Norfolk Island Lagoonal Reef Ecosystem Health Assessment
August 2025

UNSW SYDNEY

CORAL REEF HEALTH

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

This report was prepared for Marine Parks Management East Section, Marine and Islands Parks Branch, Parks Australia by Associate Professor Tracy Ainsworth, The University of New South Wales, Associate Prof. Troy Gaston, The University of Newcastle, Prof. William Leggat, The University of Newcastle. and Prof. Moninya Roughan University of New South Wales.

This report was prepared with field and research assistance of Tom Moir University of Newcastle, Zachary Anderson and Dr Pietro Pollo University of New South Wales, and Susan Prior and James Wong The University of Newcastle. This report is also prepared with assistance from Norfolk Marine Park Managers.

Thanks also go to the community and businesses of Norfolk Island for support and assistance.

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Executive Summary

State of the Reef Report – Norfolk Marine Park (NMP) Inshore Coral Reef Ecosystems (2024/25)

The 2024/25 reporting period for Norfolk Marine Park's (NMP) inshore coral reef ecosystems presents a mixed picture of reef condition and resilience. Key findings are mixed and highlight both encouraging signs of ecological recovery from the 2023/24 coral bleaching event and ongoing stressors that can limit future reef health and recruitment and if continued may result in rapid decline of reef health.

Sea Surface Temperature and Coral Bleaching

During the austral summer of 2024/25, sea surface temperatures remained below the long-term average. This period of cooler conditions was significant in that no bleaching responses were observed across monitored inshore coral reef habitats. The absence of thermal stress has allowed for a minimum two-year recovery window following the widespread bleaching event of 2023/24. Continued low-stress summers will be critical to maintaining this recovery trajectory.

Algal Cover and Reef Substrate Availability

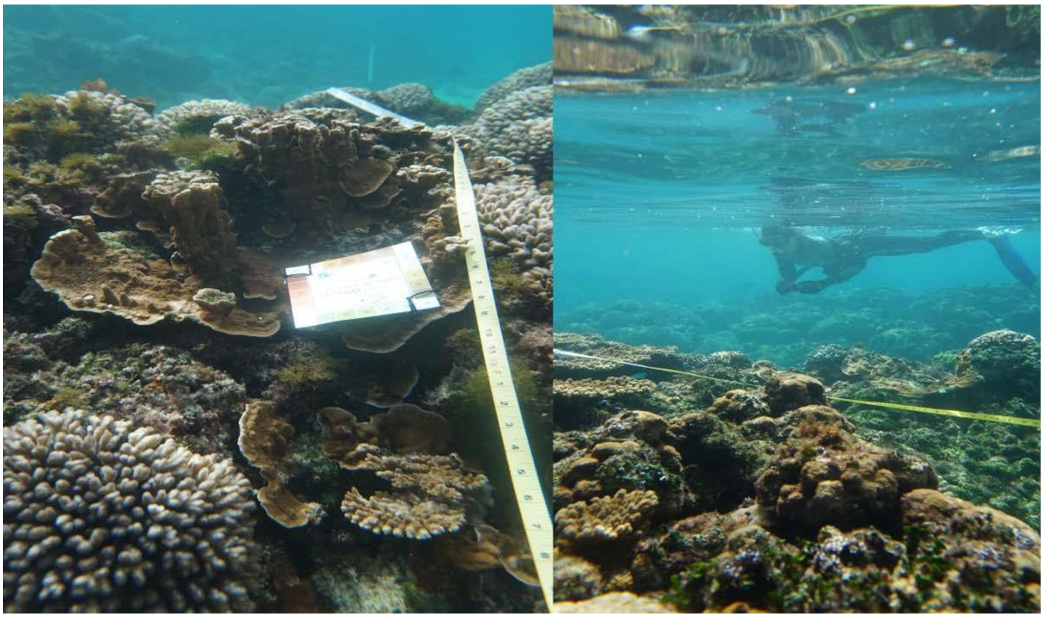
Despite the reprieve from heat stress, and conditions of low stress to corals, algal cover continues to increase across all surveyed inshore bays. This increased algal covered has resulted in a decline in the amount of free space on the reef surface, reducing the availability of suitable substrate for coral larval settlement. This trend represents a long-term risk to reef resilience, as high algal dominance and low substrate availability may suppress coral recruitment and hinder the replenishment of coral populations in coming years.

Flooding, Run-off, and Sedimentation

From April 2025 onwards, the inshore reef environment has been significantly affected by severe rain events leading to prolonged flooding, catchment run-off, and sedimentation. Elevated sediment loads in nearshore waters reduce light availability for corals and smother benthic organisms, compounding pressures from algal growth. The persistence of these conditions is of concern, as it has the potential to drive further declines in coral cover and ecosystem function.

2025 Outlook

Overall, Norfolk Marine Park's inshore coral reefs have benefitted from the absence of thermal stress in the 2024/25 summer, enabling ongoing recovery from the prior bleaching event. However, rising algal cover, declining free space, and intensified sedimentation represent escalating challenges for the health of the inshore coral reef ecosystems. These pressures have the potential to severely constrain coral recruitment and slow ecosystem recovery from marine heatwave and coral bleaching events. Targeted management of catchment inputs, coupled with ongoing monitoring of reef condition, is essential to support the resilience of inshore coral reef ecosystems in Norfolk Marine Park.



Norfolk Marine Park Lagoonal Inshore Reefs Report Card August 2025

Benthic Patterns

Increasing algal cover across all inshore Bays

Declines in available benthic free space across all inshore Bays.

Continued increase in urchin populations.

Continued increase in CCA

Continued increase in Ascidian cover

High fish diversity and habitat in early 2025.

Coral and Reef Health

SST remained low with no coral bleaching

Coral disease remains across all inshore bays including high rates of white syndromes and coral growth anomalies

Potential for limited coral recruitment following 2023/4 marine heatwave and bleaching event

Ongoing disturbance from land-based run-off and pollution events throughout early 2025.

Red arrow – Indicates a trend having a negative impact on reef health
Orange arrow – Indicated trend that may negatively impact reef health in the future
Green arrow/tick – Indicates a trend/response that is positively impacting reef health

NMP 2025 Management Issues and Program Recommendations

Issue 1: Declines in coral and reef health on inshore-lagoonal reefs

Findings:

- Coral cover on inshore NMP reefs has remained consistent since 2020, approximately 26% of the benthic community. In contrast fringing reef coral cover in 2025 was found to be approximately 42% of the benthic community.
- *Acropora* and *Montipora* are the primary habitat forming species, contributing to approximately 70% of the coral community.
- NMP inshore reef remains at risk of phase shift due to losses of the primary habitat forming genera *Acropora* and *Montipora*. Both species are at risk of continued disease outbreak, while *Montipora* is susceptible to coral bleaching.
- Persistent coral disease across inshore reefs and potential for a new disease outbreak in 2025 associated with land-based run off into the inshore coral reefs.
- Potential recruitment failure following marine heatwave and coral bleaching events.

Recommendations:

- Continued monitoring of coral cover to detect early signs of potential phase-shift to an algal dominated coral reef system.
- Establishment of a risk management strategy if future early declines in coral cover are detected on inshore reefs. This may include trials of removal of red cyanobacteria (weeding of other algal types has not been successful), more significant interventions to stop/slow terrestrial inputs or methods to moderate water temperature during thermal coral bleaching events.

Issue 2: Land-Based Run-off and Declining Water Quality

- Severe rainfall and flooding events in 2025 have increased sediment and nutrient run-off into NMP inshore coral reefs and fringing reefs.
- Elevated turbidity and sediment deposition are likely contributing to smothering of reef surfaces, reducing light availability, promoting algal growth and coral disease.
- Prolonged poor water quality in lagoonal habitats on NMP has previously been linked to persistent coral disease outbreaks, intensive monitoring in 2025 will track disease outbreaks and rates associated with the rainfall events of 2025.

Recommendations:

- Strengthen catchment management to reduce sediment and nutrient inputs.

- Maintain monitoring of severe rainfall events, turbidity, sedimentation, and nutrient levels in lagoonal reefs.
- Improve integration of land–sea management practices to reduce run-off impacts on inshore and fringing reefs, this would allow for implementation of terrestrial reactive management practices that would undertaken to improve reef health.

Issue 3: Increasing Algal Cover and Dominance on Inshore Reefs

Findings:

- Turf algae cover continues to rise across all lagoonal bays rising from less than 10% to over 20% between 2020 and 2025.
- Decline in free space is potentially reducing substrate available for recruitment of corals, and beneficial crustose coralline algae.
- High algal cover is likely to constrain coral recruitment and limit potential recovery from past bleaching and disease events.

Recommendations:

- Continue protection of herbivore populations within lagoonal reefs to aid in reducing algal communities
- Continue annual benthic monitoring to track changes in substrate composition.
- Where turf algal continues to increase consider algal removal trials prior to summer spawning events to increase free space on the inshore reefs.

Issue 4: Herbivore Populations and No-Take Zones

Findings:

- Evidence from Cemetery Bay indicates increasing urchin populations, while Emily and Slaughter Bay populations are also increasing they are not yet at the densities seen in Cemetery Bay of on undisturbed exposed reef control sites, increased urchin populations can contribute to algal control within the Bays.
- No-take zones provide critical refuge for herbivores, supporting ecosystem function in inshore bays.
- Fish diversity and abundance up to April 2025 remained high, however the impact of further large rainfall events that can reduce salinity and increase turbidity in the Bays leading to reduced fish abundance and needs to be assessed.

Recommendations:

- Maintain current no-take zone protections in Cemetery Bay, Emily Bay, and Slaughter Bay.

- Continued monitoring of algal, invertebrate and fish communities to evaluate the effectiveness of no-take areas for promoting herbivore recovery and controlling algal cover.

Issue 5: Community Awareness and Engagement

Findings:

- Community outreach during the monitoring program has strengthened local understanding of reef issues with continued local engagement in outreach activities held on Island. This is evidenced by increased community engagement from members of the public (questions, discussion around the history of the Bays, personal experiences) and community group representatives (e.g., Norfolk Island Fishing Association) with researchers when undertaking work in the Bays and at public presentations.
- Tourists, who contribute significantly to reef use, remain less engaged by current outreach efforts (e.g. public presentations by researchers when on island, discussions with researchers when undertaking work) and other methods to engage with tourists and tourism operators should be considered.

Recommendations:

- Continue community engagement through presentations, school programs, and partnerships with local organisations.
- Provide targeted education materials for visitors at Emily and Slaughter Bay.
- Continue to encourage community participation in citizen science to strengthen local stewardship.

Report Introduction and Aims

Norfolk Marine Park (NMP) protects a network of inshore coral reef ecosystems that are of high ecological, cultural, and conservation value. These reefs provide habitat for diverse marine life, contribute to the health and resilience of surrounding ecosystems, and hold social and economic significance for local communities. However, like many coral reef systems globally, NMP's inshore reefs are increasingly exposed to multiple stressors including marine heatwaves, cyclones, algal overgrowth, sedimentation, and catchment run-off.

To understand and respond effectively to these pressures, the **Norfolk Marine Park Long-Term Monitoring Program** was established to provide a consistent, scientifically robust assessment of coral reef condition. The program tracks ecological change over time, enabling managers to evaluate both short-term impacts and long-term trends in reef health. The monitoring program underpins evidence-based management by supplying the data necessary to identify risks, measure recovery, and assess the effectiveness of conservation actions.

The long-term monitoring program is designed to:

- Document the status and trends of key ecological indicators of reef health.
- Detect and quantify responses of coral reefs to acute stress events, such as bleaching and decreased water quality due to terrestrial inputs, often associated with catchment flood events increasing sedimentation and nutrient inputs.
- Assess recovery dynamics and resilience of coral communities.
- Provide early warning of ecological decline through changes in substrate composition, algal cover, and recruitment potential.
- Provide information to encourage better catchment management adjacent to the lagoon.
- Support management decision-making within Norfolk Marine Park.

Monitoring is conducted across the inshore bays (Emily Bay, Slaughter Bay, Cemetery Bay) and Norfolk Island fringing reef systems (Elephant Rock, Crystal Pool) within the Marine Park. Standardised survey methods applied from 2020 ensure consistency and comparability across years and include:

- **Benthic Surveys**: Transect-based snorkel surveys with photo-quadrats to provide a permanent record of the proportion of live coral, algal cover, and available free space on the reef substrate. In 2025 ROV mapping of benthic habitats across all bays have been added and are conducted alongside benthic survey periods and during disturbance periods for additional long-term reef records and support of reef health assessment. The metrics and records provide an insight into the balance between coral growth and competitive algal expansion.

- **Recruitment Assessment**: Settlement tiles and natural substrate observations are used to evaluate the capacity for new coral larvae to colonise the reef, a key indicator of long-term recovery potential.
- **Temperature Monitoring**: Sea surface temperature (SST) data are collected through *in situ* loggers, a newly deployed subsurface and benthic temperature observation array, and validated against satellite observations, enabling identification of marine heatwave events, bleaching risk, and ongoing ocean temperature stratification.
- **Water Quality Monitoring**: Visual observations and water sampling are used to track turbidity, sedimentation, and nutrient inputs, particularly following storm and flood events.
- **Disturbance Recording**: Impacts from cyclones, heavy rainfall, and other acute events are documented alongside ecological surveys, ensuring attribution of observed changes to specific stressors.

The LTMP record provides important context for interpreting recent conditions on NMP's reefs. For example, during the 2023/24 summer, widespread coral bleaching was recorded due to elevated sea surface temperatures. In contrast, the austral summer of 2024/25 experienced below-average SST, and no bleaching responses were observed. This temperature respite provided for a minimum two-year recovery window for coral communities and coral recruitment to occur into the affected NMP. However, NMP has experienced 5 years of ongoing disturbance from severe rainfall events resulting in nutrient inputs and sedimentation from land-based run-off.

The combination of acute disturbance events and chronic pressures highlights the importance of sustained monitoring. Maintenance of a consistent record of reef condition provides a baseline for understanding the Bays, critical evidence to guide adaptive management strategies and information to understand changes in the ecosystem. Findings from the 2025 coral reef health update will inform ongoing conservation actions and support the resilience of Norfolk Marine Park's inshore coral reef ecosystems in the face of a changing climate.

Environmental drivers and organismal/ecosystem responses can be linked in an ecological framework that summaries these interactions (Figure 1). Coral cover and algal cover (including *Lyngbya* and red cyanobacteria (Red CB)), and ecological indicators of responses to changing environmental drivers including, coral disease, coral recruitment, crustose coralline algal (CCA) cover, urchin abundance, and ascidian cover from 2020 to 2027. Additionally, fish diversity and habitat usage, particularly herbivory, are key responses to the environmental drivers and indicators of environmental change.

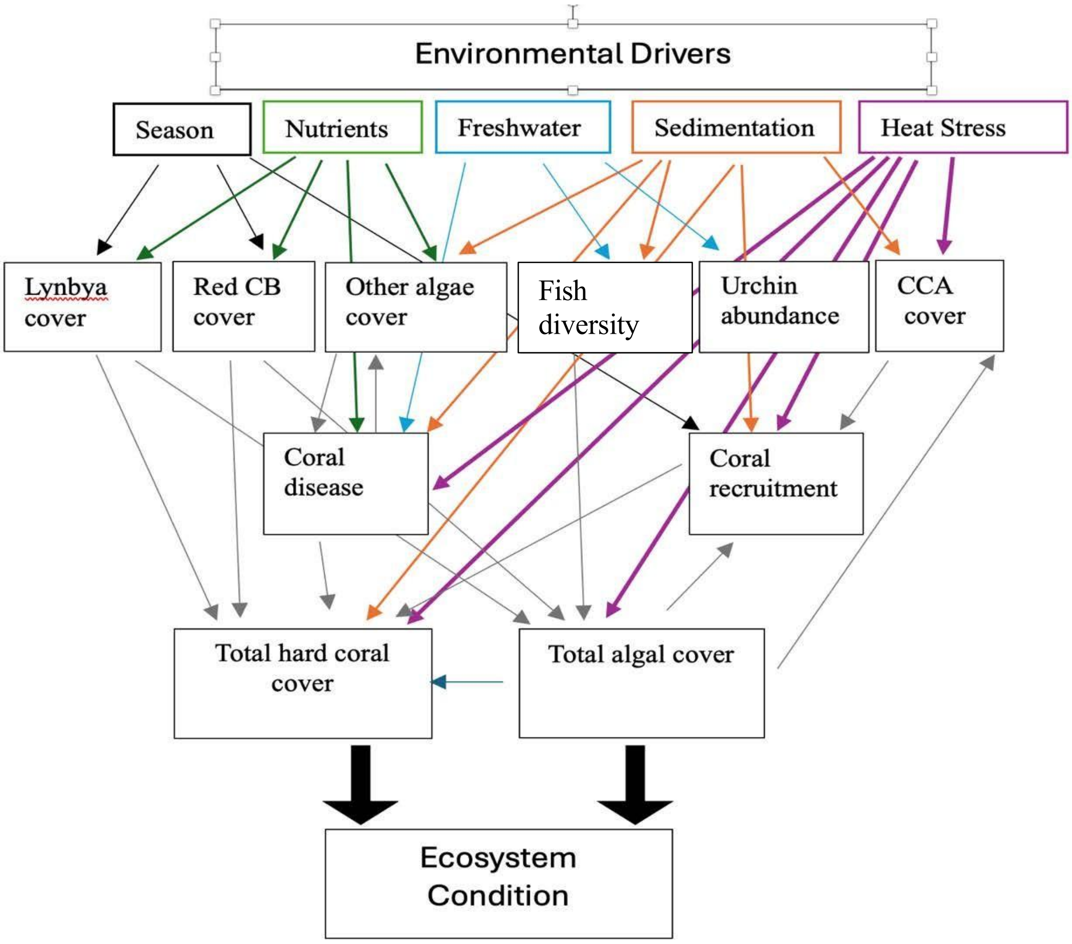


Figure 1. Ecological framework showing linkages between environmental drivers, organismal and ecosystem responses.

The current report provides a 6-month update for August 2025 on the State of The Reef for The Norfolk Marine Park (NMP) under the Our Marine Parks Program 2025-2027. The NMP long-term monitoring program (LTMP) aims to provide:

1. Evidence of coral and coral reef health in the NMP, including rates of coral disease, coral cover, algal populations and cover;

2. Evidence for indicator organism abundance including urchin populations, crustose coralline algae and ascidians;

3. Fish diversity and habitat associated with coral and reef health;

4. Detailed assessment of thermal condition and driver of reef health in the NMP.

Previous NMP LTMP surveys (2020-24) of the inshore NMP coral-reef lagoon have revealed increasing algal populations linked to reef decline and inshore pollution, including red cyanobacteria and *Lyngbya*, alongside multi-year trends of increasing algal cover on the reefs. Surveys to-date have indicated that this ongoing increase in algal cover is evident across all monitored inshore bays and is coupled with a decline in available free space. Trends of increasing algal cover, decreasing free space are linked to reductions in the substrate available for coral larvae settlement, raising concerns for future recruitment and reef resilience across multiple coral reef ecosystems.

From 2021- 2023 the NMP also experienced severe rainfall events that were linked to coral disease outbreaks and declines in reef condition. Beginning in April 2025, a series of severe rainfall events again caused extensive flooding, run-off, and sedimentation on the inshore NMP. Land-based pollution, run-off and sediment outflows result in reduced water clarity and quality, smothering of benthic organisms, and exacerbated competition between algae and corals.

Coral disease rates have been consistently high within the inshore reefs and at levels consistent with severe disease outbreaks occurring since 2020. Inshore flooding events have occurred in March, April, May, June and July 2025 associated with rain events exceeding 80 mm into the KAVHA catchment and wetland area adjacent to the inshore-lagoonal reefs. Diseases, including white syndromes, tissue loss and coral tumours remain high and preliminary observations indicate further disease outbreaks occurring associated with the inshore flooding events of 2025.

Finally, deployment of oceanographic monitoring equipment and establishment of subsurface and benthic temperature observation array which provides the first detailed records of thermal variance across the NMP. Findings to-date suggest that the NMP thermal environmental is characterised by minimal thermal variation to a depth of 20 m, with ocean temperatures consistent across the different reef habitats within the inshore to offshore areas, depths, and ocean exposure. Further year-round assessment of the thermal environment is continuing and will provide insights into the seasonal thermal environment of the coral reef habitats of the NMP.

Methodologies

Following the established ***LTMP program design*** benthic surveys were conducted in December 2024 and April 2025. Benthic surveys consisted of 24 x 10 metre belt transects in Emily Bay and 27 x 10 metre belt transects Slaughter Bay (Figure 2), within each transect (10 m), 10 photos (TG-6 Olympus underwater camera) at 1m increments using a 0.5 m2 photo quadrat to standardize the area (n = 10 photos transect-1). The resulting photos were analysed using the online platform *CoralNet* (https://coralnet.ucsd.edu) applying a grid of 100 points per photo for annotation. A standardised label set was used as per LTMP 2020-25 with data generated for benthic community cover and composition. Labelset includes; coral taxa (as per previous), algal categories, and invertebrate categories as listed below. Resulting cover was summed across each transect so that each category is described as the % cover transect^{-1}.

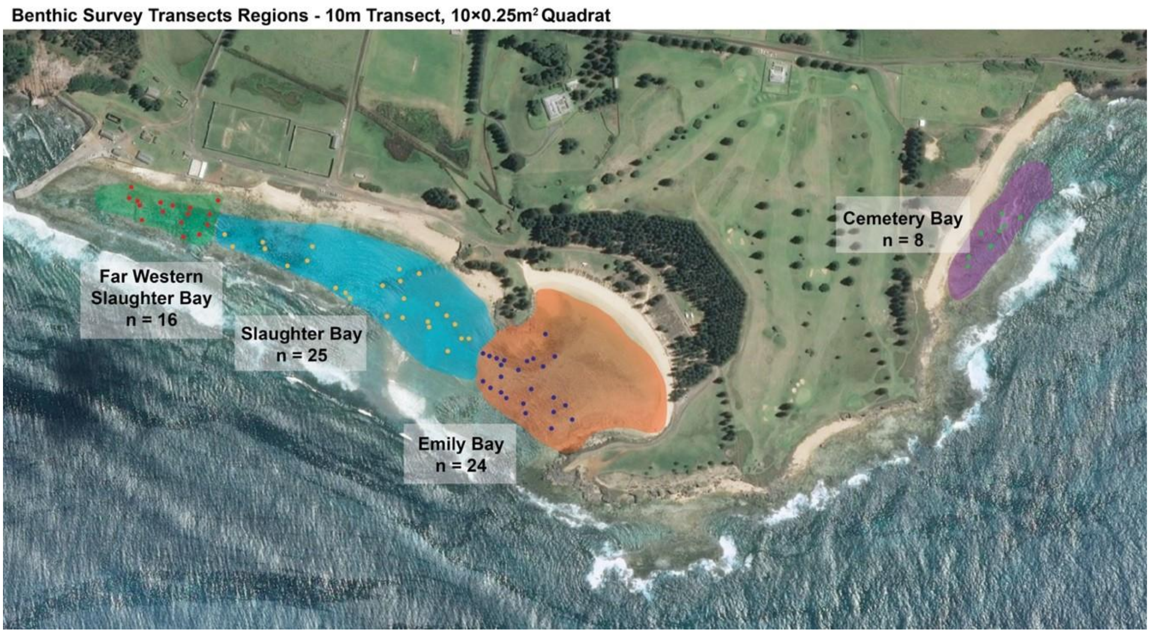


Figure 2. Benthic Health and Community Assessment Survey site locates Emily Bay, Slaughter Bay, Far Western Slaughter Bay and Cemetery Bay. Dots indicate location of surveys.

Surface drone mapping of inshore and fringing coral reef ecosystems of NMP.

We used a BlueRobotics *BlueBoat* unmanned surface vessel (USV) to conduct systematic surveys across Emily Bay and Slaughter Bay. The BlueBoat was equipped with a downward-facing GoPro Hero 13 camera, programmed to capture high-resolution images at 0.5-second intervals. The vessel travelled at approximately 1 ms^{-1}, resulting in an image footprint spacing of ~0.5 m along each transect.

Transects were planned to run parallel to the shoreline, following the reef contours when possible, with 10 m spacing between adjacent tracks, ensuring consistent spatial coverage of the reef. This survey design enabled rapid and repeatable image acquisition across large reef areas while minimizing diver-based survey limitations.

In total, the USV acquired approximately 36,000 raw images across both bays (Emily and Slaughter Bay). Initial data cleaning involved removing sections dominated by sand or lacking benthic cover. To facilitate spatial analysis, raw survey tracks were segmented into 510 continuous transects of 10 m length each (Figure 3). Each transect contained on average ~23 georeferenced images. After cleaning and transect extraction, the dataset was reduced to ~11,700 images extracted over 510 different 10 m transects. Some examples of these images can be seen in Figure 4.

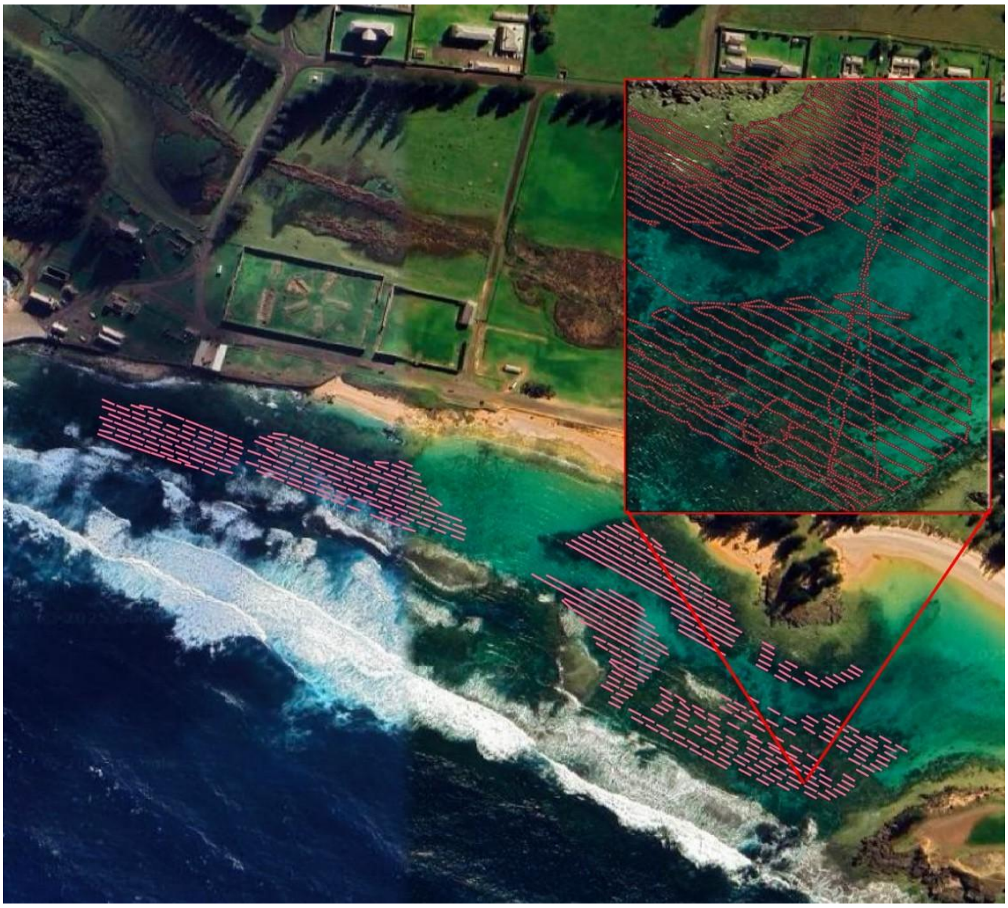


Figure 3: Map of cleaned data surveys focusing on areas of reef. Inset shows raw USV tracks before transects are extracted.

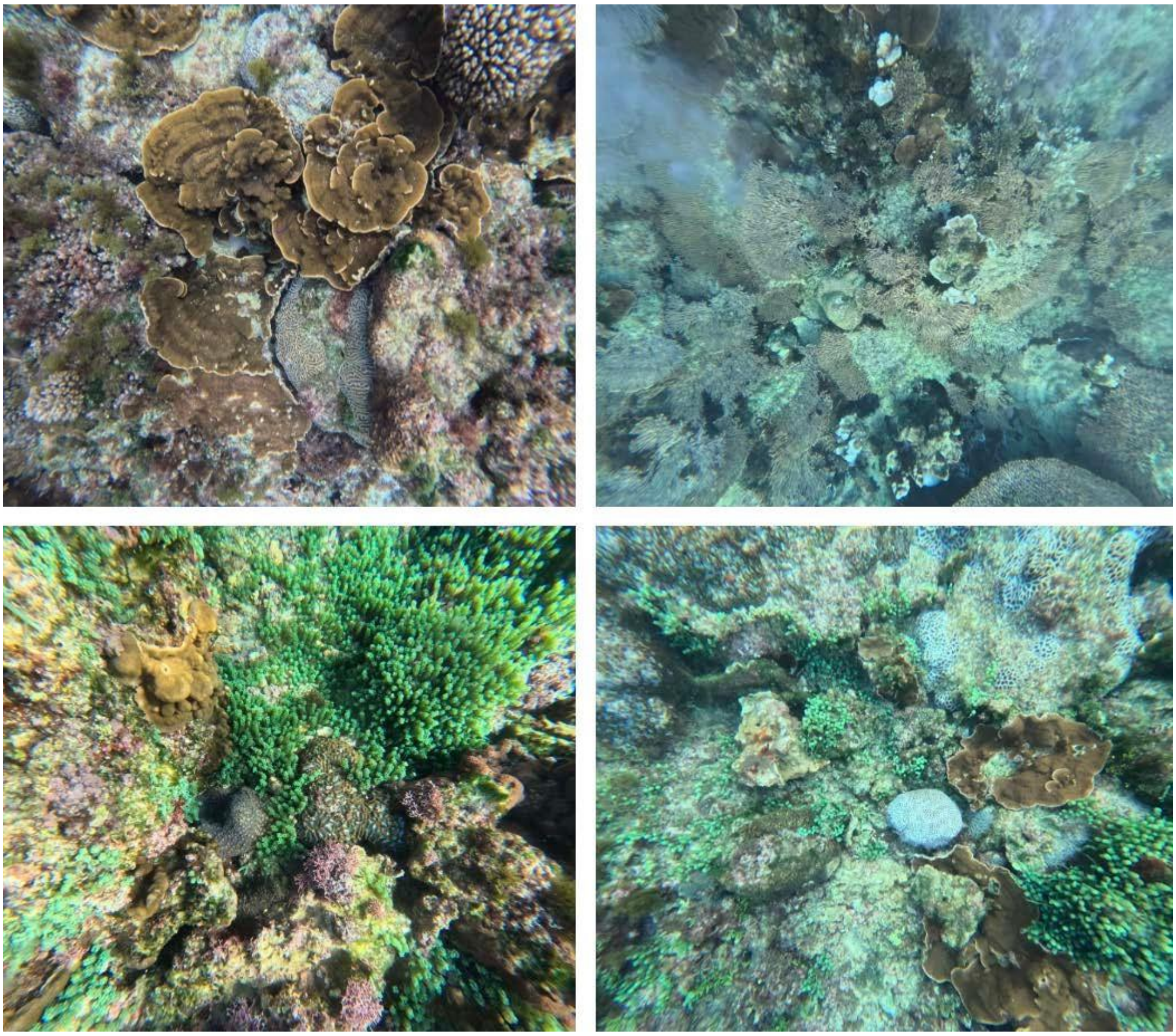


Figure 4: Example images taken from downward facing GoPro mounted on Blueboat USV.

Fish Survey Methodology.

Field sampling was undertaken in December 2024, April 2025 and June 2025. RUVS (remote underwater video) were used to determine fish community composition within Emily Bay and Slaughter Bay using two (2) different approaches:

1. Spatial comparison – reef and sand habitats throughout Emily Bay (eastern and western sites) and Slaughter Bay (eastern, central and western sites)
2. Species associations relating to habitat types around Salthouse.

Three (3) replicate RUVs (GoPro Hero 10/11/12) were deployed at each site in each zone for a minimum of thirty (30) minutes. Upon retrieval, each video was downloaded and a filename containing location, date, time and treatment created. Each video is watched in its entirety using EventMeasure™ software to record the abundance (measured as MaxN – maximum number of any species within a single frame) for each species. This allows for calculation of number of Species (taxa richness) and Shannon Diversity Index.

Figure 6: Map of Emily Bay and Slaughter Bay showing sampling regions.

Coral recruitment 2024 – 25 tile placements

Figure 7. Placement locations for coral recruitment tiles within Emily Bay, Slaughter Bay, Cemetery Bay

Assessment of Temperature Conditions Austral Summer 2025

Sea surface temperatures remained below marine heatwave and coral bleaching thresholds throughout the 2024/25 Austral summer. Brief anomalous SST conditions were recorded in February-March 2025, with short SST deviations above the MMM, not conducive to heat stress conditions.

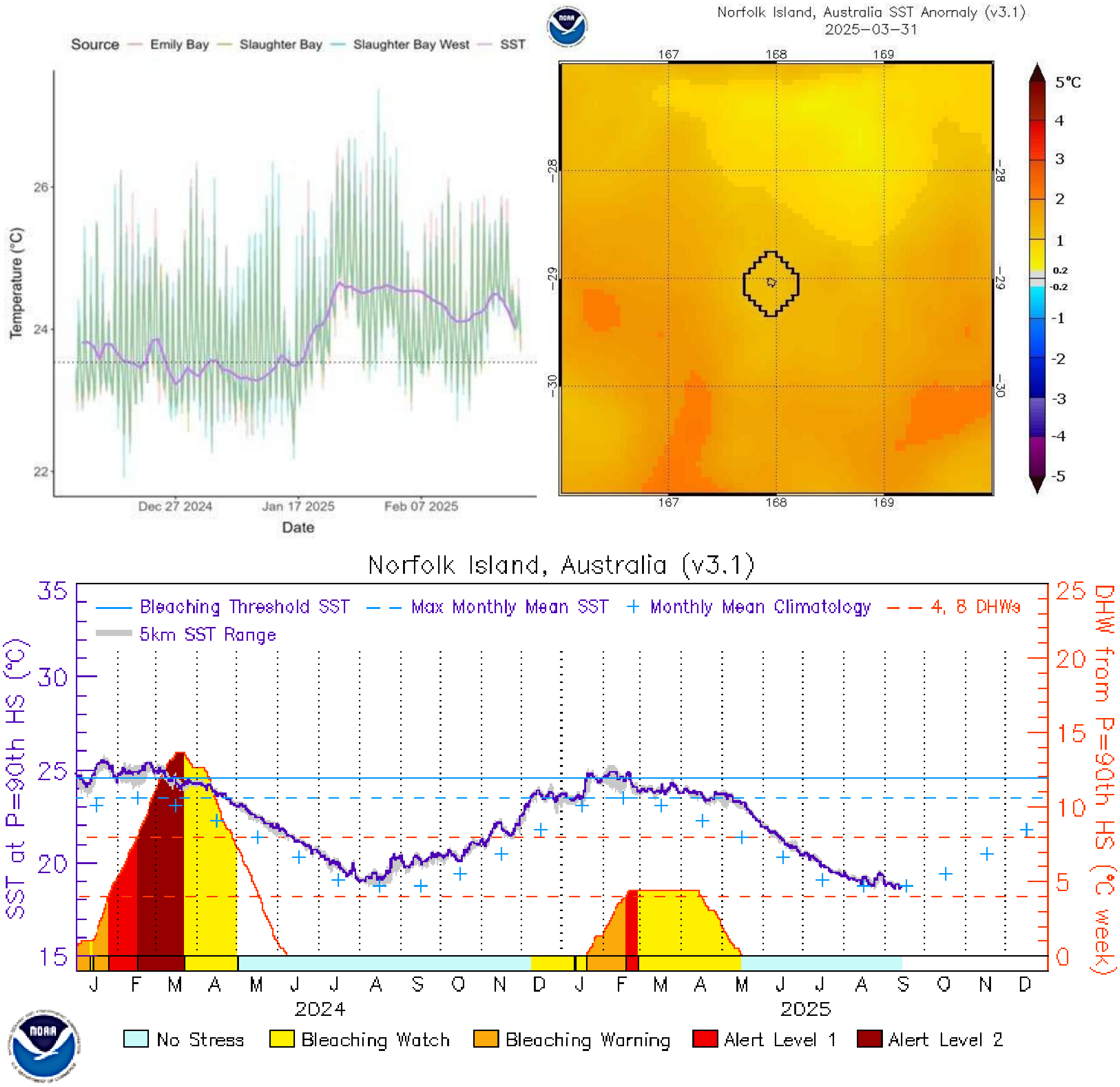


*Figure 8. In situ temperatures from deployed temperature loggers on inshore-lagoonal reefs of NMP (top LHS), Satellite derived SST anomaly for summer 2025 (top RHS) and satellite derived SST for 2024-2025 (MMM blue line) and accumulated thermal stress (Degree Heating Weeks, DHW) for Norfolk Island from January 2024 - April 2025. Shading represent various coralbleachingalertlevels.ImagefromNOAACoralReefWatch (*https://coralreefwatch.noaa.gov/product/vs/gauges/norfolk_island.php)

Norfolk Island Catchment Run-off and Reef Water Quality Monitoring 2025

From April 2025 severe rain events resulted in high-water flow into KAVHA catchment above the Emily and Slaughter Bay Lagoonal reefs, which had previously been dry since July 2024 (Figure 9). Catchment to reef water quality sampling was conducted by A/Prof Troy Gaston from April 15th to July 2025, including prior to the first flooding event, at the peak of water flow into the lagoon on April 16th, following the event on April 18th and during subsequent events in June and July 2025. Surface drone monitoring of the benthic condition associated with events exceeding a 3-day accumulation exceeding 80 mm were conducted in April, June, July, and September 2025.

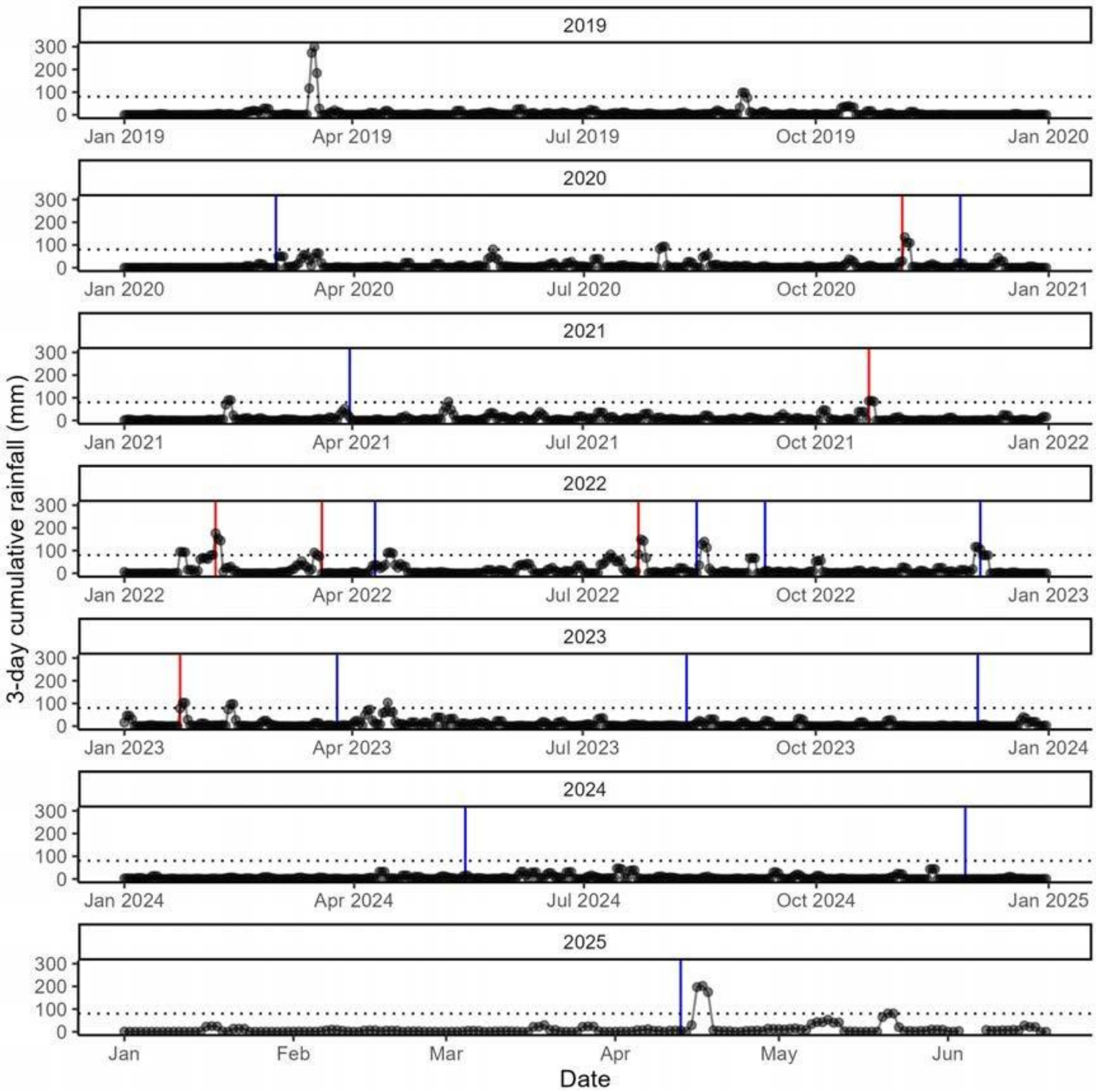


Figure 9. Three day accumulated rainfall from March 2020 to July 2025. Dotted line shows 80 mm 3-day accumulation required for runoff to impact Emily Bay lagoon.

In April 2025 the sand plug preventing polluted water flow into Emily Bay breached allowing contaminated water flows into Emily Bay. The sand plug re-established and re-broke on subsequent events in May, June and July 2025, each time resulting in water flows into Emily Bay. FWC (*fluorescent whitening tracing*) as indicators of anthropogenic contaminated run-off conducted across the Norfolk Island catchments during April 2025 demonstrates the influx of water sources from anthropogenic use areas (*detailed water quality analysis was also conducted from April to July 2025*).

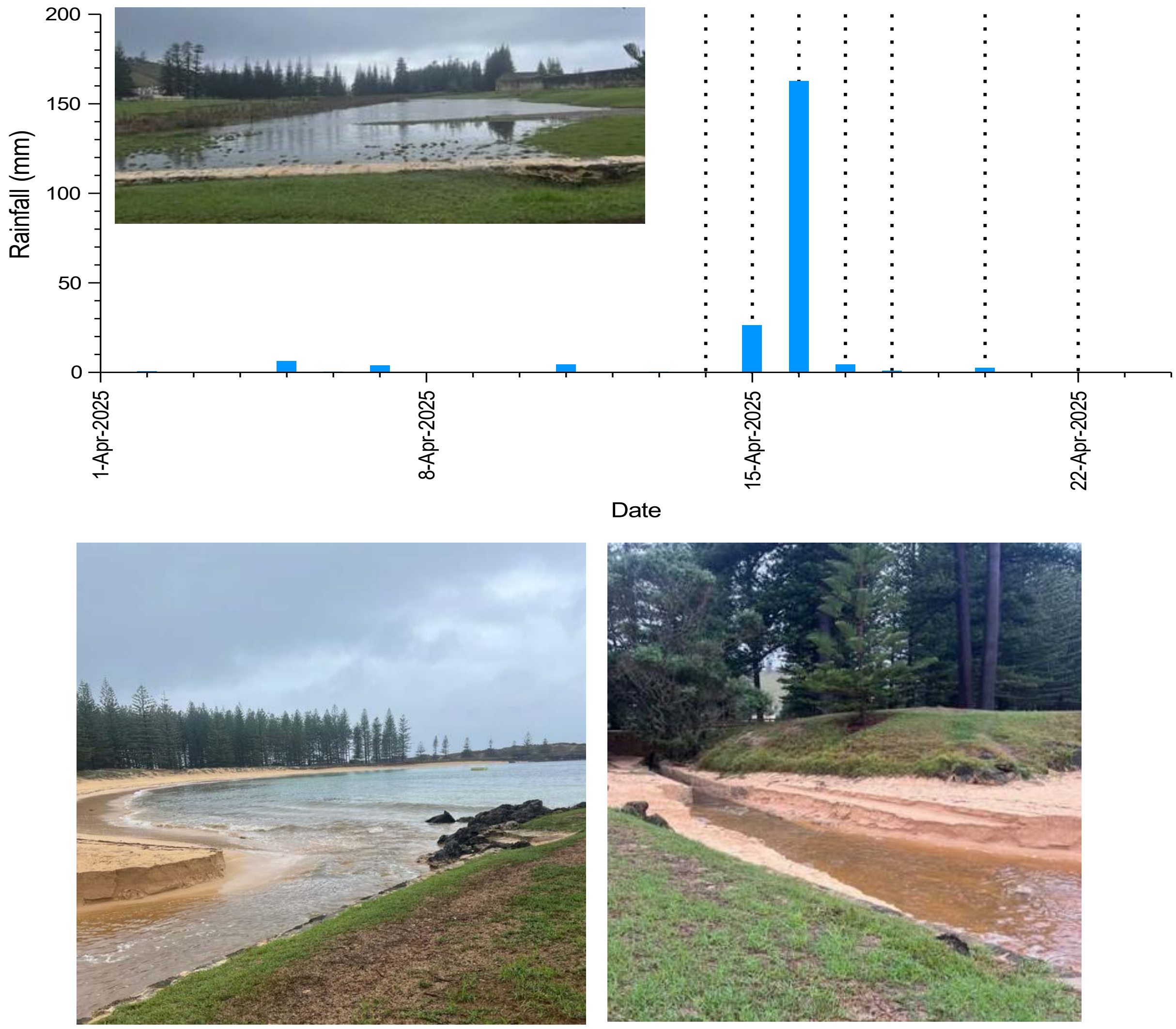


Figure 10. TOP FWC monitoring (dotted lines) of anthropogenic land-based run-off into Emily Bay lagoonal reef associated with catchment overflows (inset). BOTTOM. Images of Emily Bay sand plug washed out April 16th during inflows from the KAVHA wetland.

Trends in Benthic Community Structure across inshore coral reef ecosystems.

Long-term monitoring of benthic community structure within Norfolk Marine Park shows distinct trends across major functional groups between 2020 and 2025. **Hard coral cover** remains relatively stable across the monitoring period (~25 % of the benthic structure). No sustained declines in coral cover have been evident and cover in 2025 is comparable to earlier years. This suggests that despite bleaching in 2023/24 and coral disease and other benthic community changes, some resilience persists within inshore coral populations. **Macroalgae** exhibited marked fluctuations, with peaks exceeding 30% cover in 2022 and elevated levels >20% persisting through to 2025. ***Caulerpa***, a common macroalgal genus, increased steadily after 2022, with mean cover more than doubling by 2025. **Turf algae** showed the strongest increase, rising consistently from below 10% in 2020 to nearly 25% by 2025. Turf expansion represents a significant ecological shift, as it reduces free substrate. These trends across algal types reflect sustained algal expansion in NMP inshore bays. Taken together, the data highlight a potential shift in benthic community composition, with algal groups expanding and placing higher risk of phase shift in the ecosystem. The benthic community patterns indicates mounting pressure on reef resilience, with potential consequences for coral recovery and long-term ecosystem health in Norfolk Marine Park. Overall inshore community trends are evident in Figure 11, and assessment per inshore reef site and benthic community type are further provided below (Figure 12, 13, 14 and 15).

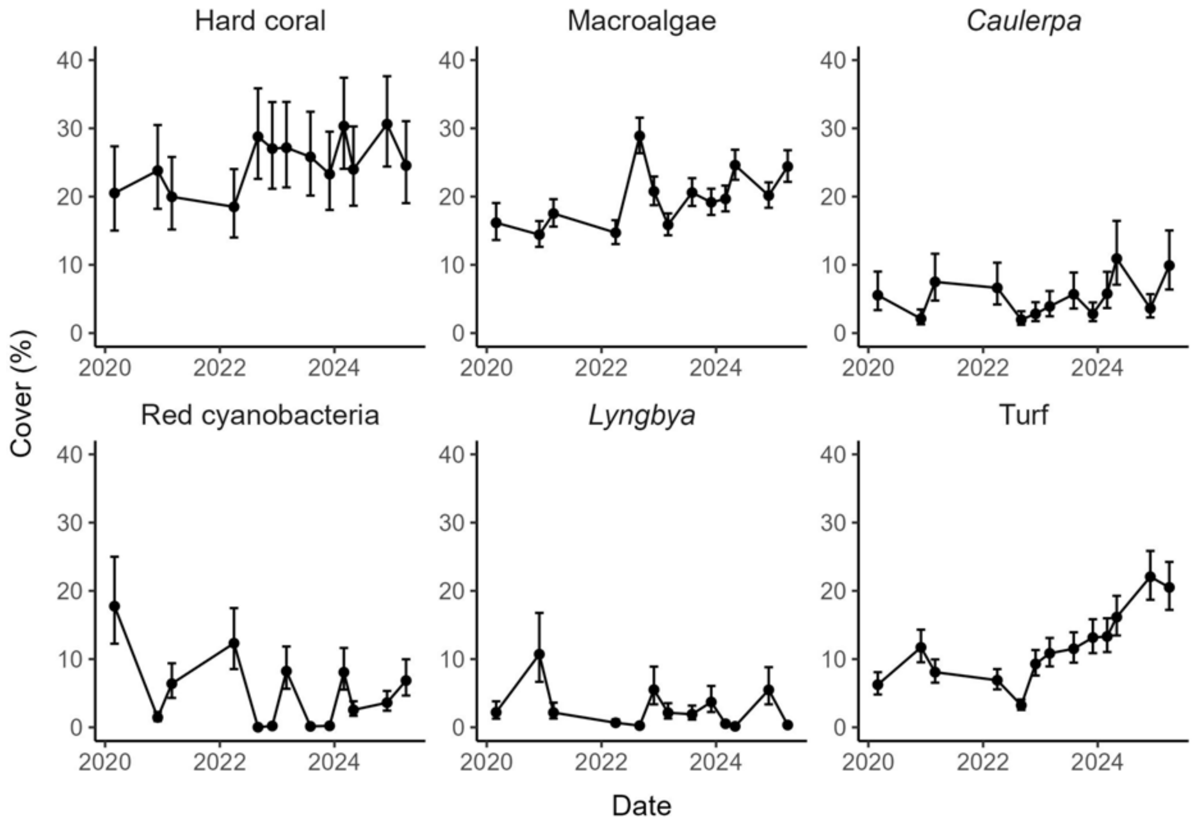


Figure 11. Benthic community composition trends 2020-2025 across inshore lagoonal sites of NMP.

Emily Bay

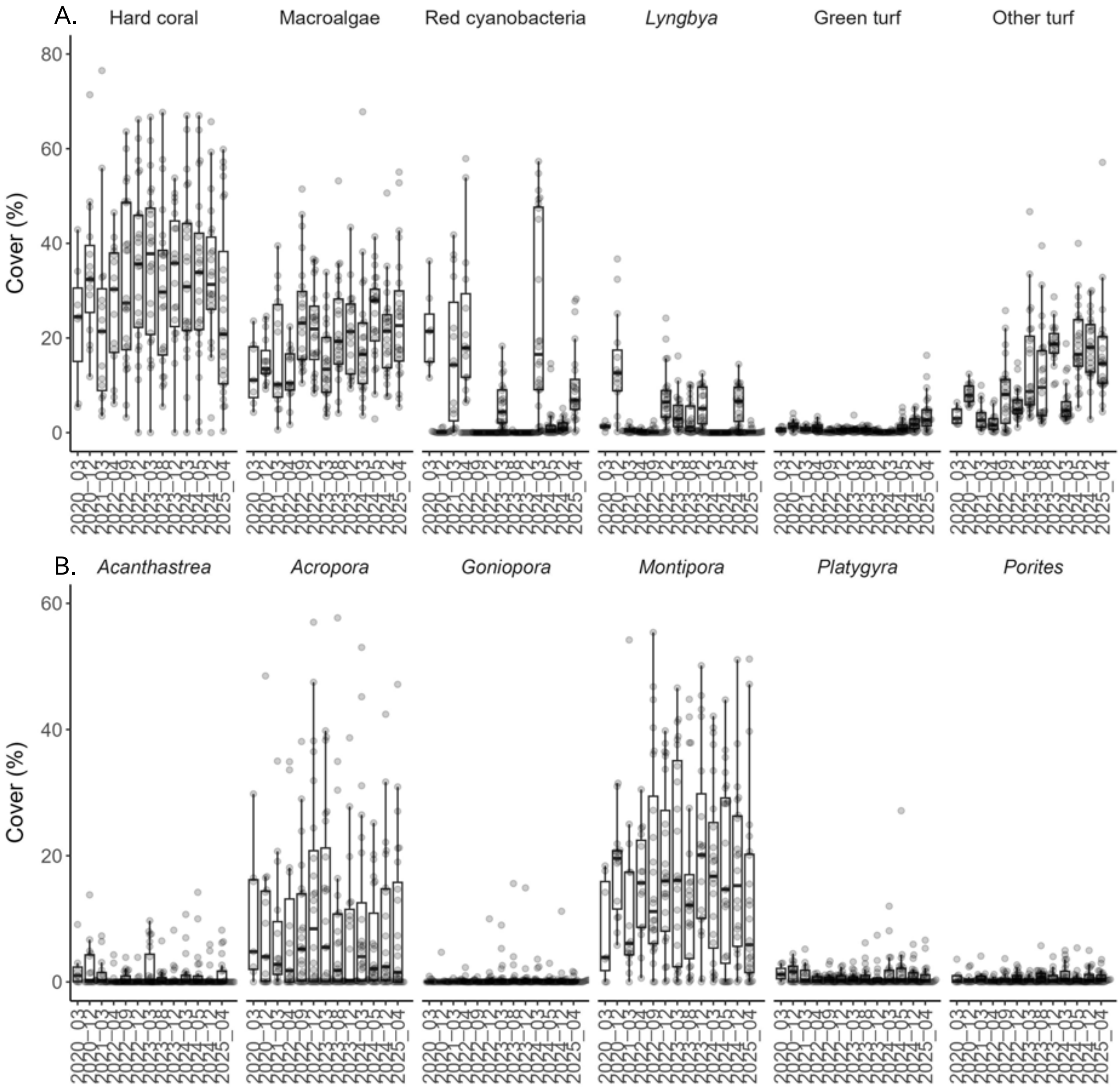


Figure 12. Community cover patterns from 2020 – 2025 recorded at Emily Bay for the main benthic groups (A) and main hard coral taxa (B). Dark line represents the medium value, boxes upper and lower values represent the interquartile range (25th and 75th percentile) and line represent the maximum and minimum values. Points represent outliers (i.e. transects placed on anonymously high areas of cover for the group being plotted).

Slaughter Bay

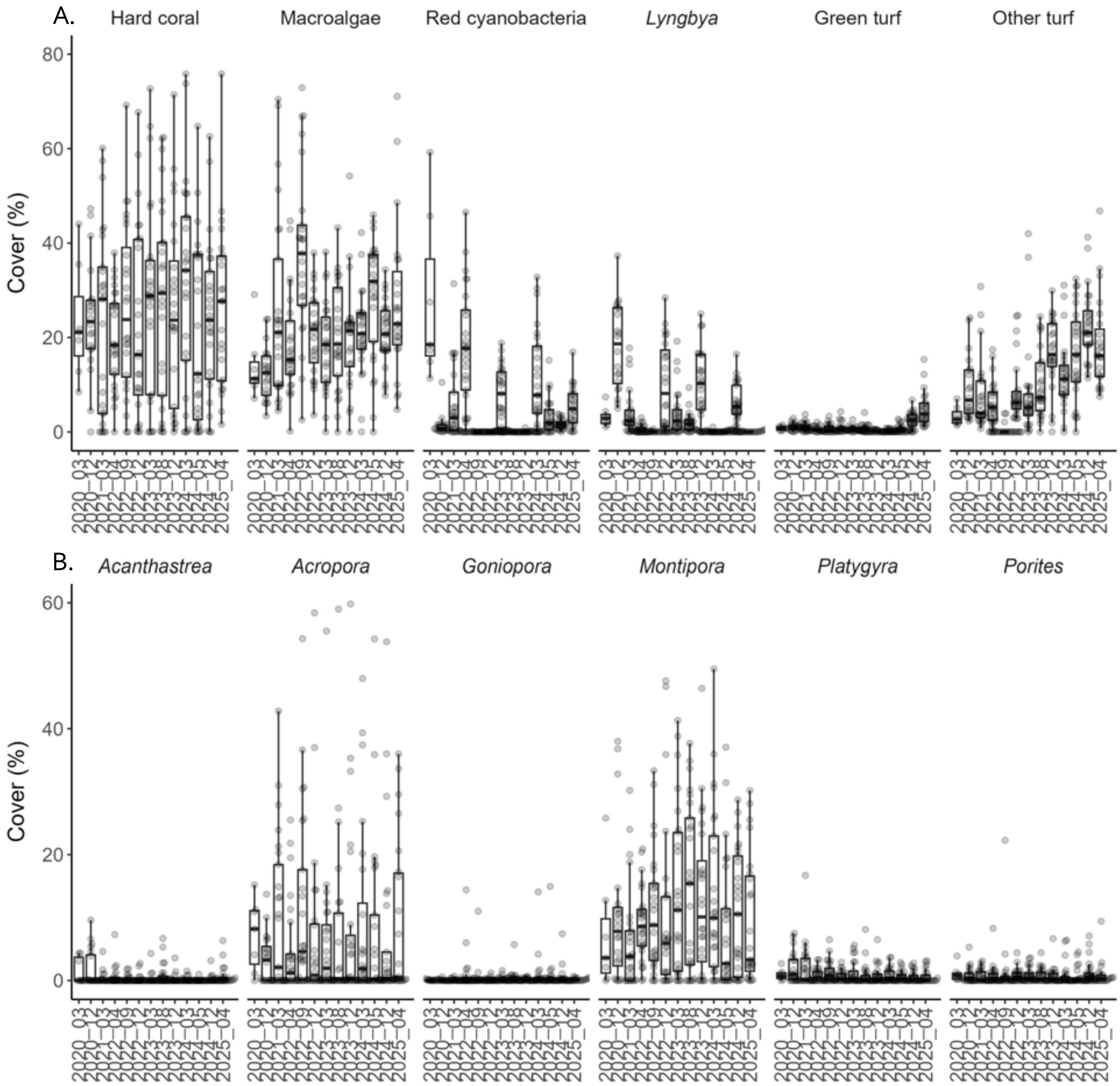


Figure 13. Plots showing community cover patterns from 2020 – 2025 recorded at Slaughter Bay for the main benthic groups (A) and main hard coral taxa (B). Dark line represents the

medium value, boxes upper and lower values represent the interquartile range (25th and 75th percentile) and line represent the maximum and minimum values. Points represent outliers (i.e. transects placed on anonymously high areas of cover for the group being plotted).

Far Western Slaughter Bay

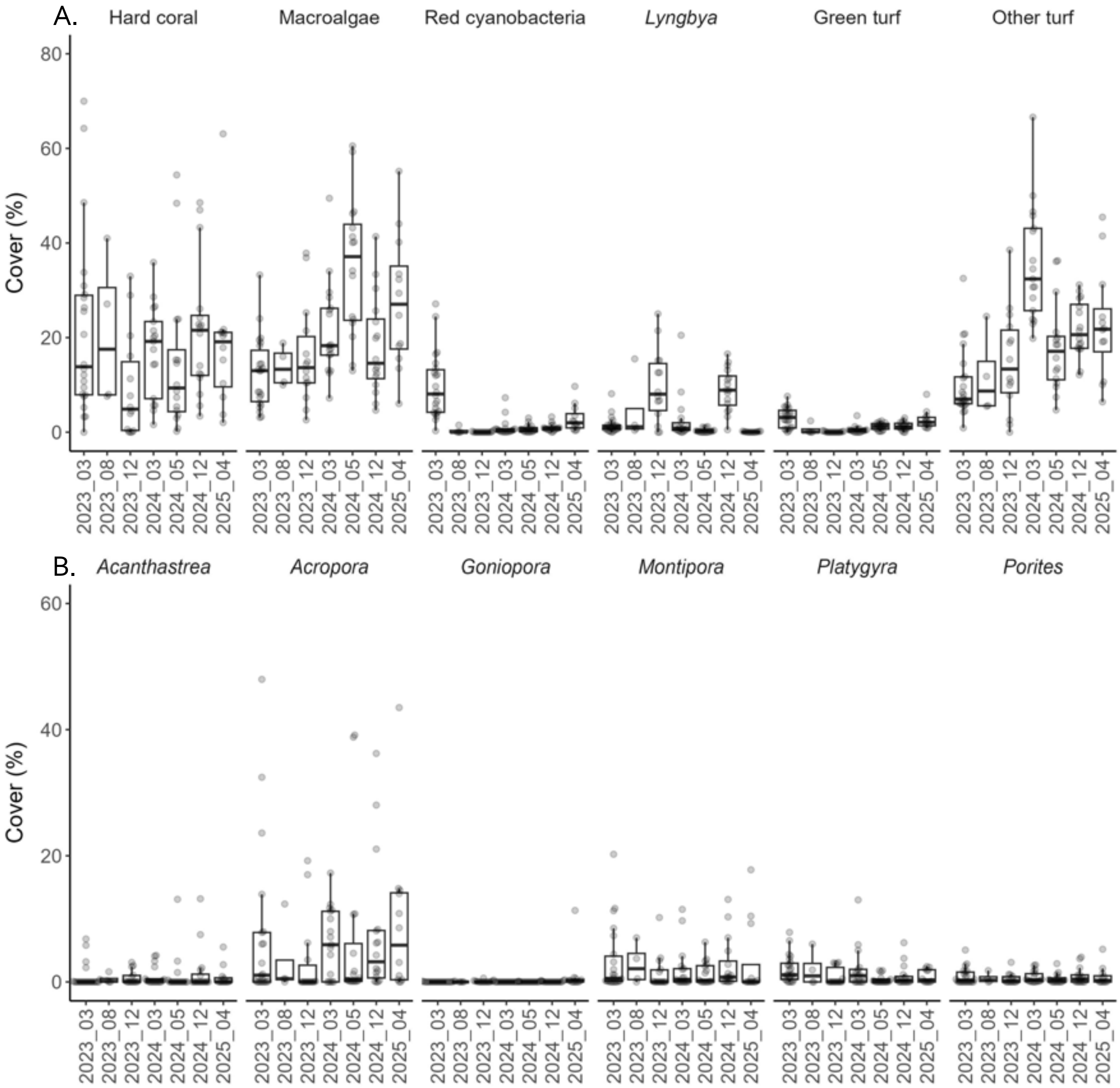


Figure 14. Plots showing community cover patterns from 2020 – 2025recorded at Far Western Slaughter Bay for the main benthic groups (A) and main hard coral taxa (B). Dark line represents the medium value, boxes upper and lower values represent the interquartile range (25th and 75th percentile) and line represent the maximum and minimum values. Points represent outliers (i.e. transects placed on anonymously high areas of cover for the group being plotted)

Cemetery Bay

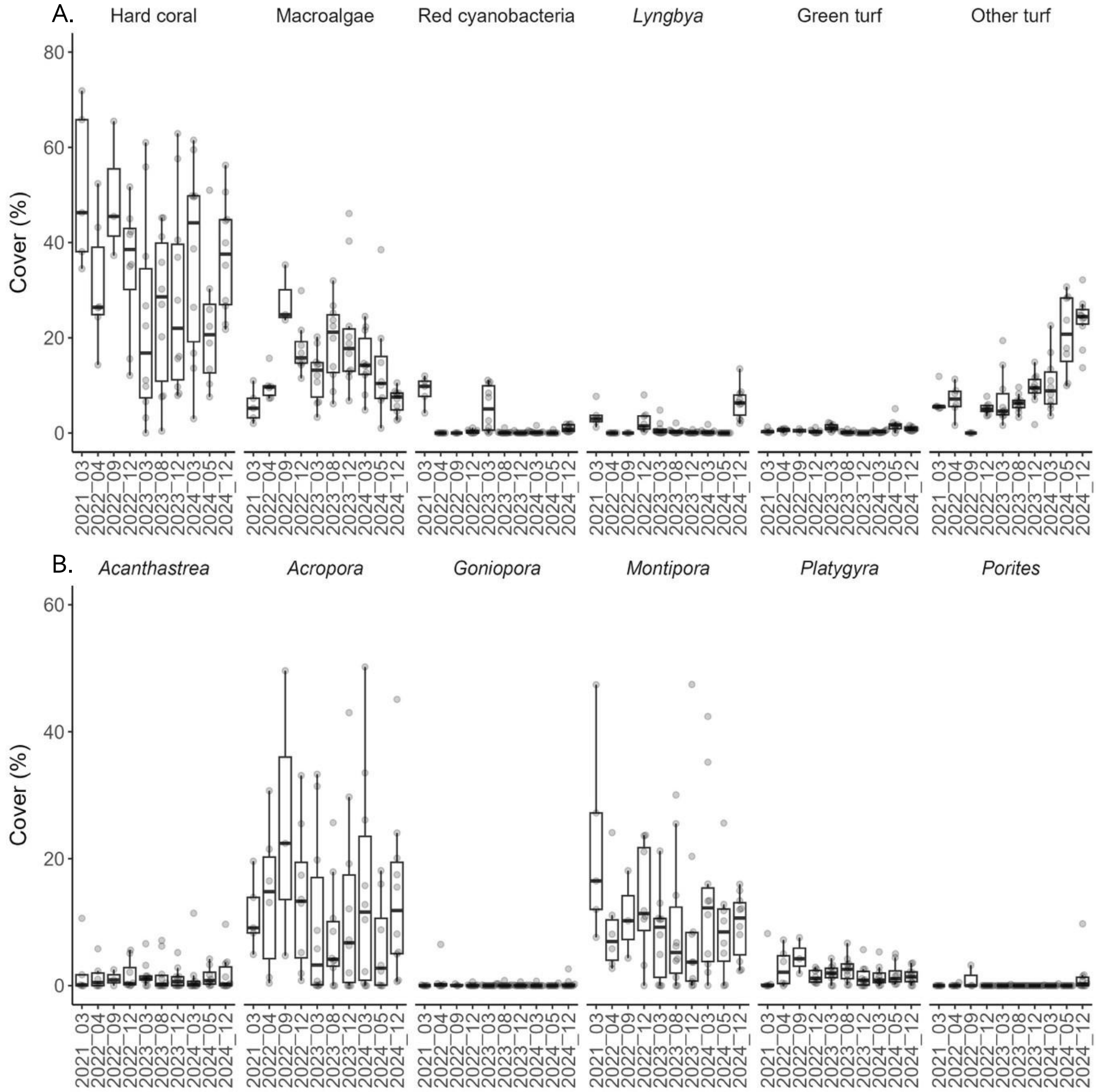


Figure 15. Plots showing community cover patterns from 2020 – 2025 recorded at Cemetery Bay for the main benthic groups (A) and main hard coral taxa (B). Dark line represents the medium value, boxes upper and lower values represent the interquartile range (25th and 75th percentile) and line represent the maximum and minimum values. Points represent outliers (i.e. transects placed on anonymously high areas of cover for the group being plotted).

Fringing reefs of Norfolk Island Marine Park, Elephant Rock

Benthic cover at the offshore reef of Elephant rock, a site removed from the impacts of land-based pollution into the KAVHA catchment, at a depth of ~3 m, is similar to that recorded in Coral Sea and Great Barrier Reef coral reef ecosystems.

Hard coral cover is on average 45% (SE +/- 8.7%), while CCA cover is the highest recorded to date in the Norfolk Marine Park of 11.8% (SE +/- 2%). Urchin cover was found to be 0.96% of cover, two to three times higher than that recorded at inshore sites.

Both red cyanobacteria (2.2%) and *Lyngbya* (0.6%) were evident at the time of survey (May 2025) indicating these are naturally occurring at low levels in the areas of the marine park not affected by land-based run-off. Turf algae (12% +/-2.3%) and macroalgae (15.6% +/-2.8%) were evident at the offshore sites, both of which significantly lower than that of the lagoonal sites where each now exceed 20% of the benthic cover.

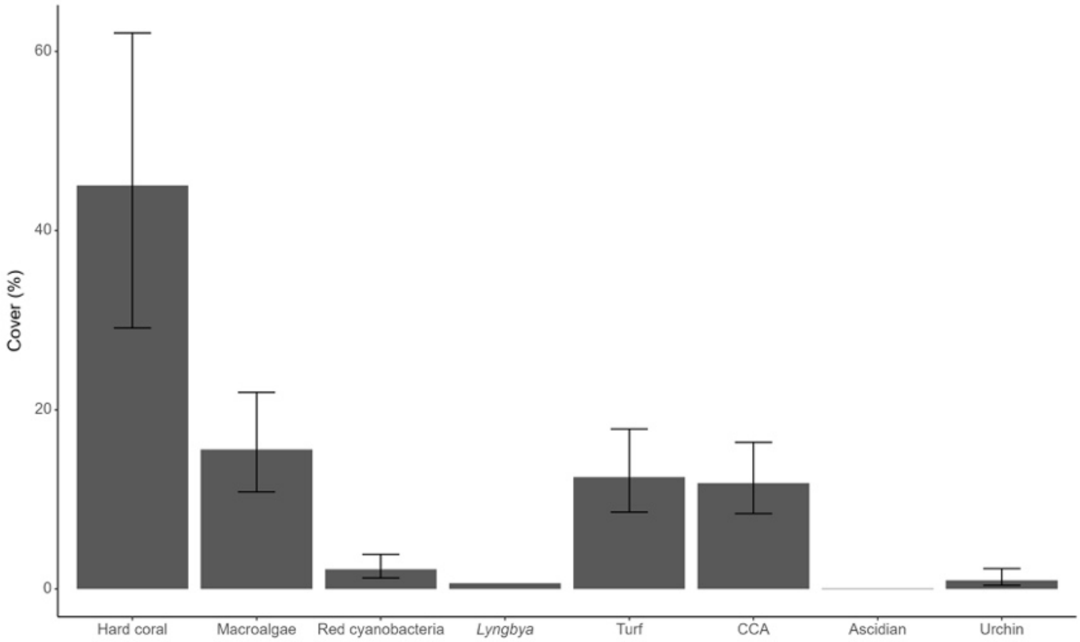


Figure 16. Community structure of fringing coral reef at elephant Rock, NMP, May 2025.

These results suggest that removed from disturbance and land-based pollution the Norfolk Marine Park coral reef ecosystem is a coral dominated coral reef, with high levels of coral cover similar to that recorded on undisturbed tropical coral reef ecosystems. **Turfing and**

macroalgae contribute approximately 27% of the benthic cover offshore, these are significantly lower than that recorded in the lagoonal reefs impacted by land-based runoff. In total, algal communities on inshore reefs account for almost 60% of the benthic cover on inshore-lagoonal reefs and less than 30% of benthic cover on offshore reefs in 2025. As such inshore-lagoonal reefs are potentially on a trajectory to sustained algal dominance if algal communities continue to sustain high levels across all seasons within the lagoons.

Importantly CCA cover is significantly higher at offshore sites than inshore, lagoonal sites, suggesting that CCA cover has potentially been replaced by algal cover within the lagoon. Prior to 2024 CCA cover remained below 2% on the lagoonal reefs, however peaks of 4% in 2025 suggest CCA populations have the potential to increase within the lagoon. CCA is critical to coral recruitment and settlement of corals, and as such is a significant driver of future population structure on the coral reef. Our results also suggest that recovery of urchin populations is occurring in the lagoon, but urchin density is not yet comparable to that found in offshore and less accessible areas. As such recovery time for urchin populations following the removal of fishing effort likely requires several years and/or recruitment periods to return to pre-fished populations.

Assessment of indicator organism reef associations 2020-2025

Following the established ***LTMP program design***, benthic surveys were conducted 2020 to April 2025. Benthic surveys consisted of 24 x 10 metre belt transects in Emily Bay and 27 x 10 metre belt transects in Slaughter Bay (Figure 2). Within each transect (10 m), 10 photos (TG-6 Olympus underwater camera) at 1m increments were captured using a 0.5 m^2 photo quadrat to standardize the area (n = 10 photos transect-1). The resulting photos were analysed for recorded invertebrates (*including urchins and ascidians as reported here*) using the online platform *CoralNet* (https://coralnet.ucsd.edu) applying a grid of 100 points per photo, for annotations of urchins. Individual urchins present were confirmed by counts within each photo quadrat allowing urchins to be reported as counts. Each are reported as a proportion of all cover.

In 2025 we find continued upward trends in CCA and urchin populations, while Ascidians remain a feature of the benthic population across all inshore lagoonal reef sites.

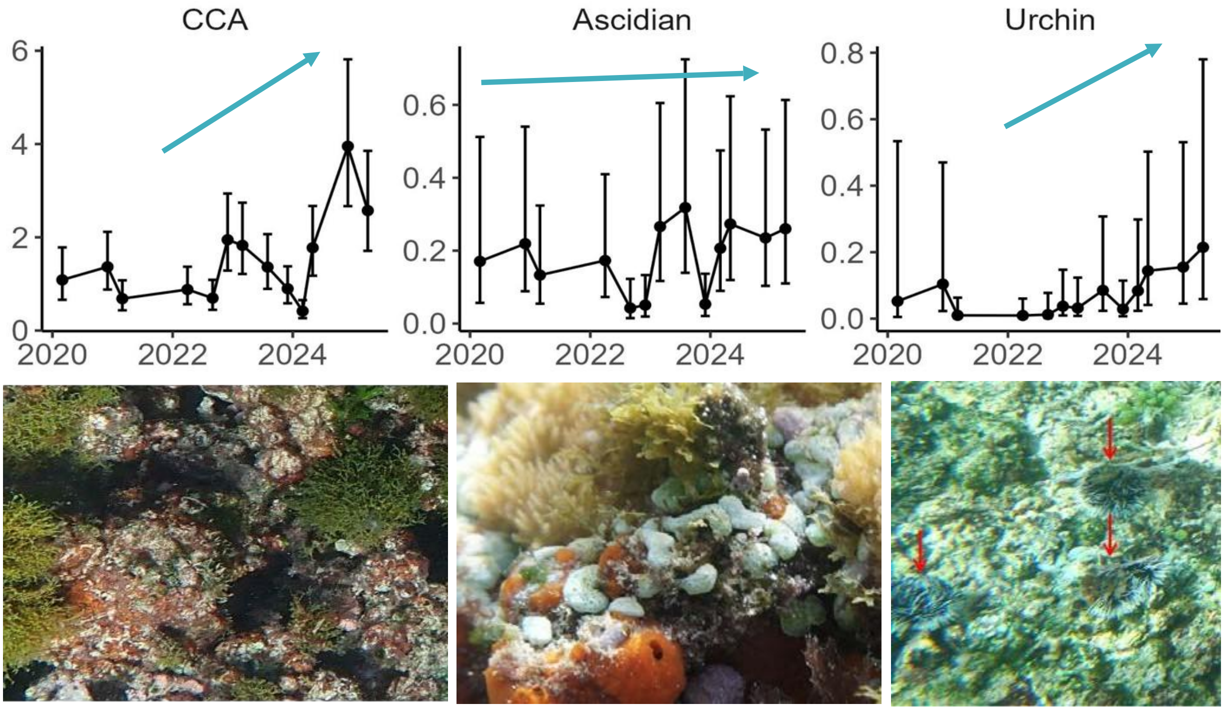


Figure 17. Longterm trends in CCA, Ascidian and Urchin populations on inshore-lagoonal reefs of NMP. Bottom. Images showing, calcifying algae, Ascidian, urchin.

Assessment of Coral Reproduction and Recruitment

Coral recruitment in 2025 was not documented and it is unclear if a recruitment failure occurred in 2025 (Figure 7, Table 1). During outreach events in April 2025 local residents reported not noticing the usual coral spawn slicks around the island in late December, January and February 2025 indicating the potential for reduced coral spawning in 2024/25. Reductions in coral reproduction and recruitment are known to occur in the year following a bleaching event, as occurred in 2024. Therefore, further assessment of coral reproduction and recruitment is necessary throughout summer to determine reproductive status annually particularly in years following bleaching events.

Table 1. Location of deployed settlement tiles (deployed December 2024, collected April 2025).

Location	Latitude	Longitude
Cemetery Bay	29° 03.5554' S	167 ° 58.0884' E
	29° 03.5583' S	167 ° 58.0876' E
	29° 03.5625' S	167 ° 58.0797' E
Slaughter Bay	29° 03.5717' S	167 ° 57.5745' E
	29° 03.5787' S	167 ° 57.5732' E
	29° 03.5754' S	167 ° 57.5695' E
	29° 03.5691' S	167 ° 57.5785' E
Slaughter Bay (Pier)	29° 03.5195' S	167 ° 57.3371' E
	29° 03.5248' S	167 ° 57.3251' E
	29° 03.5236' S	167 ° 57.3285' E
	29° 03.5244' S	167 ° 57.3352' E

NMP Fish diversity and Habitat Usage

Taxa richness was found to increase from Eastern Emily Bay to Western Slaughter Bay over reef however there is no difference in taxa richness of sand habitats (Figure 18). Taxa richness was significantly greater than sand within any zone. Results to-date (August 2024) indicate there is no significant difference in species diversity between coral reef; coral reef with macroalgae matrix; and coral reef with rocky reef and macroalgae. Further analysis of fish communities following the disturbance events of 2025 are underway to assess ongoing habitat usage patterns.

Labridae (wrasses) are the most dominant fish family in all zones over reef throughout Emily Bay and Slaughter Bay. Many of the Labridae species are well known reef-associated species (*Thalassoma spp., Gomphosus varius, Pseudolabrus luculentus*). Over sand, *Mugilidae* (mullets) and Labridae (wrasses) are the dominant families. *Apogonidae* (cardinal fishes) are only found over sand in western Slaughter Bay, representing many juvenile endemic Norfolk Island species. *Mugilidae* (mullets) and *Mullidae* (goat fishes) are known sand-associated species given their feeding ecology.

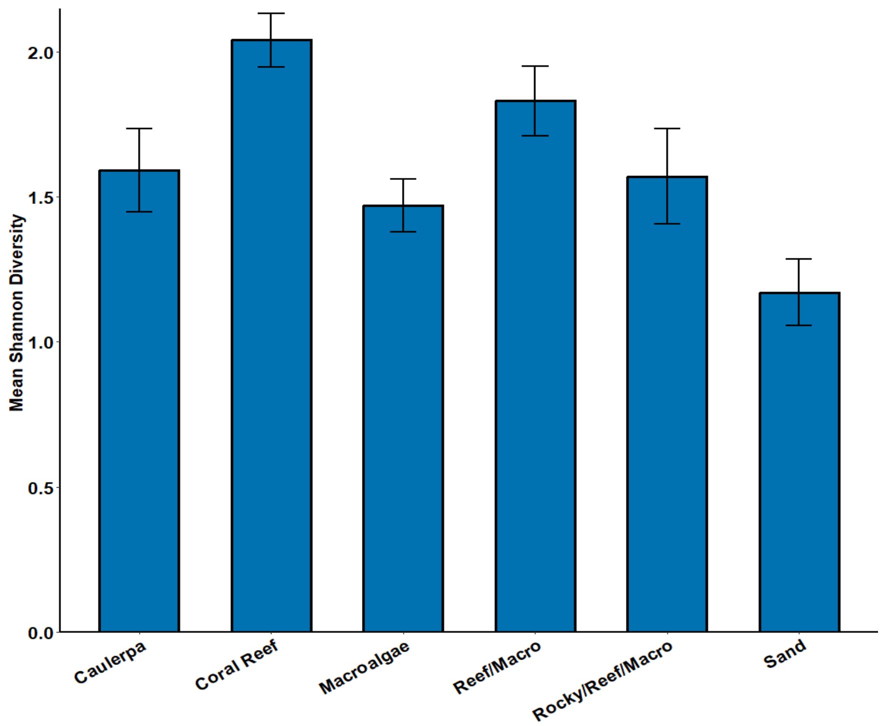


Figure 18: Mean diversity (Shannon) over different habitats at Salthouse. Values are mean ± se.

Community Outreach and Engagement Activities 2024-25

School outreach and citizen science intensive program related to the study areas within Norfolk Marine Park.

Associate Professor Troy Gaston (University of Newcastle) delivered outreach activities for approximately 50 year 7, 8 and 9 students from the Norfolk Island Central School on the 5th December. A/Professor Gaston and A/Professor Ainsworth delivered outreach activities for approximately 15 year 10 students in March.

Community public presentations and training workshop for monitoring website to be designed for delivery by citizen scientists.

Associate Professor Tracy Ainsworth (University of New South Wales), Professor Bill Leggat (University of Newcastle) and A/Professor Troy Gaston gave a public presentation at the Norfolk Discovery Centre in April 2025. This included an outline of the Citizen Science web page (https://coralreefhealth.com) where they answered questions on the use of the website.

Citizen Scientist contributions to ocean data collection around Norfolk Island

A Moana sensor kit was provided by Professor Moninya Roughan to the local dive operator on Norfolk Island allowing for a citizen science temperature measurement. Ocean data is returned to UNSW cloud servers via a solar powered deck unit that transmits over the cell phone network when in cell range. The data are automatically quality controlled and plotted and returned to the citizen scientist via email. The data are also sent to the Australian Ocean Data Network for archival. Citizen scientists' temperature data collection has occurred on 25 occasions in 2024 (Oct – Dec) and 52 occasions in 2025 (Jan-April). Citizen collected temperature data shows a seasonal temperature increase from Nov – March (21.9-24ºC), with a decline to 23.4 in April. Most interesting is that the water column to 18 m is well mixed, with mostly uniform temperatures through the water column on every profile.

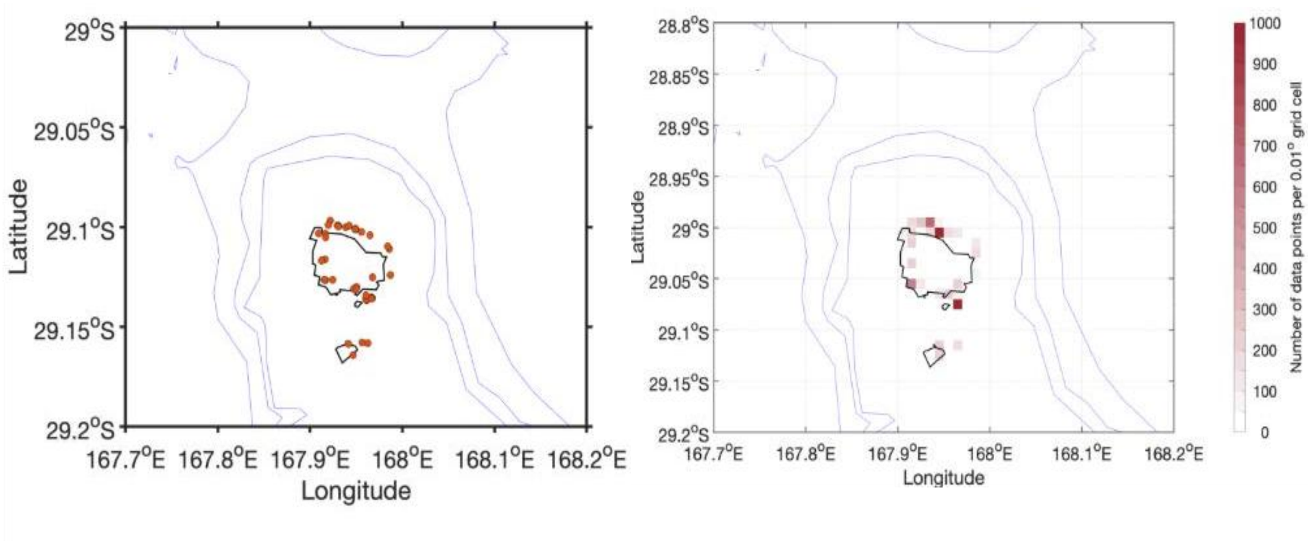


Figure 19: LHS Locations of citizen collected temperature data collected at Norfolk Island by citizen scientists from Oct 2024 - April 2025. RHS Number of collections per grid cell.

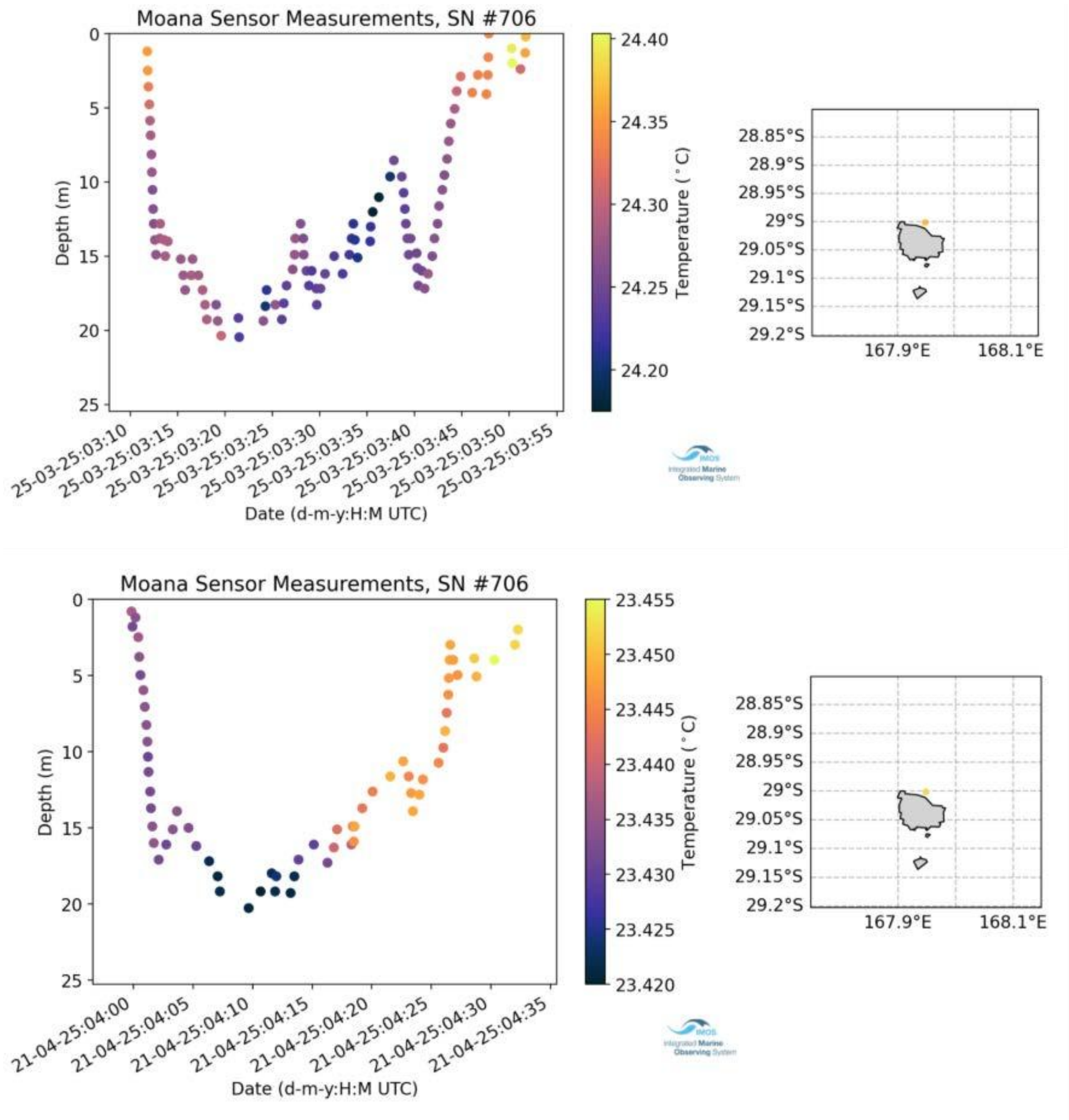


Figure 20. March and April citizen collected temperature data 2025, showing well mixed temperatures of 24.2-24.4 °C.

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