ANNUAL SUMMARY REPORT OF THE GREAT BARRIER REEF CORAL REEF CONDITION 2023–2024

Coral cover remains high while impacts of mass coral bleaching yet to be determined

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AIMS acknowledges the Traditional Owners of all the land and sea Countries in which we work, and we pay our respects to their elders past, present and emerging. We honour their continuing culture, knowledge, beliefs and spiritual relationship and connection to Country. We also recognise Aboriginal and Torres Strait Islander peoples as the Traditional Owners of the land and sea Country on which the Australian Institute of Marine Science works and as Australia's first scientists.

AIMS LONG-TERM MONITORING PROGRAM **GREAT BARRIER REEF ANNUAL SUMMARY REPORT CORAL REEF CONDITION 2023 - 2024** Total number of reefs surveyed 94 NORTHERN GREAT BARRIER REEF HARD CORAL COVER PER REEF RD CORAL COVE CROWN-OF-THORNS STARFISH OUTBREAK IN-WATER BLEACHING Status & Trend Status & Trend Status & Trend Status & Trend 6 Media ed outbreaks Very high 6 Minor 35.8 % in 2023 t ential outbre 1 Medium 7 None 2 High Number of reefs surveyed aks 1 None 39.5% 25 Cooktown CENTRAL GREAT BARRIER REEF Status & Trend Status & Trend Status & Trend Status & Trend 4 0. 2 1 19 Lov 12 Very high 3 Minor m 30.7 % in 2023 to 12 None 8 Medium Number of 39 0 No 15 High 34% Townsvill No COTS 37 reef SOUTHERN GREAT BARRIER REEF d | September 2023 - May 2024 Status & Trend Status & Trend Status & Trend Status & Trend Very high Rockhampto Established outbre 1 ree m 34.0 % in 2023 to Potential outbreaks 1 ree 6 13 None 0 Nor Medium No outbreaks 39.1% Number of reefs surveyed 30 23 re Aerial surveys were not conducted on 15 LTMP reefs (6 Northern, 7 Central and 2 Southern) rvey Site Locations LEGEND HARD CORAL COVER: Low 0% - 10% Moderate 10% - 30% High 30% - 50% Very High 50% - 75%

CROWN-OF-THORNS (COTS): No COTS 0 No Outbreak >0 - 0.1 COTS Potential Outbreak 0.1 - 0.22 COTS Established Outbreak 0.22 - 1 COTS Severe Outbreak Over 1 COTS (Number of COTS divided by tow numbers)
BLEACHING PREVALENCE: None 0 colonies bleached Low 0% - 10% colonies bleached Medium >10% - 30% colonies bleached High >30% - 60% colonies bleached Very high >60% colonies bleached Extremely high >90% colonies bleached

Average hard coral cover increased and remained high in the Northern, Central and Southern GBR in 2024. The amount of hard coral cover was similar to last year and within the margin of error. Furthermore, increases in hard coral cover reflect the timing of surveys – 67% of surveys were conducted prior to the onset of mass coral bleaching, and 55% before the impact of two tropical cyclones in the Central GBR.

From January to March 2024, a marine heatwave (prolonged above average water temperatures) led to the fifth mass coral bleaching event on the GBR since 2016. The 2024 event, which was part of the fourth global mass bleaching event, had the largest spatial extent of bleaching recorded to date on the GBR, bridging all three regions (Northern, Central and Southern GBR). The exposure to accumulated heat stress surpassed previous events (up to 15 Degree Heating Weeks [DHWs]) and 46% of reefs were exposed to the highest level of heat stress yet recorded. This was the first time the Southern GBR has been exposed to heat stress approaching 15 DHWs and resultant severe bleaching.

Despite current high levels of hard coral cover, the GBR remains exposed to the consequences of climate change, particularly more frequent and intense marine heatwaves. The increasing frequency and spatial extent of mass bleaching events in recent years, evidenced by the unprecedented intensity and footprint of the 2024 event, poses a significant risk to the state of the reefs in the GBR, as does the ongoing risk of outbreaks of the crown-of-thorns starfish and tropical cyclones.



Australian Government

In Short



- This report summarises the condition of coral reefs in the Northern, Central and Southern Great Barrier Reef (GBR) from the Long-Term Monitoring Program (LTMP) surveys of 94 reefs conducted between August 2023 and June 2024 (reported as '2024').
- Over the past 38 years of monitoring by the Australian Institute of Marine Science (AIMS), hard coral cover on reefs of the GBR has decreased and increased in response to cycles of disturbance and recovery.
- Percent hard coral cover is one standard measure of reef condition recorded by scientists worldwide, it provides a simple and robust measure of reef health and is used in this report. Other important data, such as diversity or composition of coral assemblages, are collected and reported by LTMP in other ways.
- Changes in coral cover are qualified with respect to the margin of error, defined by 95% credible intervals (CIs). Credible intervals describe the level of uncertainty in the estimates of hard coral cover.
- Above-average water temperatures (i.e. sea-surface temperature anomalies of 1–2.5°C) occurred on the GBR over the austral summer, peaking in March 2024 and resulting in the fifth mass coral bleaching event since 2016.
- The mass coral bleaching on the GBR was part of a global event declared by NOAA and ICRI in April 2024.
- The Central GBR was impacted by two tropical cyclones: Cyclone Jasper (Category 5 December 2023) and Cyclone Kirrily (Category 3 – January 2024). Although Cyclone Jasper was a Category 5 in the Coral Sea, it was only Category 2 when traversing the GBR.
- Crown-of-thorns starfish (COTS) outbreaks have persisted on four Southern GBR reefs, while four reefs of the Northern GBR have low numbers of starfish.
- In 2024, hard coral cover has increased across the GBR, but regional hard coral cover remains similar to that reported in 2022 and 2023. Importantly, most surveys were conducted prior to the mass coral bleaching event and passage of two cyclones, and the full impact of these events is yet to be determined. Its also important to note that bleached coral is still recorded as live coral during surveys, and the fate of these corals is not yet known.
- Of the 94 reefs surveyed, only two reefs had hard coral cover <10%, 36 reefs had hard coral cover between 10% and 30%, and 35 reefs had coral cover between 30% and 50%. The remaining 21 reefs had hard coral cover between 50% and 75%.
- On the <u>Northern GBR</u>, region-wide average hard coral cover increased to 39.5% (35.0% 44.0% CIs), a regional high, but remained within the margin of error of 2023 (35.8% average; 32.1% 39.5% CIs). All surveys were completed prior to the peak heat stress which occurred in March 2024.
- On the <u>Central GBR</u>, region-wide average hard coral cover increased to **34.0%** (30.3% 37.9% CIs), a regional high but remained within the margin of error of 2023 (30.7% average; 27.5% 34.0% CIs). Twenty-three of 39 reefs were surveyed before the peak heat stress which occurred in March 2024, while 17 reefs were surveyed before cyclone impacts.
- On the <u>Southern GBR</u>, region-wide average hard coral cover increased to **39.1%** (33.7% to 44.5% CIs) from 34.0% (29.1% 38.9% CIs) in 2023. Fourteen of 30 reefs were surveyed prior to the peak heat stress in March 2024.
- The high coral cover reported this year is good news but does not mean all is fine on the GBR as it continues to face cumulative stressors. 2024 saw the fifth mass coral bleaching event since 2016 with the largest spatial footprint of coral bleaching yet recorded, coupled with the impact of two tropical cyclones. The impacts on coral cover from these events are partially captured in this year's report. A full assessment of changes in coral cover following these disturbances will be recorded during the next survey season.
- It is important to note that recent increases in hard coral cover can be quickly undone, as many corals are susceptible to elevated heat stress, wave damage and crown-of-thorns starfish predation, all of which impacted the GBR this year.
- The results presented here are our best understanding of reef condition before the impact of summer's disturbances.



Photo credit: AIMS LTMP

In Short





Figure 1: Summary of the results from the 94 reefs surveyed by manta tows between August 2023 and June 2024, 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) Average reef-level percent hard coral cover. b) The coral change metric displays the magnitude and direction of the absolute annual change in reef-level percent hard coral cover between 2024 and the previous survey within the last two years. c) The COTS outbreak status of each reef is defined by the average number of COTS recorded per 2-minute manta tow: No COTS (0 COTS), No Outbreak >0 – 0.1 COTS), Potential Outbreak (>0.1 – 0.22 COTS), Established Outbreak (>0.22 – 1 COTS) and Severe Outbreak (>1 COTS). Reefs are defined as Recovering when they were previously classified with an Established or Severe Outbreak but currently have COTS numbers below outbreak thresholds. d) The coral bleaching severity (percent of hard corals bleached) recorded during in-water LTMP manta tow surveys. e) The coral bleaching severity (percent of hard corals bleached) recorded during in-water LTMP manta tow surveys. e) The coral bleaching severity (percent of hard corals bleached) recorded during aerial surveys.



Photo credit: AIMS LTMP







With reef surveys extending over 38 years, the Australian Institute of Marine Science <u>Long-Term Monitoring Program</u> provides a unique and invaluable record of change in reef status by repeatedly and consistently surveying coral reef communities on representative reefs across the entire span of the Great Barrier Reef.

This annual summary of the status and trends in hard coral cover is derived from <u>manta tow surveys</u> of coral reefs (Figure 1). These surveys are a broadscale technique that covers reef slopes of whole reef perimeters in a short amount of time. More detailed surveys of fish and coral assemblages are also conducted along permanently marked transects on 71 reefs; however, the data from these are still being analysed and undergoing quality assurance and quality checking. They will become available on the online dashboard once completed. Our Monitoring <u>Dashboard</u> presents a synthesis of all AIMS' coral reef monitoring data across each of the surveyed reefs and at various spatial aggregations (including Natural Resource Management regions and latitudinal sectors).

For this annual summary, the GBR Marine Park is divided into three regions (Northern, Central and Southern GBR; Figure 1) that show different trajectories of change in hard coral cover over time. These changes are mostly in response to the cumulative impacts of the main disturbances: severe tropical cyclones, outbreaks of crown-of-thorns starfish and coral bleaching. Since 2016, GBR-wide summaries are no longer displayed, as this spatial resolution oversimplifies the variability of coral cover dynamics. Presentation of patterns for the three regions separately offers an easily interpretable overview without oversimplification or getting lost in the complexity inherent at finer spatial scales (i.e. individual reefs).

A total of 94 reefs were surveyed from August 2023 to June 2024 (reported as '2024'). <u>Online reports</u> on the status and trends of individual reefs and reefs grouped by latitudinal sectors, including their disturbance history, are available shortly after the completion of each survey trip and quality checking of the data. Data summaries are <u>available for download</u>. The reefs of the GBR are dynamic, and there is considerable variation among regions in the decline and recovery cycles of hard coral cover and community composition in response to disturbances. Understanding these dynamics in the context of the disturbance regimes is critical 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 <u>Box 1</u>). The number of reefs able to be surveyed each year is a small portion of the number of reefs found on the GBR (~100 vs 3000). However, the LTMP survey reefs were selected to provide a <u>representative sample</u> across the length and breadth of the GBR that captures multiple geographical and ecological gradients (e.g. latitude and position across the continental shelf) and encapsulates many of the <u>bioregions</u> and all the <u>management zones</u> defined in the 2004 rezoning of the Great Barrier Reef 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 for the type of ecological time series data used in this report. Temporal trends in hard coral cover presented in this report are analysed using Bayesian hierarchical models, and more detail of these analytical methods is presented here.



There was substantial variation in the condition of the 25 individual reefs surveyed in the Northern GBR (Figure 1a, Image 1). Nine of 25 reefs had coral cover >10% - 30%, 12 reefs had >30% - 50% cover and four reefs had >50% - 75% cover (Figure 1a).

A total of 24 of the 25 Northern GBR reefs surveyed in 2024 had been previously surveyed within the past two years. Of these, six had lower hard coral cover than in the previous surveys (Figure 1b). However, only two were outside the margin of error, and these declines were most likely due to crown-of-thorns starfish predation and coral disease.

Region-wide hard coral cover was relatively stable from 1985 to 2010, then declined to the lowest recorded levels in 2017 following cumulative impacts from crown-ofthorns starfish outbreaks, severe tropical cyclones (STCs Ita and Nathan), and back-to-back mass coral bleaching events in 2016 and 2017. There was a period of strong recovery from 2017 to 2022. Hard coral cover has increased further since 2023, from 35.8% (32.1% – 39.5% Cls) to 39.5% (35.0% – 44.0% Cls) in 2024, the highest level since surveys began, but it remains within the margin of error of the previous two years (Figure 2).

Surveys in 2024 found low crown-of-thorns starfish numbers at some reefs in the region (Image 1A), but all reefs were classified as either No COTS or No Outbreak (Figure 1c). Additionally, COTS feeding scars were observed on 14 reefs, indicating the presence of low numbers of starfish.

Northern GBR reefs surveyed by the LTMP experienced accumulated heat stress between 3.64 and 8.73 DHWs¹ during peak heat accumulation in March 2024. LTMP manta tow surveys were conducted from November 2023 to February 2024 before the height of summer; however, low coral bleaching (<10% of corals) was still observed on 17 out of 25 reefs, and one reef had medium bleaching (>10% to 30% of corals) (Figure 1d, Image 1C,D). No bleaching was observed on the remaining seven reefs (Figure 1d). We discuss the severity and spatial extent of the 2024 mass coral bleaching event in more detail below.

1 DHWs (degree heating weeks) 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 DHWs and coral mortality is expected above 8 DHWs. Further information available from NOAA.



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 38-year time series; blue shading represents 95% credible intervals. A total of 25 reefs were surveyed in 2024. Note that many reefs in this region were surveyed before the peak heat stress occurred in March 2024.



Image 1: Photos showing the variable state of reefs in the Northern GBR in 2024. A. Low numbers of Crown-of-thorns starfish below outbreak levels were recorded on a number of reefs. B. <u>McSweeney Reef</u> is still in the early stages of recovery from recent disturbances. C & D. Minor bleaching was recorded on several reefs throughout the Northern GBR, such as <u>Swinger Reef</u> and <u>North Direction Island</u>. E. Outer shelf reefs such as <u>Davie Reef</u> have diverse fish and corals. F. Flourishing coral assemblages at <u>Middle Banks</u>. Note that all surveys were conducted before the peak summer heat in March 2024. More information on individual survey reefs can be found <u>on the AIMS Reef Reporting Dashboard</u>.

Central Great Barrier Reef Condition Summary 2024

(Cooktown to Proserpine)

Surveyed August 2023 to June 2024



The status of the reefs in the Central GBR was variable in 2024. Of the 39 reefs surveyed, two reefs had <10% hard coral cover; 18 had hard coral cover >10% – 30%, 14 reefs had hard coral cover >30% – 50%, and five had hard coral cover >50% – 75% (Figure 1a, Image 2). A total of 30 of the 39 Central GBR reefs surveyed in 2024 had been previously surveyed within the past two years. Thirteen of these reefs had lower hard coral cover than in the previous surveys (Figure 1b), but only two had declines outside the margin of error. Hard coral cover was higher on 17 reefs (Figure 1b), with estimates outside the margin of error on 11 reefs.

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 until 2016. From 2016, region-wide hard coral cover decreased continuously to 2019, largely due to repeated mass coral bleaching in 2016 and 2017 and outbreaks of crown-of-thorns starfish. From 2017 to 2022, hard coral cover recovered, but then declined in 2023. In 2024 it increased to 34.0% (30.3% – 37.9% CIs), the highest level since surveys began, but it remained within the margin of error of the previous two years (Figure 3).

There were no *Potential, Established* or *Severe Outbreaks* of crown-of-thorns starfish recorded on Central GBR reefs in 2024 (Figure 1c). Nevertheless, small numbers of COTS feeding scars were observed on 11 reefs, indicating the presence of low levels of COTS on these reefs.

Cyclone Jasper crossed the Central GBR between Cooktown and Port Douglas in December 2023. No reefs in the cyclone path were surveyed after the cyclone and impacts from this event will be gauged next season. Shortly after the storm, tourism operators noted a large flood plume causing freshwater bleaching and coral mortality at inshore reefs, especially Low Isles, which will be next surveyed in 2025. Cyclone Kirrily transited the Central GBR in late January and resulted in variable impacts on the 22 reefs that were surveyed after the passage of the storm. Some reefs, such as Kelso, John Brewer, Helix and Chicken, had evidence of storm damage and declines in hard coral cover ranging from 6% to 9.9% since last being surveyed. Other reefs appear to have escaped with little impact.

Central GBR reefs surveyed by the LTMP were exposed to accumulated heat stress of between 3.37 and 9.31 DHWs over the summer. This resulted in low (<10% of corals) to medium (>10% – 30% of corals) coral bleaching (Image 2C,D) on 16 of the 39 survey reefs in the Central GBR during the 2024 LTMP surveys (Figure 1d). The remaining 23 reefs had no bleaching recorded (Figure 1d, Image 2E,F); however, these reefs were all surveyed in August and September 2023, months before the heat stress occurred.



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 38-year time series; blue shading represents 95% credible intervals. A total of 39 reefs were surveyed in 2024, but 23 of these were completed prior to the peak heat stress in March 2024, and the impacts of the bleaching remains to be determined.



Image 2: Variable reef state on the Central GBR. **A.** Storm damage from Cyclone Kirrily on Kelso Reef. **B.** Coral assemblages were patchy at <u>Beaver Reef</u>. **C.** High coral cover but medium bleaching (10% – 30% of corals) at <u>Slate Reef</u> on the outer shelf off the Whitsundays **D.** Bleaching at <u>Chicken Reef</u>, on the outer shelf off Townsville. **E.** Flourishing coral gardens on the back reef of <u>Agincourt Reef No. 1</u> offshore from Port Douglas. **F.** Coral cover has increased rapidly at <u>Hyde Reef</u> on the outer shelf off the Whitsundays. More information on individual survey reefs can be found <u>on the AIMS Reef Reporting Dashboard</u>.

Southern Great Barrier Reef Condition Summary 2024

(Proserpine to Gladstone)

Surveyed September 2023 to May 2024



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 38-year survey history. Tropical Cyclone Hamish in 2009 reduced coral cover to the lowest levels recorded by the LTMP in 2011 (Figure 4). A rapid and substantial increase in hard coral cover occurred from 2011 to 2017, reaching 36.7% (30.1% - 44.3% Cls). However, outbreaks of crown-of-thorns starfish began in 2018, and regional coral cover decreased to 29.0% (22.8% - 36.2% Cls) in 2019. In 2021, coral cover had increased to 37.8% (31.6%- 44.4% Cls), but it declined again to 34.0% (29.1% -38.9% Cls) by 2023 (Figure 4). In 2024, coral cover had increased to 39.1% (33.7% - 44.5% Cls), but it remains within the margin of error of the past three years.

The state of individual Southern GBR reefs was variable (Image 3) with nine reefs having hard coral cover >10% - 30%, nine reefs with hard coral cover >30% -50% and 12 reefs with hard coral cover >50% - 75% (Figure 1a). Of the 30 reefs surveyed in 2024, 25 reefs had been surveyed in the past two years. Hard coral cover was lower than previous surveys on five of these, with estimates outside the margin of error on one reef (Figure 1b). Twenty reefs had higher hard coral cover than previously surveyed, of which nine had estimates outside the margin of error (Figure 1b).

The Southern GBR has been the epicentre of crown-ofthorns starfish outbreaks in recent years and remained so in 2024 with the focus in the Swain reefs. One of the 30 reefs was classified as having a *Severe Outbreak*, one reef had an *Established Outbreak* and one reef had a *Possible Outbreak* (Figure 1c; Image 3A). Low numbers of crown-of-thorns starfish were recorded on four reefs classified as *No Outbreak* and the remainder had *No COTS*, while COTS outbreaks have run their course on other reefs with low coral cover (Image 3B).

In 2024, Southern GBR reefs surveyed by LTMP were exposed to the highest levels of accumulated heat stress (6.22–11.64 DHWs) ever recorded in this region. LTMP manta tow surveys were conducted at 11 reefs during the height of thermal stress in March. Very high bleaching (>60% – 90% of colonies) was recorded at four of these reefs, while three had high (>30% – 60%) bleaching and the remaining four reefs had medium (>10% – 30% bleaching (Figure 1d; Image 3C,D)). Five reefs were surveyed in May after peak heat had occurred and all had bleaching between 1% and 30% of corals. The remaining reefs in this region were all surveyed in September and October 2023, well before the onset of heat stress, with little bleaching recorded (Image 3E,F).



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 38-year time series; blue shading represents 95% credible intervals. A total of 30 reefs were surveyed in 2024, but 14 of these were surveyed prior to the peak heat stress in March 2024.



Image 3: Various disturbance events have impacted the Southern GBR in 2024, including coral bleaching and crown-of-thorns starfish outbreaks. **A.** A severe outbreak of crown-of-thorns starfish was still active at <u>Tern Island</u> in the Pompeys. **B.** Elsewhere in the Southern GBR, crown-of-thorns starfish infestations have run their course and reduced coral cover to very low levels, particularly in the Swains, such as <u>Gannet Cay</u>. Coral bleaching was recorded in the Southern GBR including **C.** <u>Pompey Reef No. 1</u> and **D.** <u>Reef 21-060</u>. High coral cover is still found at many reefs in the Southern GBR, like **E.** <u>Masthead Island</u> and **F.** <u>Fairfax Island</u> in the Capricorn-Bunkers. More information on individual survey reefs can be found <u>on the AIMS Reef Reporting Dashboard</u>.





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 <u>manta tow</u> <u>surveys</u>, which are visual estimates of percent hard coral cover over the area covered by an observer during one 2-minute tow (\sim 2000 m²). 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% – 10%, >10% – 30%, >30% – 50%, >50% – 75% and >75% – 100%; Image 4).

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% – 100% hard coral cover, and AIMS defines >30% – 50% hard coral cover as a high value, based on historical surveys across the GBR.

<u>Other techniques</u> for determining percent hard coral cover involve counting the number of points within sampling units (quadrats and photos), as used by the LTMP during 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 percent 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 commonly lower than those obtained from fixed site surveys as they encompass the entire reef, including sandy back reef habitats that generally have low coral cover.



Image 4: 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 reef surfaces, and the categorisation is based on the proportion of the substrate covered in live hard coral colonies.



In the austral summer of 2023–2024, much of the GBR was subjected to a level of accumulated heat stress that caused mass coral bleaching to occur (Figure 5). This was the fifth mass bleaching event on the GBR since 2016 and part of the fourth global mass bleaching event. In response to this event, AIMS and the Reef Authority undertook aerial surveys of 1080 reefs (Image 5) across the GBR and Torres Strait during the peak summer heat in March 2024. In addition to regular LTMP surveys, AIMS also conducted dedicated inwater bleaching surveys on 36 reefs during this time (22 February to 20 March 2024) to evaluate the prevalence and severity of bleaching. In-water bleaching surveys were conducted from Lizard Island in the Northern GBR to Lady Musgrave Island in the Southern GBR at three depths -Shallow (2–5m), Mid (7–9m) and Deep (9–12m) – and consisted of assessments of the prevalence of coral bleaching (i.e. the number of colonies affected). The level of bleaching of an individual coral colony was recorded as 1. No bleaching 2. Partial bleaching (5%-50% of colony white) 3. Fully bleached (>50% of colony white) 4. Dead (colony recently dead and overgrown with light green algae). Data were then summarised as the percent of colonies in each category at each depth at each site.

The 2024 bleaching event had the highest levels of exposure to heat stress to date, with some reefs in the Southern GBR experiencing up to 15 DHWs (Figure 5), far surpassing the level of heat accumulation they had been subjected to in previous events. 2024 also saw a record-breaking spatial footprint of coral bleaching, with 49% of reefs having high levels (>30% of corals bleached) and 32% of reefs having very high to extreme levels of coral bleaching (>60% of corals bleached; Image 6). In-water surveys conducted at the height of the event also confirmed that severe bleaching (whole colonies fully bleached white) was prevalent at 94% of reefs, and recent mortality due to intense thermal stress was present at 89% of reefs across all three regions of the GBR. The severity and prevalence of bleaching was variable among reefs, but some clear regional patterns emerged.

The Northern GBR aerial survey reefs were exposed to maximum heat accumulation between 1.84 and 9.7 DHWs over the summer (Figure 5). There was variation in the levels of heat stress accumulation across the Northern GBR. Aerial surveys revealed reefs north of Lockhart River were least affected, while the inner- and mid-shelf reefs between Lizard Island and Cape Sidmouth suffered very high and extreme levels of bleaching after being subjected to accumulated heat stress between 4.9 and 9.7 DHWs.



Figure 5: Accumulated heat stress (points on map) and the level of bleaching (bar charts) recorded during aerial surveys of GBR reefs surveyed in March 2024. DHW categories: Bleaching low risk = 0–2 DHWs, Bleaching warning = 2–4 DHWs, Bleaching possible = 4–6 DHWs, Bleaching probable = 6–8 DHWs and widespread bleaching with possible mortality= >8 DHWs. Source: NOAA/NESDIS/STAR Coral Reef Watch program. Coral bleaching prevalence categories: 0 = no bleaching, 1 = low bleaching (<10% of corals), 2 = medium bleaching (>10% – 30%), 3 = high bleaching (>30% – 60%), 4 = very high bleaching (>60% – 90%), 5 = extreme bleaching (>90%). Note that these are the same categories used by LTMP manta tow surveys.



Image 5: Bleached hard coral colonies on the flat and upper reef slope of Great Palm Island during aerial surveys of the mass coral bleaching event in March 2024. Photo credit: Neal Cantin, AIMS.

The 2024 Mass Coral Bleaching Event



Levels of bleaching recorded from aerial surveys showed bleaching intensity decreased further north and at offshore reefs in the region. Throughout the Northern GBR, 27.6% of reefs had no bleaching recorded, 33% had low bleaching and 39.4% had high to extreme bleaching. In-water bleaching surveys (additional to LTMP) within Princess Charlotte Bay and around Lizard Island revealed partial to fully bleached colonies with low levels of early onset mortality at the time of survey (late February and early March 2024).

In-water bleaching surveys additional to LTMP were conducted just prior to the maximum period of heat stress (mid-March) and are likely to underrepresent the true extent of bleaching at the peak of the event (Figure 6). Furthermore, LTMP surveys in the Northern GBR, including around Lizard Island, were all conducted prior to March 2024, and coral cover for this region had not yet changed in response to this bleaching event. Nevertheless, early-onset low coral bleaching (<10% of corals) was still observed on 17 out of 25 LTMP reefs, and one reef had medium bleaching (>10% to 30% of corals) prior to the onset of elevated heat stress.

The Central GBR experienced elevated thermal stress throughout the summer, with aerial survey reefs ranging from 2.4 to 11.4 DHWs (Figure 5). Heat stress accumulation was highest around Cairns (5.1–9.5 DHWs), inshore reefs in the Palm Island Group around Townsville (5.2–9.5 DHWs) and the inner (5.8– 8.95 DHWs) and outer shelf (5.2–11.4 DHWs) reefs of the Whitsundays (Figure 5). Levels of bleaching observed from the aerial surveys closely matched the accumulated heat stress levels.

Across the Central GBR, 8.1% of aerial survey reefs were categorised as having no or low bleaching (1% – 10% of corals), 15.8% as having medium bleaching (11% – 30% of corals) and 76.1% having high, very high or extreme bleaching (>30% of corals; Figure 5). Around Cairns, 5% of aerial survey reefs had low bleaching, 40% had medium bleaching and 55% had high, very high or extreme bleaching. Townsville inshore aerial surveys recorded 22% of reefs with low bleaching, 18% with medium bleaching and 60% with high, very high or extreme bleaching. Aerial surveys recorded 19% of Whitsunday reefs with low bleaching, 22% with medium bleaching and 59% with high, very high or extreme bleaching.

In addition to regular LTMP surveys, dedicated in-water bleaching surveys in the Central GBR recorded variable levels of bleaching prevalence and low levels of early onset coral mortality (Figure 6). In the Central GBR, 23 of 39 LTMP survey reefs were surveyed too early to detect the impacts of the 2024 bleaching event, but 16 reefs were surveyed between March and May 2024. These reefs all had low (<10% of corals) to medium (>10% - 30% of corals) coral bleaching during the 2024 LTMP surveys.



Depth 🖨 Shallow 🚔 Mid 🚔 Deep

Figure 6: Proportion of coral colonies not bleached, partially bleached, fully bleached, or dead across depths from in-water surveys of 36 reefs conducted by the AIMS Bleaching Response team.



Image 6: Bleached hard coral colonies at Miall Island on the Southern GBR during the mass coral bleaching event in March 2024. Photo credit: Josh Parker, AIMS.



The Southern GBR experienced the most intense exposure of the three regions, with the highest levels of accumulated heat stress on record for the GBR, high prevalence of fully bleached corals and the highest levels of early onset mortality recorded during in-water bleaching surveys (Figures 5, 6). While there was variation in the amount of heat stress recorded among aerial survey reefs (Figure 5), the highest levels of heat stress were recorded in southern inshore reefs around the Keppel Island group (11.4–13.3 DHWs), and further south near Gladstone (15.3–15.6 DHWs - cf LTMP survey reefs). Offshore reefs of the Capricorn-Bunker (10.9–11.7 DHWs) and Swain sectors (7.3–9.9 DHWs) all had heat stress accumulation to the level where widespread bleaching and coral mortality are expected (Figure 5).

Aerial surveys also revealed that all reefs around the Keppel Island group and the Capricorn-Bunkers had high, very high or extreme bleaching (>30% of corals), and while the Swain reefs were more variable, 91% of reefs had high, very high or extreme bleaching levels in shallow reef habitats.

In the Southern GBR, in-water bleaching surveys additional to LTMP surveys revealed a much higher proportion of fully bleached corals than either the Northern or Central GBR, and higher levels of early onset mortality at the time of in-water bleaching surveys across all three depths (Figure 6).

Of the 11 reefs surveyed by the LTMP during the height of the heat stress in March 2024, 7 had high to very high bleaching (>30% – 90%) and a further 4 had medium bleaching of >10% – 30%. All other Southern GBR LTMP reefs were surveyed either before the onset of heat stress or in May 2024, after the heatwave had abated; these surveys recorded bleaching of between 1% and 30%.





Photo credit: Christine Giuliano, AIMS.

The results from both the aerial and in-water surveys have documented the greatest spatial extent of accumulated heat stress and high to extreme bleaching to impact the GBR in recorded history. High to extreme bleaching was observed across all regions of the GBR, with the highest impacts in the inshore and mid-shelf reefs in the Southern, Central and Northern GBR. Prevalence of fully bleached corals in the Southern GBR was close to 100% in some shallow-water habitats, and early-onset mortality ranged from 1% to 75%. Reefs with a higher prevalence of partially bleached and fully bleached corals are more likely to suffer adverse health impacts from this bleaching event. Bleaching-related impacts can be direct effects (partial or whole colony mortality) that reduce coral cover or indirect, chronic effects such as reduced growth and reproduction and increased susceptibility to coral disease.

These results only partly tell the story. The full effects of the impacts of the 2024 bleaching event will continue to unfold over the coming months, as fully bleached corals can remain that way for several months, as late as September or October, depending on the species. Further in-water surveys at permanent locations are required to capture changes in hard coral cover following the bleaching, and these surveys will begin in September 2024 when the LTMP scientists return to the reef.

Photo credit: Christine Giuliano, AIMS.

Assessing the Long-term Health of the Great Barrier Reef



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 past few years have revealed increases in hard coral cover across much of the GBR. In 2022, we reported the highest-recorded coral cover in the Northern and Central GBR since the LTMP began monitoring in the 1980s, after rising from the lowest-recorded cover in the preceding decade. There was little change in hard coral cover in 2023, but this year coral cover has again increased. However, 60 out of 94 reefs were surveyed before the two cyclones and the mass coral bleaching event and impacts of these events will become apparent once surveys are completed next year.

The 2024 mass coral bleaching event was the most extensive in terms of accumulated heat stress and the large spatial footprint of high to extreme bleaching. Some parts of the GBR saw unprecedented levels of heat accumulation. The increased frequency and extent of bleaching events since 2016 remains highly concerning.

Crown-of-thorns starfish are coral predators, and their outbreaks represent a major cyclic disturbance on the GBR. The Great Barrier Reef Marine Park Authority's Crown-ofthorns Starfish Control Program has been active on the GBR during the current outbreak. The program deploys targeted surveillance and culling operations to systematically suppress starfish numbers and protect coral across hundreds of priority reefs. Recent evidence from the COTS Control Program and the LTMP demonstrates that targeted control has effectively suppressed outbreaks and protected coral from COTS predation across entire reefs and sectors. The findings also suggest that the southward progression of the outbreak 'wave' through the GBR may have been delayed and reduced via the suppression of adult COTS.

In 2024, the number of *Severe Outbreaks* has continued to decrease from previous years, although outbreaks were still recorded in the <u>Swain</u> sector of the Southern GBR. LTMP surveys revealed low numbers of crown-of-thorns starfish in the far northern GBR and around Lizard Island, which suggests that starfish numbers are increasing in these areas.

Much of the recent hard coral cover increase 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 percent hard coral cover, as documented in the 2022 and 2024 results. However, fast-growing corals are particularly susceptible to waves generated by strong winds and tropical cyclones. They are also highly susceptible to heat stress 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* corals predominate. The prognosis for the future disturbance regime under climate change is one of increasingly frequent and longer lasting marine heatwaves. The consequences of climate change are evidenced by multiple mass coral bleaching events since 2016 in the three GBR regions. Such bleaching events were rare prior to the late 1990s but have become a biennial occurrence in the last decade. Simultaneously, the continuing risk of tropical cyclones and crown-ofthorns starfish outbreaks, and chronic stressors such as high turbidity, increasing ocean temperatures and changing ocean chemistry, can all negatively affect recovery rates. Additionally, more frequent acute disturbances mean that the intervals for recovery are becoming shorter. Enabling coral reefs to survive these stressful conditions requires a combination of a reduction in global greenhouse emissions to stabilise temperatures, best practice management of local pressures, and the development of interventions to help reefs adapt to and recover from the effects of climate change.

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



Photo credit: Christine Giuliano, AIMS.

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