cover than the Northern or Central GBR, but it has also been the most dynamic over the 36-year survey history. Tropical Cyclone Hamish in 2009 reduced coral cover to the lowest levels recorded by the LTMP in 2011 (Figure 4). A large increase in hard coral cover occurred from 2011 to 2016, reaching 37% in 2017. However, outbreaks of crown-of-thorns starfish began in 2018 and regional coral cover decreased to 29% in 2019. In 2021, coral cover had increased to 38% but declined again in 2022 to 34% (Figure 4).

The state of individual Southern GBR reefs was variable (Image 3) with one reef having cover of <10%, 13 reefs having cover >10% – 30%, six reefs with cover >30% –50% and eight reefs with cover >50% – 75% (Figure 1a). Of the 28 reefs surveyed in 2022, 24 reefs have been surveyed in the last two years. Hard coral cover decreased on six of these, whereas 18 reefs had increased hard coral cover (Figure 1b).

In January 2022, there was widespread low-level bleaching (<10% of colonies) of sensitive species during LTMP in-water surveys; however, no instances of more severe bleaching were observed (Figure 1d). Aerial surveys by AIMS and GBRMPA in March 2022 revealed widespread bleaching across much of the Southern GBR. However, the severity of bleaching varied substantially. Of the 28 reefs surveyed by the LTMP this year, 16 were captured during the aerial surveys in March. Two reefs had no bleaching, seven reefs had minor bleaching, four had moderate bleaching and three had major levels of bleaching (Figure 1e). The impacts of this event are discussed in more detail below.

The Southern GBR has been the epicentre of crown-of-thorns starfish outbreaks in recent years, and this was the same in 2022, with the focus in the Swain reefs. Three of the 27 reefs were classified as having *Active Outbreaks,* two reefs had *Incipient Outbreaks* and three reefs had *Potential Outbreaks* (Figure 1c). Low numbers of crown-of-thorns starfish were recorded on two reefs classified as *No Outbreak* and the remainder had No COTS.

The Great Barrier Reef Marine Park Authority's Crown-of-thorns Starfish Control Program has been actively removing substantial numbers of starfish in this area.

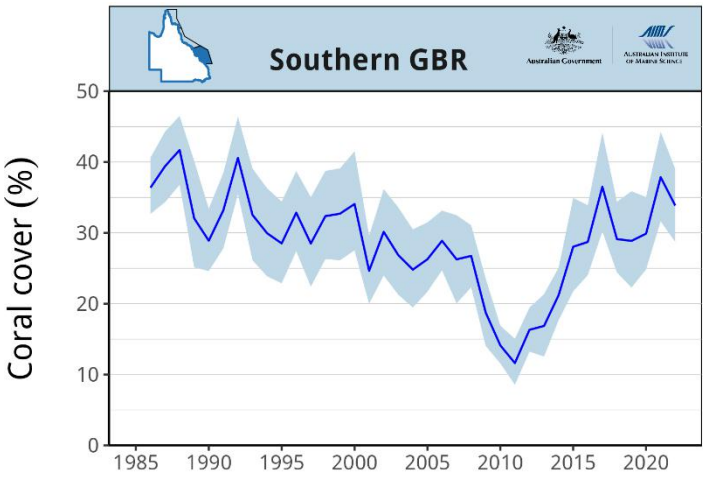


Figure 4: Trends in average hard coral cover (blue line) for the Southern GBR based on manta tow surveys. Survey data from 137 reefs contributed to the 35-year time series; blue shading represents 95% confidence intervals. A total of 28 reefs were surveyed in 2022.

Image 3: Many reefs in the Southern GBR have high coral cover, such as A. Reef 21-187 in the Pompey sector and B. Lady Musgrave Reef in the Capricorn-Bunkers. However, C. surveys of agents of coral mortality revealed D. outbreaks of crown-of-thorns starfish continue to decimate coral populations on many reefs in the Swain sector. Such outbreaks have reduced hard coral cover from E. very high levels in 2016 to F. very low coral cover in 2022 as seen at Jenkins Reef in the Swain sector. More information on individual survey reefs can be found here.

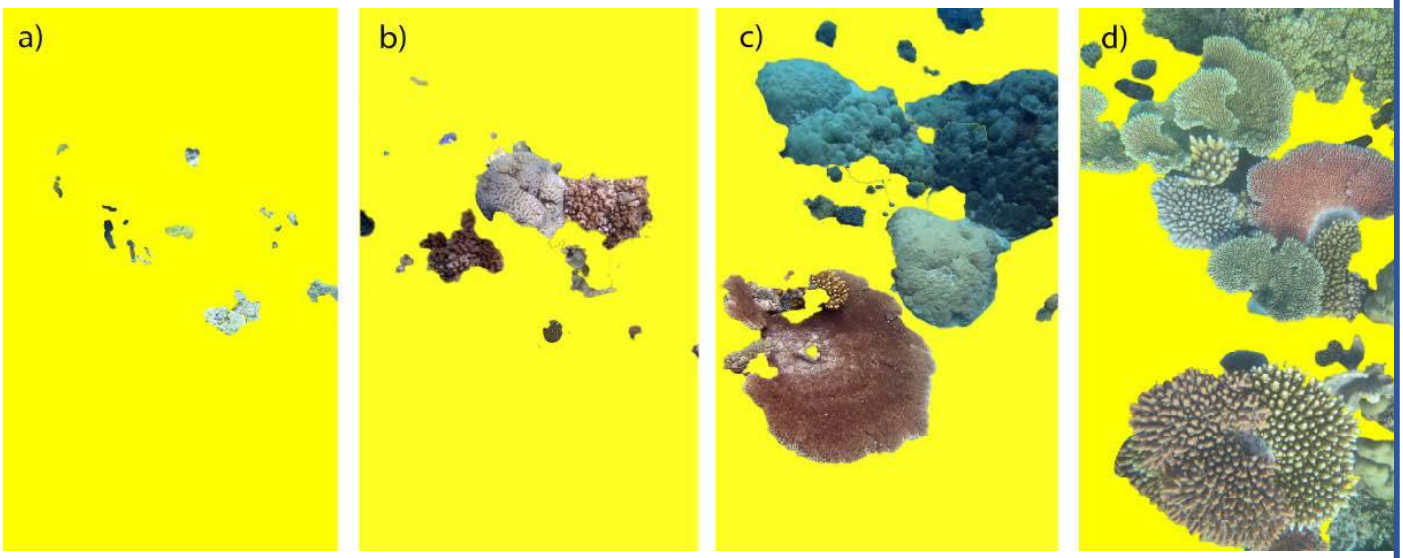
BOX 1: What does 'percent hard coral cover' mean?

There are many ways to measure the status of coral reefs. One of the most common is to use percent hard coral cover as an 'indicator' of reef condition because it describes the abundance of a critical ecosystem engineer on coral reefs. This measure describes the proportion of the seafloor that is covered in live hard coral. Percent hard coral cover is widely used by scientists worldwide and is a standard measure that applies to all locations. While it does not tell us anything about the diversity or composition of coral assemblages, it provides a simple and robust measure of reef health.

Percent hard coral cover can be estimated using various techniques. The technique used for this report is manta tow surveys, which are visual estimates of percent hard coral cover over the area covered by an observer during one 2-minute tow (~2000m^2). The percent hard coral cover for a reef is then estimated as the average of the estimates from all tows around a reef and reported as broad categories (e.g., 0 = 0%, >0% – 10%, >10% – 30%, >30% – 50%, >50% – 75% and >75% – 100%; Box 1 Image).

A coral reef consists of more than just hard coral and contains a diverse array of other corals, sponges, algae, sand, rock and invertebrates. It is relatively rare for GBR reefs to have 75% to 100% hard coral cover and AIMS defines >30% – 50% hard coral cover as a high value, based on historical surveys across the GBR.

Other techniques for determining percent hard coral cover involve counting the number of points within sampling units (quadrats, photos), as used by LTMP in fixed site surveys, or the linear distance along a tape measure (line-intercept) that intersect live hard coral colonies. Adding up the total number of points of live hard coral cover and then expressing this as a percentage of the total number of points within a sample yields the estimates of hard coral cover. Data from both the fixed site and manta tow surveys conducted by the LTMP are highly correlated and show the same trends in hard coral cover estimates. However, manta tow estimates are generally lower than those obtained from fixed site surveys as they encompass the entire reef, including sandy back reef habitats that have low coral cover.



Box 1 Image: Examples of categories of percent hard coral cover a) >0% — 10%, b) >10% — 30%, c) >30% — 50% and d) >50 — 75%. The yellow areas show non-hard coral substrate, and the categorisation is based on the proportion of the substrate covered in live hard coral colonies.

Extent and Severity of the 2022 Mass Coral Bleaching Event

In the austral summer of 2021/22, much of the GBR was subjected to a level of accumulated heat stress that caused mass coral bleaching to occur. This was the fourth such event since 2016 and the first to ever occur in a La Niña year and is a sign that the GBR is experiencing the consequences of climate change.

To detect coral bleaching, surveys need to occur during or after the summer heatwave. In 2022, the peak heat stress occurred during March.

Of the 87 reefs surveyed in-water by LTMP this season, 44 were surveyed in September and December 2021 before the peak bleaching season, and 43 were surveyed during the peak bleaching season from January to May 2022. Of the 43 surveyed during the peak of the bleaching, 11 had no bleaching, 24 had minor bleaching (>0% – 10%), seven had moderate bleaching (>10% – 30%) and one had major bleaching (>30% – 60%).

Aerial surveys undertaken by AIMS and GBRMPA at the peak of the event in March 2022 revealed widespread bleaching across the GBR, with reefs in the Central GBR most severely affected (Image 5).

The aerial surveys included 47 reefs surveyed by the LTMP and recorded coral bleaching on 45 of these reefs (Figure 1e). Aerial surveys recorded severe bleaching (>60% of coral colonies bleached) on 18 LTMP survey reefs, predominantly in the Central GBR (17 reefs: Figure 1e).

It is important to place these results into the context of the accumulated heat stress experienced by survey reefs during the 2022 event, recorded as DHW. Accumulated heat stress was variable across the GBR, and the highest values were observed on inshore and outer shelf reefs in the Northern and Central GBR in 2022 (Figure 5). Of the 87 LTMP reefs, 20 had thermal stress accumulation representing low bleaching risk (0 – 2 DHW), eight were at bleaching warning levels (2 – 4 DHW), 49 were at where bleaching was possible (4 – 6 DHW) and nine were categorised as bleaching probable (6 – 8 DHW) (Figure 5). Widespread mass coral bleaching is expected between 4 DHW and 8 DHW, with a greater risk of mortality above 8 DHW (Figure 5). This agrees with the observations from aerial surveys of widespread bleaching across the GBR.

Only one survey reef (Mantis Reef in the Northern GBR; 11.08 DHW) experienced heat stress above the levels at which mortality from coral bleaching is expected (8 DHW; Figure 5).

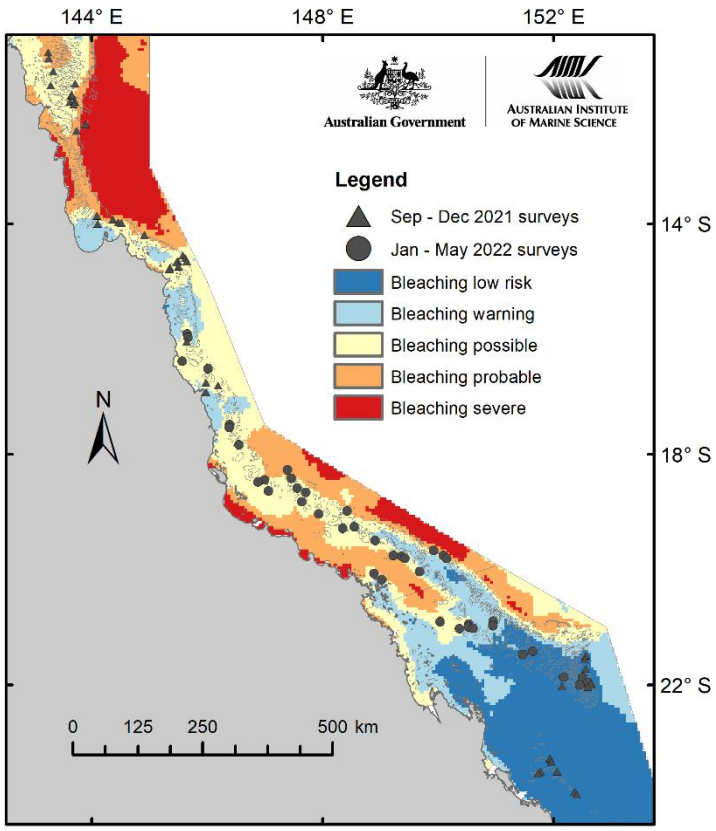


Figure 5: Exposure level of the 87 LTMP reefs surveyed in 2022 to accumulated heat stress during the austral summer of 2021/2022. Bleaching low risk = 0 – 2 DHW, Bleaching warning =2 – 4 DHW, Bleaching possible= 4 – 6 DHW, Bleaching probable= 6 – 8 DHW, Severe bleaching >8 DHW. Widespread bleaching is expected above 4 DHW, while coral mortality is predicted above 8 DHW. Source: NOAA/NESDIS/STAR Coral Reef Watch program

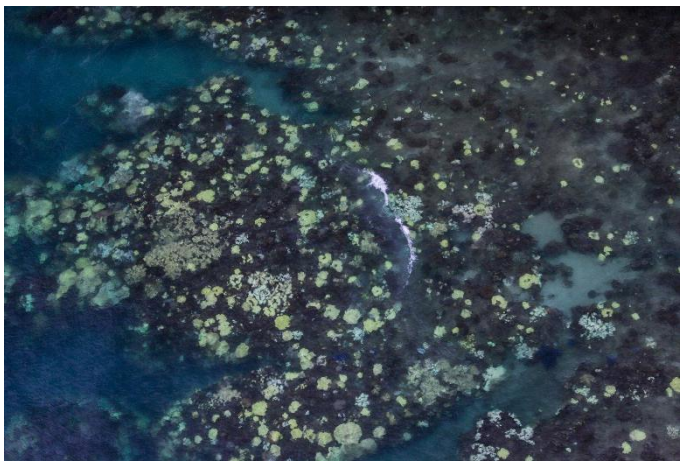


Image 4: Bleached hard and soft coral colonies on the upper reef slope and reef flat at Great Palm Island during the peak of the mass coral bleaching event in March 2022. Photo credit: Jessica Stella, GBRMPA.

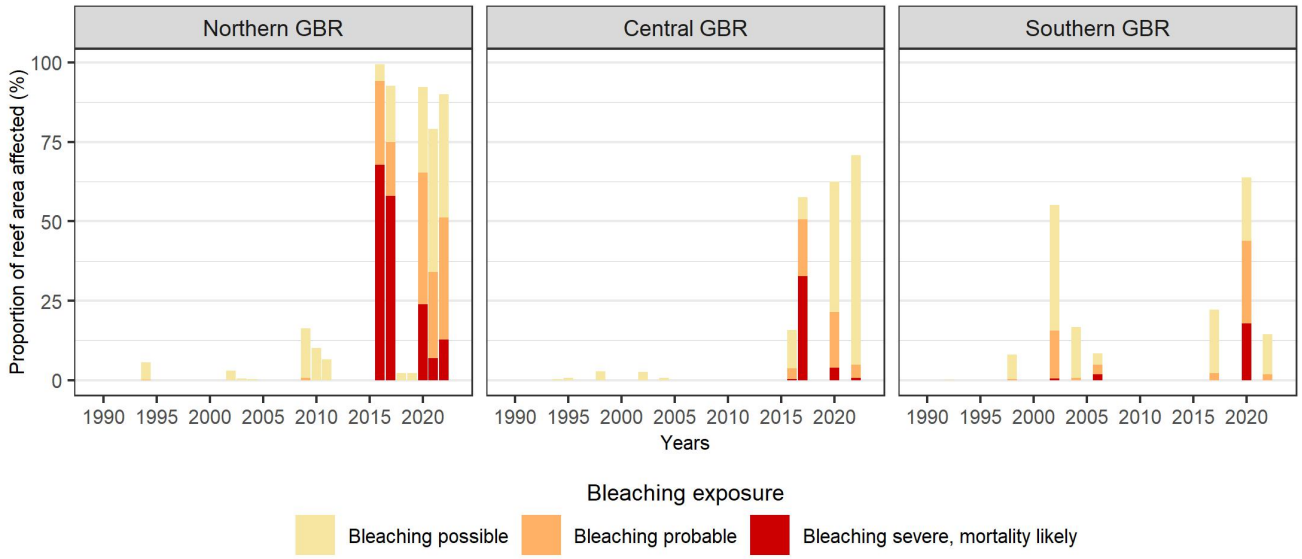


Figure 6: Comparison of accumulated heat stress from 1990 to 2022. Data are the proportion of reefs in each reporting region (Northern, Central and Southern GBR) exposed to heat stress where bleaching is possible (4 – 6 DHW), where bleaching is probable (6 – 8 DHW) and where severe bleaching and coral mortality are likely (>8 DHW).

Heat stress accumulation between 4 and 8 DHW can cause some mortality but is more likely to produce sub-lethal effects like reduced growth, reproductive output and larval settlement following moderate bleaching. These sub-lethal effects can have long-lasting impacts on the recovery dynamics of coral reefs; however, the full extent of these impacts is poorly understood and will only become evident in the future.

The LTMP surveys are representative but remain a small proportion of GBR reefs, and there are reefs not surveyed that would have experienced high levels of accumulated heat stress above thresholds at which we would expect to see coral mortality. Over the past four decades, heat stress has been measured from satellite estimations of sea surface temperature in relation to the climatological maximum monthly mean.

The GBR has experienced a notable increase in the magnitude and extent of heatwaves in the past seven years, with about 60% of the reefs in the Northern GBR experiencing severe levels of thermal stress in 2016 and 2017 (Figure 6).

While the GBR experienced large-scale bleaching in 2020 and 2022, the extent of reefs severely affected by thermal anomalies has been consistently lower than in 2016 and 2017 (Figure 6). Therefore, the expected mortality due to thermal stress over the last two years is likely to be much lower than after the 2016, 2017 and even 2020 bleaching events.

A point of concern, however, is the increasing frequency and extent of bleaching events. Mass bleaching events are occurring almost annually and pose significant risks to the future condition of the coral reefs in the GBR.

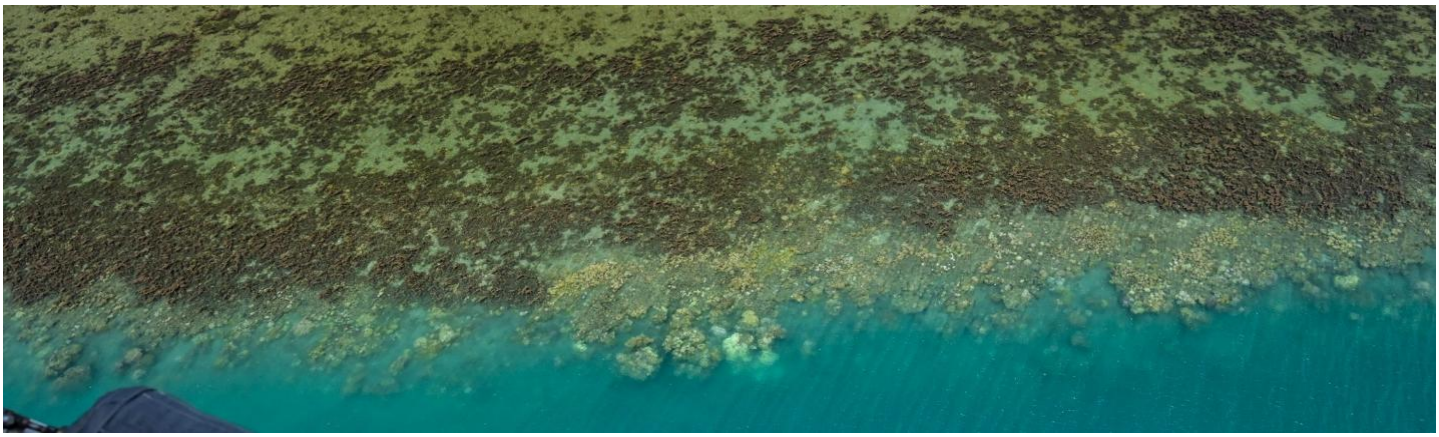


Image 5: Bleached hard and soft coral colonies on the upper reef slope and reef flat in the Far Northern GBR during the peak of the mass coral bleaching event in March 2022. Photo credit: Neal Cantin AIMS

Assessing the Long-term Health of the Great Barrier Reef

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Determining the status of the GBR requires robust long-term datasets collected using standard methods. Long-term data are particularly important to avoid the 'shifting baseline' syndrome, as the results each year are always considered in the context of the long-term trends.

The last few years have revealed continued recovery across much of the GBR. The recent hard coral cover increases have brought the Northern and Central GBR to the highest recorded coral cover since the LTMP began monitoring in the 1980s.

This recovery has occurred despite the latest two mass coral bleaching events in 2020 and 2022, which underlines that widespread coral bleaching does not necessarily lead to coral mortality. The 2020 and 2022 events saw accumulated heat stress at the survey reefs to a level where widespread bleaching occurred (4 – 8 DHW), but not to the level where widespread coral mortality was expected (>8 DHW). Nonetheless, the increased frequency and extent of bleaching events remains concerning.

As recorded previously, most of the recovery was driven by increases in the fast-growing *Acropora* corals, which have proliferated across many GBR reefs. Once established, these corals enter an exponential growth phase that rapidly increases measures of percent hard coral cover, as documented in this year's results. However, they are particularly susceptible to wave damage, like that generated by strong winds and tropical cyclones.

They are also highly susceptible to coral bleaching and are the preferred prey for crown-of-thorns starfish. Therefore, large increases in hard coral cover can quickly be overturned by disturbances on reefs where *Acropora* predominate.

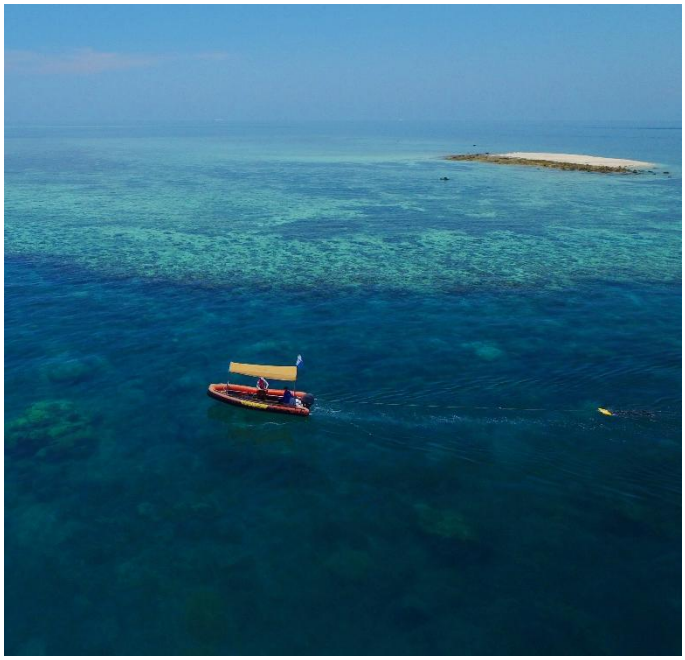
The prognosis for the future disturbance regime under climate change is one of increasingly frequent and longer lasting marine heatwaves, with the on-going risk of crown-of-thorns starfish outbreaks and tropical cyclones. There have been four mass coral bleaching events in the past seven years. Mitigation of these climatic threats requires immediate global action on climate change.

Crown-of-thorns starfish as coral predators are a major cyclic disturbance on the GBR. The Australian Government's Crown-of-thorns Starfish Control Program has been active on the GBR during the current outbreak and seeks to decrease starfish numbers at key reefs to reduce the amount of coral lost and diminish the starfish brood stock that propagates the outbreak 'wave' southward through most of the GBR.

In 2022, the number of Active Outbreaks has continued to decrease from previous years, although outbreaks were still recorded in the Swain sector of the Southern GBR. The LTMP provides data to routinely assist in the prioritisation and analyses of the effectiveness of the Crown-of-thorns Starfish Control Program.

The predicted consequences of climate change, which include more frequent and intense mass coral bleaching events, are now a contemporary reality. Simultaneously, chronic stressors such as high turbidity, increasing ocean temperatures and changing ocean chemistry can all negatively affect recovery rates, while more frequent acute disturbances mean that the intervals for recovery are becoming shorter.

Measuring and understanding the process of, and limitations to, coral reef recovery will be a continued focus of AIMS' research and monitoring.



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