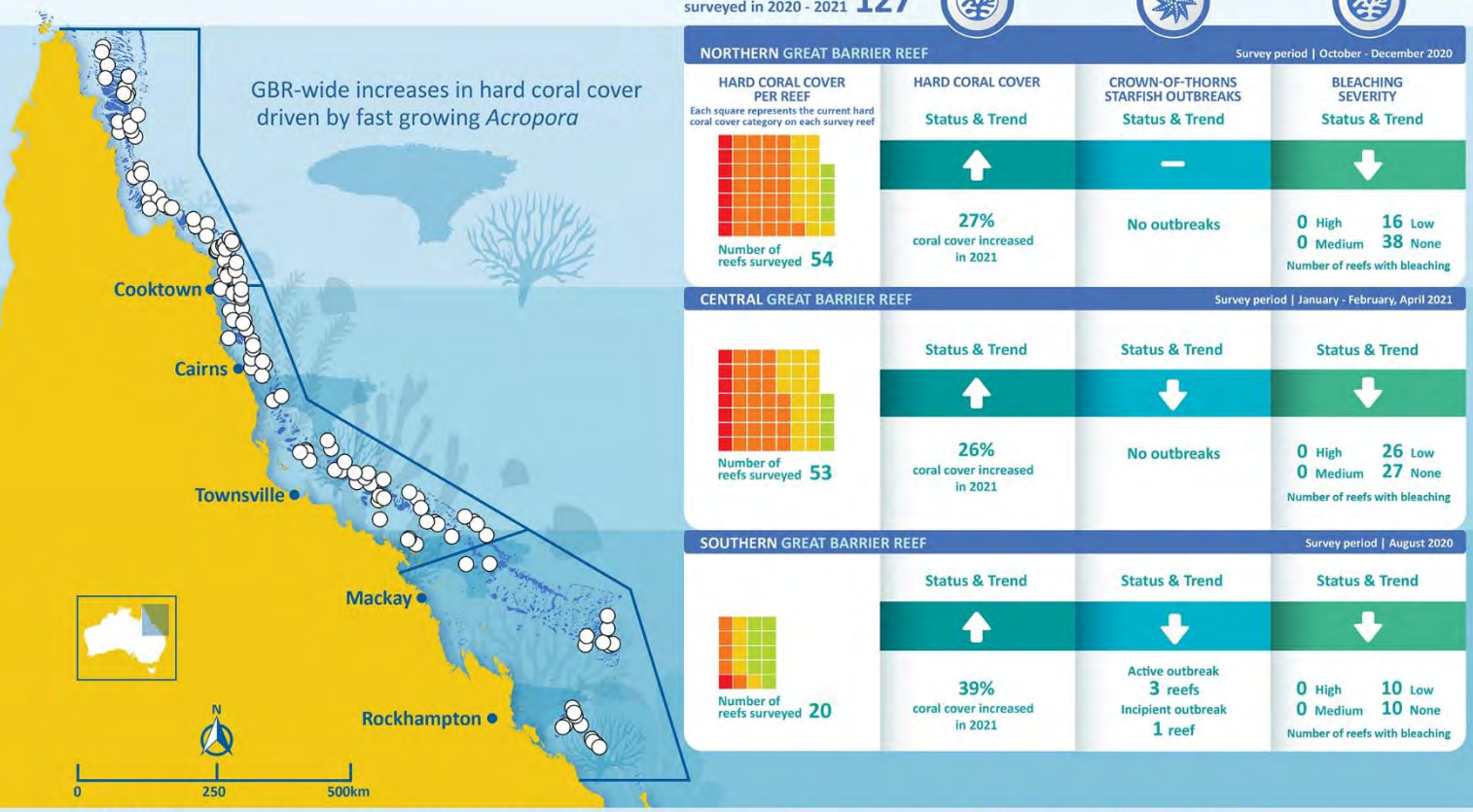
ANNUAL SUMMARY REPORT OF
CORAL REEF CONDITION 2020/2021

Australian Government | Australian Institute of Marine Science

Reef in recovery window after decade of disturbances

AIMS LONG-TERM MONITORING PROGRAM 2020 - 2021 RESULTS



Total number of reefs surveyed in 2020 - 2021 **127**

NORTHERN GREAT BARRIER REEF	HARD CORAL COVER PER REEF	HARD CORAL COVER	CROWN-OF-THORNS STARFISH OUTBREAKS	BLEACHING SEVERITY
Survey period | October - December 2020	Each square represents the current hard coral cover category on each survey reef	Status & Trend	Status & Trend	Status & Trend
	Number of reefs surveyed **54**	27% coral cover increased in 2021	No outbreaks	0 High, 16 Low, 0 Medium, 38 None — Number of reefs with bleaching
CENTRAL GREAT BARRIER REEF				
Survey period | January - February, April 2021	Number of reefs surveyed **53**	26% coral cover increased in 2021	No outbreaks	0 High, 26 Low, 0 Medium, 27 None — Number of reefs with bleaching
SOUTHERN GREAT BARRIER REEF				
Survey period | August 2020	Number of reefs surveyed **20**	39% coral cover increased in 2021	Active outbreak 3 reefs; Incipient outbreak 1 reef	0 High, 10 Low, 0 Medium, 10 None — Number of reefs with bleaching

LEGEND

- Survey Site Locations
- **HARD CORAL COVER:** Low >0% - 10% | Moderate >10% - 30% | High >30% - 50% | Very High >50% - 75%
- **CROWN-OF-THORNS (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:** **Low** Under 10% colonies bleached | **Medium** Between 10% and 30% colonies bleached | **High** Over 30% colonies bleached

SUMMARY

Hard coral cover increased across all three regions (Northern, Central and Southern) in the last two years, and most reefs surveyed had moderate or high coral cover.

After a decade of cumulative disturbances, the Great Barrier Reef (GBR) has experienced a low disturbance year in 2021. There was no prolonged heat stress or any cyclones of note, and decreased numbers of crown-of-thorns starfish outbreaks across much of the GBR. Results from 2021 revealed minimal loss of coral from the 2020 coral bleaching event, as only a few survey reefs experienced heat stress during 2020 above the threshold at which extensive coral mortality is expected.

While there has been recovery of hard coral cover, this was driven by fast-growing Acropora corals which are vulnerable to the common disturbances affecting the GBR. Surveys also recorded shifts in coral communities on some outer shelf reefs in the Northern and Central GBR following the 2016/17 mass coral bleaching events.

The GBR remains exposed to the predicted consequences of climate change, including more severe cyclones and more frequent and intense marine heatwaves. The observed recovery has been seen previously and can be reversed in a short amount of time.

- This report summarises the condition of coral reefs of the Great Barrier Reef (GBR) from the Long-Term Monitoring Program (LTMP) surveys of 127 reefs conducted between August 2020 and April 2021 (reported as '2021').
- Over the 35 years of monitoring by AIMS, the reefs of the GBR have shown an ability to recover after disturbances.
- In 2021, widespread recovery was underway, largely due to increases in fast growing *Acropora* corals.
- Survey reefs experienced low levels of acute stressors over the past 12 months with no prolonged high temperatures or major cyclones. Numbers of outbreaks of crown-of-thorns starfish on survey reefs have generally decreased; however, there remain ongoing outbreaks on some reefs in the Southern GBR.
- Overall, 59 out of 127 reefs had moderate (>10% - 30%) hard coral cover and 36 reefs had high (>30% - 50%) hard coral cover.
- On the Northern GBR, region-wide hard coral cover was moderate and had continued to increase to 27% from the most recent low point in 2017.
- On the Central GBR region-wide hard coral cover was moderate and had increased to 26% in 2021.
- Region-wide hard coral cover on reefs in the Southern GBR was high and had increased to 39% in 2021.
- In 2020, most of the surveyed reefs experienced heat stress accumulation that produced widespread coral bleaching but was below thresholds where widespread mortality is expected to occur. Consistent with this, surveys in 2021 recorded low coral mortality from the 2020 bleaching event.
- In periods free from 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, and the prognosis for the future disturbance regime is one of increased and longer lasting marine heatwaves and a greater proportion of severe tropical cyclones.

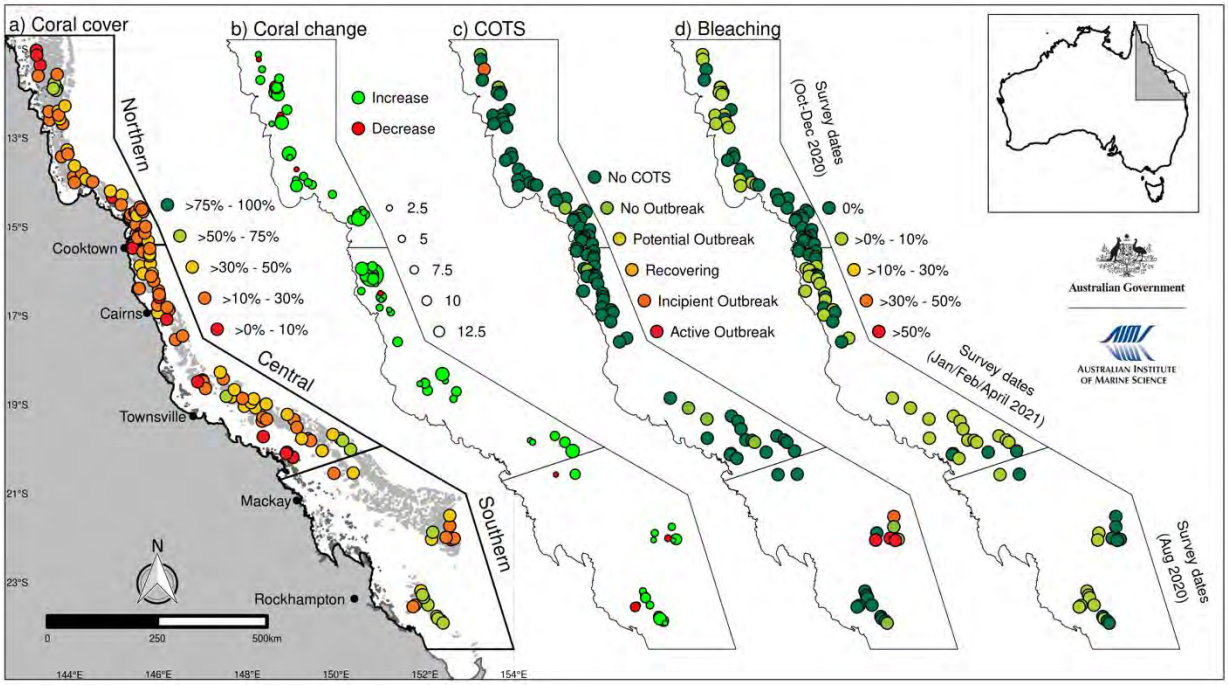


Figure 1: Summary of the results from the 127 reefs surveyed by manta tows between August 2020 and April 2021, along with the boundaries of the Northern, Central and Southern GBR reporting regions (see details of the long-term regional coral cover trends further below). a) The status of the surveyed coral reefs is defined by the category of hard coral cover. b) The coral change displays the magnitude and direction of the absolute annual change in reef-level percent hard coral cover between 2021 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 is reported as the percent of live coral colonies bleached at the time of survey per region: Northern GBR (October/November/December 2020), Central GBR (January/February and April 2021) and Southern GBR (August 2020).

Background

With reef surveys extending over 35 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 update of the state and trends in hard coral cover across the entire GBR is based on manta tow surveys of coral reefs, mainly on the mid- and outer shelf (Figure 1).

A total of 127 reefs were surveyed from August 2020 to April 2021 (reported as '2021'). Detailed reports on the state and trends of reefs by latitudinal sectors and of individual reefs, including their disturbance history, and 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 rates of decline and recovery 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.

For annual updates, 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, e.g., severe tropical cyclones, outbreaks of crown-of-thorns starfish and coral bleaching.

The LTMP provides the longest running, most spatially extensive dataset collected by standard methods on the GBR (see Box 1). Due to logistical and cost constraints, the numbers of reefs surveyed each year are 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 continual improvement in the analyses 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.

This year we have examined the effectiveness of several approaches and present an ensemble of various statistical models with a justification for the choice of the model selected in this report (see Box 2).

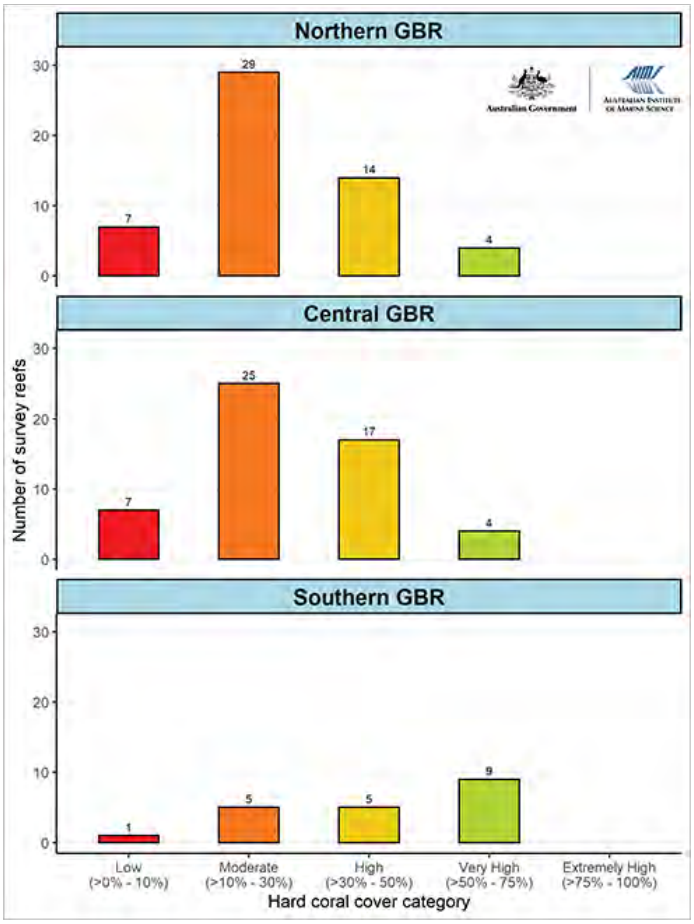
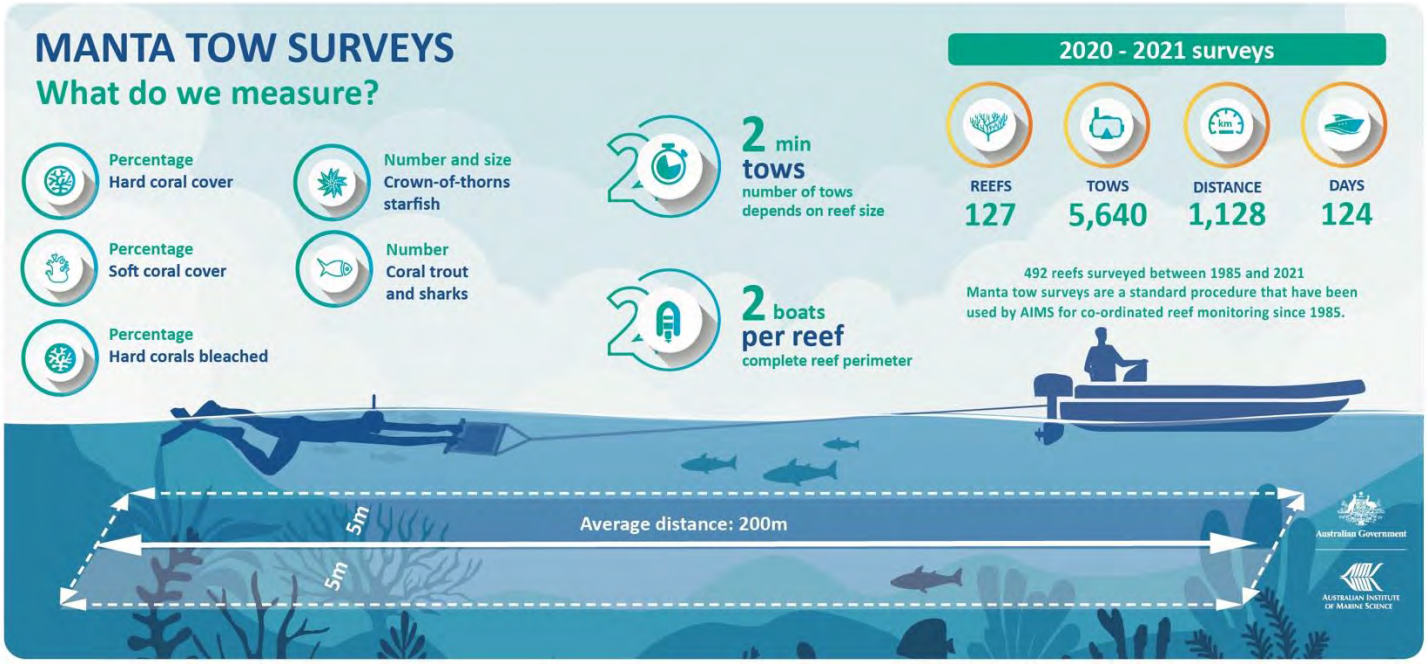


Figure 2: Status of the 127 reefs surveyed in the Northern, Central and Southern GBR in 2021. Data are the number of reefs with average hard coral cover falling within low, moderate, high and very high coral cover categories.


MANTA TOW SURVEYS
What do we measure?
Percentage
Hard coral cover
Percentage
Soft coral cover
Percentage
Hard corals bleached
Number and size
Crown-of-thorns starfish
Number
Coral trout and sharks
2 min
tows
number of tows depends on reef size
2 boats
per reef
complete reef perimeter
2020 - 2021 surveys
REEFS
127
TOWS
5,640
DISTANCE
1,128
DAYS
124
492 reefs surveyed between 1985 and 2021
Manta tow surveys are a standard procedure that have been used by AIMS for co-ordinated reef monitoring since 1985.
5m
Average distance: 200m
5m
Australian Government
Australian Institute of Marine Science

Condition Summary to April 2021
Surveyed October to December 2020

There was substantial variation in the condition of individual reefs in the Northern GBR (Figures 1 and 2, Image 1).

Seven of 54 reefs surveyed had low coral cover (>0% - 10%), 29 reefs had moderate coral cover (>10% - 30%), 14 reefs had high (>30% - 50%) and four had very high coral cover (>50% - 75%) (Figures 1 and 2).

Recovery was underway on the majority of Northern GBR reefs following a period of cumulative disturbances stretching from 2014 to 2020.

Of the 32 reefs previously surveyed in the last two years, only six had decreased in hard coral cover (Figure 1), indicating there was minimal mortality from the 2020 mass coral bleaching event at these survey reefs.

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

Region-wide hard coral cover continued to increase from the lowest levels recorded by the LTMP in 2017 to 27% in 2021 (Figure 3).

Surveys in 2021 found little evidence of crown-of-thorns starfish activity in the region, most reefs were classified as *No COTS* and *No Outbreak* and only one reef classified as *Incipient Outbreak* (Figure 1).

In 2021, surveys were conducted prior to peak summer temperatures.

During surveys, 15 of 54 Northern GBR reefs had low-level bleaching (<10% of corals bleached), with no bleaching recorded on the remainder. This indicates there was some accumulation of thermal stress in 2021.

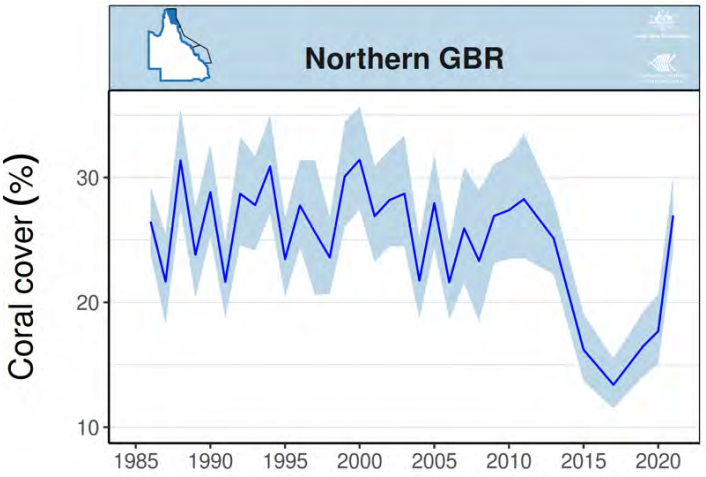


Figure 3: Trends in average hard coral cover (blue line) for the Northern GBR based on manta tow surveys. Survey data from 129 reefs contributed to the 35-year time series; blue shading represents 95% confidence intervals. 54 reefs were surveyed in 2021. Note that many reefs in this region do not have a regular survey history, and in recent years fewer inshore reefs were surveyed due to the risk of crocodile encounters.

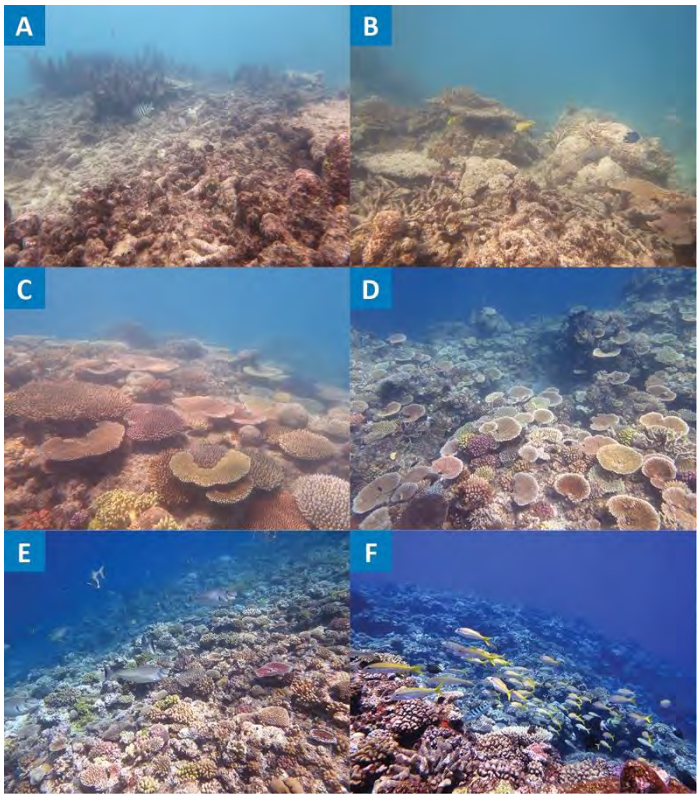


Image 1: Photos showing the variable state of reefs in the Northern GBR in 2021. Some reefs had yet to recover from a series of recent disturbances with low hard coral cover and dead standing skeletons covered in turf algae, mostly on mid-shelf reefs such as A. Monsoon Reef and B. Reef 11-049. Other mid-shelf reefs had high numbers of *Acropora* corals, such as C. Forrester Reef near Cooktown and D. Macgillivray Reef near Lizard Island. Outer shelf coral assemblages had moderate to high levels of hard coral cover such as e) Reef 14-075 and f) Ribbon Reef No. 1. More information on individual survey reefs can be found here.

Condition Summary to April 2021
Surveyed January to April 2021

Since regular surveys by AIMS began in 1985, hard coral cover on reefs in the Central GBR has generally been lower than 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 (Figure 4). Hard coral cover then recovered rapidly to the highest average regional cover in the LTMP database record in 2016 (29%).

From 2016 to 2019, hard coral cover decreased continuously to 14% (Figure 4), largely due to repeated mass coral bleaching in 2016 and 2017 and outbreaks of crown-of-thorns starfish. In 2021, hard coral cover had increased again to 26% (Figure 4).

The status of the reefs in the Central GBR was variable in 2021; 32 of the 53 reefs surveyed had low or moderate hard coral cover (<30%) while 21 reefs had coral cover higher than 30% (Figures 1 and 2, Image 2). None of the surveyed reefs had hard coral cover higher than 75% (Figure 2).

A total of 30 of the 53 Central GBR reefs surveyed in 2021 had been previously surveyed within the last two years. Hard coral cover had declined on only two reefs while increasing on most of them (28 reefs; Figure 1).

Many reefs offshore from Cairns, Innisfail, and Townsville have had outbreaks of crown-of-thorns starfish in recent years. However, there were no *Incipient* or *Active Outbreaks* of crown-of-thorns starfish recorded on Central GBR reefs in 2021 (Figure 1).

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 would have contributed to the low numbers of crown-of-thorns starfish recorded during these surveys.

Coral bleaching was widespread in the Central GBR during the last surveys in 2020, although the severity varied among reefs. The impacts of this event are discussed in more detail further below. Central GBR reefs surveyed in 2021 had low-level bleaching (<10% of corals bleached), indicating there was some accumulation of thermal stress. No bleaching levels higher than this were recorded.

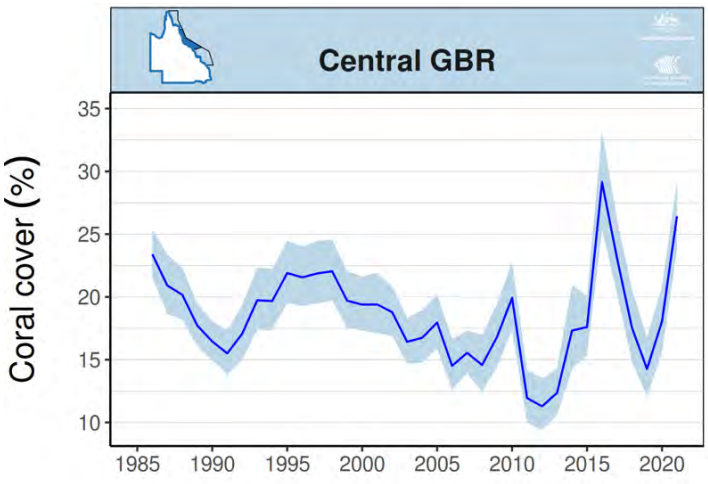


Figure 4: Trends in average hard coral cover (blue line) for the Central GBR based on manta tow surveys up. Survey data from 226 reefs contributed to the 35-year time series; blue shading represents 95% confidence intervals. 53 reefs were surveyed in 2021.

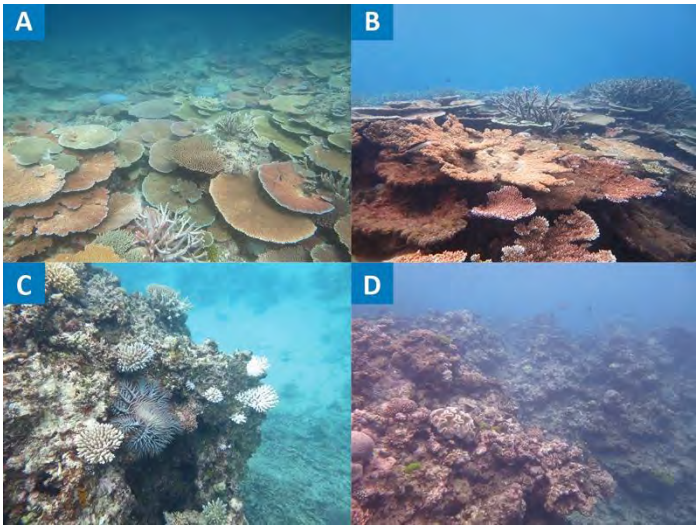


Image 2: Some Central GBR reefs had very high coral cover like, A. Rebe Reef offshore from the Whitsundays. B. Parts of John Brewer Reef have been protected from crown-of-thorns starfish impacts by the COTS Control Program. C. Numbers of COTS have declined in the Central GBR and very few COTS were recorded in 2021, although some reefs, like D. Rib Reef were badly affected by COTS in previous years and currently have very low coral cover. More information on individual survey reefs can be found here.

Condition Summary to April 2021
Surveyed August 2020

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 35-year survey history. Large declines in hard coral cover followed Severe Tropical Cyclone Hamish in 2009, which reduced coral cover to the lowest levels recorded by the LTMP in 2011 (Figure 5). 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 has increased again to 39% (Figure 5).

The state of individual Southern GBR reefs was variable (Image 3) however, there was a greater proportion of reefs with high coral cover than low or moderate coral cover, a contrast to the Northern and Central GBR where the majority of reefs had coral cover in the two lowest categories (Figures 1 and 2). Of the 20 reefs surveyed in 2021, 19 reefs have been surveyed in the last two years. Hard coral cover decreased on four of these, whereas 15 reefs increased in hard coral cover (Figure 1).

In 2016 and 2017, reefs in the Southern GBR were not exposed to the extreme sea surface temperatures that led to the mass coral bleaching on the Central and Northern GBR. However, in the austral summer of 2020, waters of the Southern GBR warmed substantially. Aerial surveys by the ARC Centre of Excellence in Coral Reef Studies revealed widespread severe bleaching across much of the Southern GBR. However, only two reefs accumulated degree-heating weeks[1] (DHW) values in 2020 that were above the level at which mortality would have been expected. The impacts of this event are discussed in more detail further below.

In 2021, there was widespread low-level bleaching (<10% of colonies) of sensitive species during surveys, however no instances of more severe bleaching were observed. The Southern GBR was the epicentre of crown-of-thorns starfish outbreaks in 2021, with three of the 20 reefs classified as having *Active Outbreaks* and one reef with an Incipient Outbreak (Figure 1). Low numbers of crown-of-thorns starfish were recorded on three reefs classified as *Recovering* or *No Outbreak*.

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.

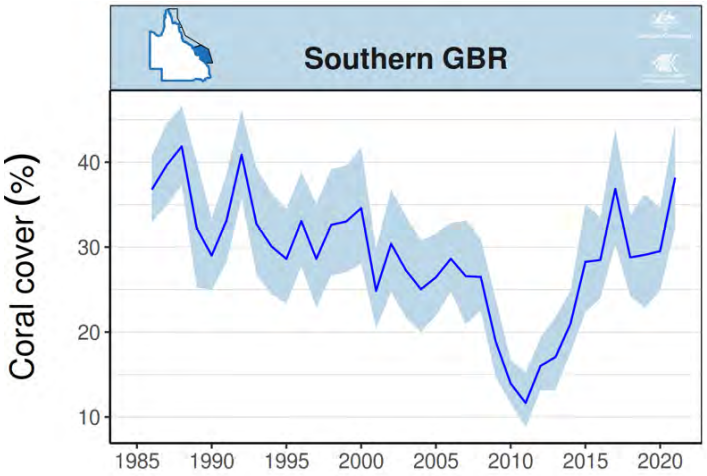


Figure 5: Trends in average hard coral cover (blue line) for the Southern GBR based on manta tow surveys. Survey data from 137 reefs contributed to the 35-year time series; blue shading represents 95% confidence intervals. 20 reefs were surveyed in 2021.

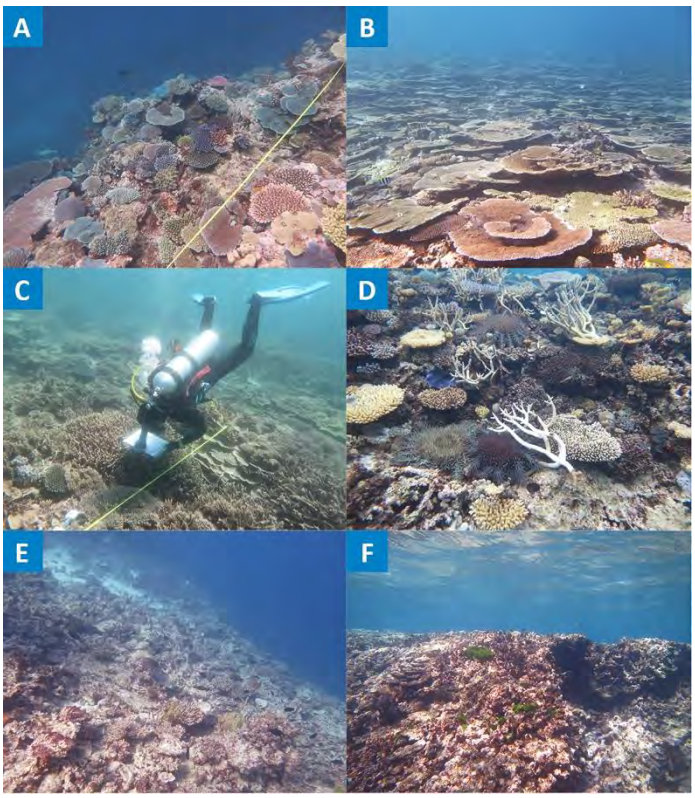


Image 3: Many reefs in the Southern GBR still have high coral cover such as A. Snake Reef in the Swain sector and B. Boult Reef in the Capricorn-Bunkers. However, C. surveys of agents of coral mortality revealed D. outbreaks of crown-of-thorns starfish continue to decimate coral populations on many reefs in the Swain sector. Such outbreaks leave very low coral cover as seen at E. Chinaman Reef, F. Horseshoe Reef, where crown-of-thorns outbreaks have run their course. More information on individual survey reefs can be found here.

1. *Degree Heating Weeks (DHW) shows 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.*

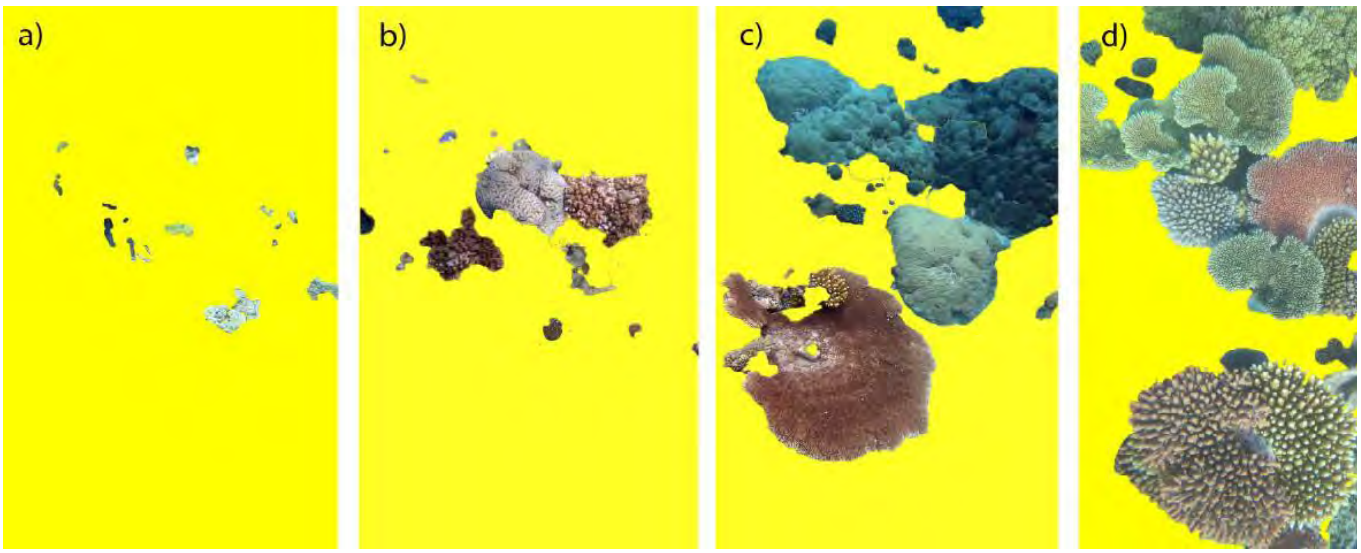
BOX 1: What does 'percent hard coral cover' mean?

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 in 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%, low = >0% - 10%, moderate = >10% - 30%, high = >30% - 50%, very high = >50% - 75% and extremely high = >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. A reef does not necessarily need to have 75 to 100% hard coral cover to be healthy, with AIMS categorising reefs with >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 then 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; although, 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) low (>0% - 10%), b) moderate (>10% - 30%), c) high (>30% - 50%), and d) very high (>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.

BOX 2: How the data were analysed

AIMS LTMP data has been collected using robust, widely accepted standard methods for 35 years (Box 1). The large dataset is complex, for example due to sampling design changes over time and logistical constraints and requires the use of statistical models for exploring the status and trends of hard coral cover on the GBR. AIMS LTMP strives to continually improve its sampling, data analyses and reporting products, and this year we have assessed the efficacy of a range of statistical models, some of which have recently become available.

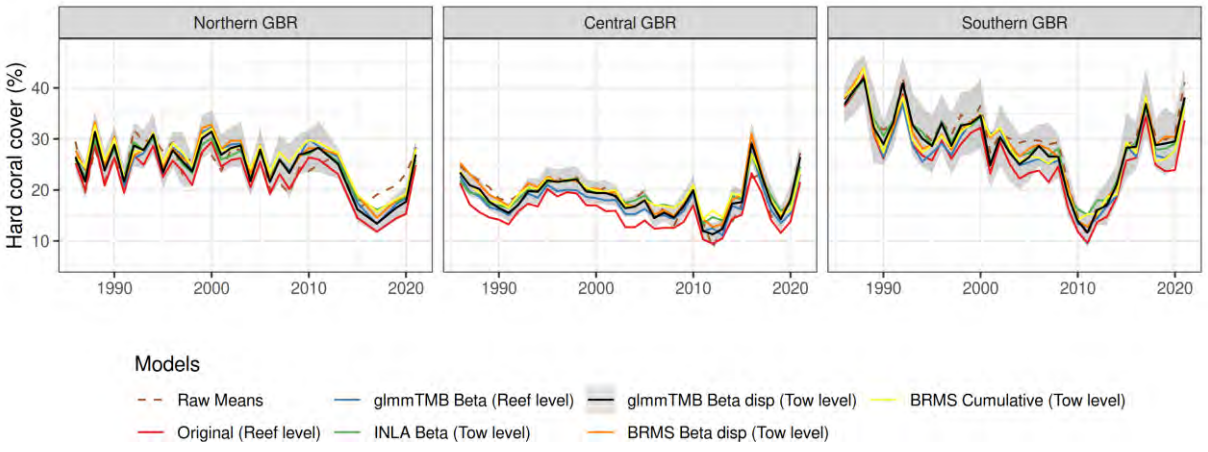
Manta tow surveys produce categorical estimates of percent hard coral cover for each manta tow path. Modelling these data presents numerous statistical challenges. For past analyses, the categorical data were first converted to numerical mid-points before being aggregated (as means) up to reef-level coral cover for each year (which served as input into statistical models). Such an approach has several potential shortcomings.

Firstly, the distributional assumptions that underpin the use of means as useful representations of the underlying data, (e.g., normality and lack of outliers) are unlikely to be satisfied for manta tow coral cover data. On the other hand, medians of data derived from categorical observations are typically very insensitive to small fluctuations and are thus not suitable for tracking changes over time. Secondly, modelling data that have already been aggregated results in the loss of a potentially important source of uncertainty (the variability in cover between tows within a reef). Ideally, the statistical models should be able to accommodate data as close to observational (tow) level as possible and have distributional assumptions that match the nature of those data.

Part of the process of continual improvement involves ensuring the most appropriate statistical models are used. This year we have shifted to a new model. Just as meteorologists use several different model outputs (an 'ensemble') to predict cyclone tracks, for this report we have explored multiple statistical models to analyse the long-term trends in hard coral cover. This ensemble imparts confidence that the model of choice gives predictions in line with all alternative models and agrees well with estimates derived directly from the raw data.

Our choice of model stemmed from the appropriateness of the model given the data and a comparison of model performance through a range of diagnostics. The chosen model (Box 2 Figure: solid black line and grey band) was a tow-level hierarchical model with a beta error distribution in which the beta shape parameter (phi) was estimated separately for each year to reduce shrinkage. Details of all models can be found here and results are presented in Box 2 Figure.

The ensemble included both Frequentist and Bayesian models fit to both reef and tow-level data. The results from the ensemble highlight that all models produce very similar temporal trends (Box 2 Figure) that correspond to the raw data, with minor differences in estimates in some years among ensemble members. Despite these minor differences, there is strong agreement among all ensemble members as to the long-term trajectories of hard coral cover.



Box 2 Figure: The ensemble of statistical models and raw data.

The impact of the 2020 mass coral bleaching event

In the austral summer of 2020, the Great Barrier Reef was subjected to accumulated heat stress to the level at which mass coral bleaching occurred across much of the GBR. This included the Southern GBR which had escaped bleaching in the 2016 and 2017 events. The third such event in five years is a sign that the Great Barrier Reef is already experiencing the consequences of climate change.

Aerial surveys undertaken by the Centre of Excellence in Coral Reef Studies in 2020 revealed extensive mass coral bleaching on the Southern GBR for the first time, as well as widespread bleaching in the Central and Northern GBR.

Of the reefs surveyed by the LTMP using manta tow in 2021, 81 were surveyed within the last two years allowing an appraisal of the impacts of the 2020 mass coral bleaching. Only twelve reefs had decreased in hard coral cover.

Decreases in coral cover on most of these twelve reefs were most likely associated with heat stress during the 2020 mass bleaching event, as there were few other acute pressures. However, three of these reefs also had crown-of-thorns starfish at densities expected to cause coral mortality and their coral cover declines cannot be attributed solely to coral bleaching.

These results indicate minor impacts on coral cover on the LTMP survey reefs from the 2020 mass coral bleaching event. However, it is important to place these results into the context of the accumulated heat stress experienced by survey reefs during the 2020 event, recorded as degree-heating weeks (DHW).

Accumulated heat stress was variable across the GBR in 2020 (Figure 6). DHW information was available for 126 out of 127 reefs surveyed in 2021. Of these, 101 reefs experienced heat stress during 2020 that was greater than the threshold at which widespread mass coral bleaching is expected (4 DHW; Figure 6). This agrees with the observations from aerial surveys of widespread bleaching across the Great Barrier Reef.

However, only 15 survey reefs experienced heat stress above the levels at which mortality from coral bleaching is expected (8 DHW; Figure 6). This agrees well with the LTMP observations that most reefs surveyed by the LTMP in 2021 appear to have undergone minimal coral mortality following the 2020 bleaching event.

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. 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.

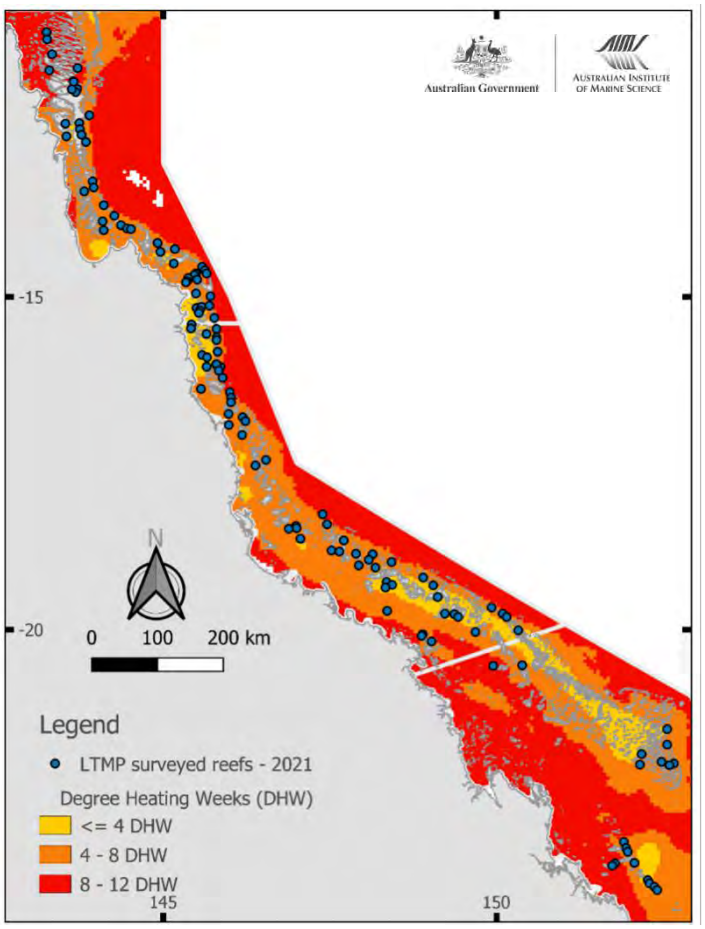


Figure 6: Exposure level of the 127 LTMP reefs surveyed in 2021 to accumulated heat stress during the austral summer of 2020. Widespread bleaching is expected above 4 DHW, while coral mortality is predicted above 8 DHW. Source: NOAA/NESDIS/STAR Coral Reef Watch program

The LTMP surveys a representative but small proportion of GBR reefs and there are reefs not surveyed that experienced high levels of accumulated heat stress above thresholds at which we would expect to see coral mortality.

This year has seen recovery underway on LTMP survey reefs across much of the GBR. However, the metric hard coral cover, while being a simple and robust measure of reef condition, reveals nothing about the diversity or composition of coral assemblages.

To assess this, the LTMP also quantifies the percent cover of different coral types using digital imagery along permanently marked transects during fixed site surveys, at a smaller subset of reefs across the length and breadth of the GBR.

The majority of 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 which rapidly increases measures of percent hard coral cover, as documented in this year's results. However, the fast growth comes at a cost, the skeleton is less dense than other slower growing corals, making them 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. This means that large increases in hard coral cover can quickly be negated by disturbances on reefs where *Acropora* predominate.

Preliminary analyses have also revealed a shift in the community composition of coral assemblages on some outer shelf reefs in the Northern and Central GBR, where the impacts of the 2016 and 2017 bleaching were greatest.

While there have been increases in hard coral cover in these areas, there has been a shift to coral assemblages dominated by *Pocillopora* corals (Image 4) rather than the typically dominant *Acropora* corals. This shift to *Pocillopora*-dominated reefs likely results from different mechanisms on different reefs and may include:

1. Adult *Pocillopora* have survived bleaching where other corals have died, and,
2. Surviving *Pocillopora* can produce more offspring after bleaching as they are more numerous and spawn more frequently than other corals like *Acropora*.

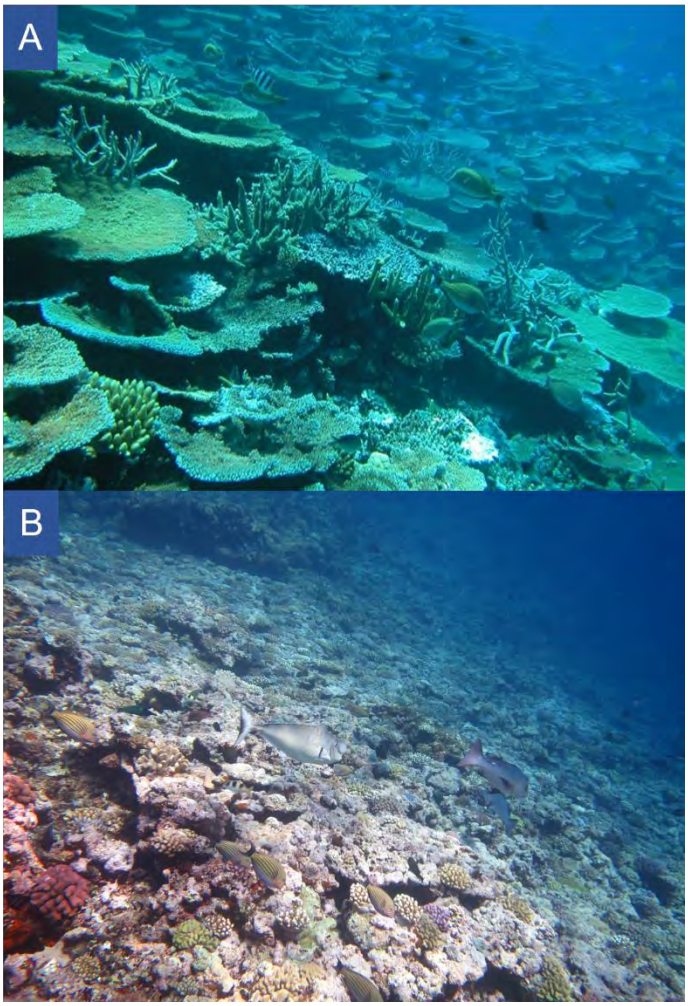


Image 4: *Coral community changes at Yonge Reef in the Northern region of the GBR from A. 2001 when* Acropora *corals were abundant to B. 2021 when* Pocillopora *corals were emerging as the dominant coral species.*

The replacement of *Acropora* corals by *Pocillopora* has important ramifications. For example, slower growth of *Pocillopora* will likely result in decreased speed of recovery. Additionally, impacts to other animals, like fishes, which are dependent on *Acropora* corals for food and shelter, may become apparent due to the reduced habitat complexity of a *Pocillopora*-dominated reef.

AIMS will continue to monitor these reefs to determine whether *Pocillopora* continues to dominate, how that will affect other parts of the reef ecosystem, as well as conduct more detailed analyses of the longer-term effects of bleaching and other disturbances on the trajectory of coral reef status.

Assessing the long-term health of the Great Barrier Reef

Australian Government | Australian Institute of Marine Science

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 couple of years have revealed that recovery is underway across much of the GBR, a promising sign illustrating that the GBR still has the capacity and necessary ecological functions to recover from disturbances.

The Central and Southern GBR had periods of recovery within the last decade which have been curtailed by disturbances, arresting recovery, and causing further coral declines. Sustained recovery of the GBR back to historical high coral cover requires the next few years to be disturbance free to allow corals to continue to grow and increase their populations.

While there have been hard coral cover increases across all three regions over recent years, the Northern and Southern GBR are still below the highest recorded coral cover in the 1980s, and preliminary analyses have documented shifts in the dominant corals on some reefs.

2021 has been a low disturbance year, while the period from 2014 to 2020 was an intense period of widespread disturbances. There were numerous severe tropical cyclones and three mass coral bleaching events in five years. The fourth wave of crown-of-thorns starfish outbreaks began around 2010 between Lizard Island and Cairns, and by 2020 had progressed south to reefs offshore from Townsville.

The prognosis for the future disturbance regime under climate change is one of increasingly frequent and longer lasting marine heatwaves and a greater proportion of severe tropical cyclones. 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 and when left unchecked, outbreaks can decimate coral populations. However, it is one of the few threats to the GBR that can be directly managed locally.

The Crown-of-thorns Control Program has been active on the GBR during the current outbreak and seeks to reduce starfish numbers at key reefs to reduce the amount of coral lost and to diminish the brood stock which propagates the outbreak 'wave' southward through most of the GBR.

In 2021, the number of Active Outbreaks has decreased from previous years, although outbreaks were still recorded in the Swain sector of the Southern GBR. The LTMP aims to assist analyses of the effectiveness of the Crown-of-thorns Control Program in the next few years.

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 over the next years.

For more information

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