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ASSESSING IMPACTS OF EXTREME WEATHER EVENTS ON INSHORE COASTAL HABITATS IN THE NORTHERN GREAT BARRIER REEF

Scott A, Chartrand K, McKenna S, Canning A, Duke N and Gaskell J

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Cover images

Helicopter and boat surveys undertaken following Tropical Cyclone Jasper. Credit: TropWATER.

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Acknowledgement of Country

The Marine and Coastal Hub acknowledges Aboriginal and Torres Strait Islander people as the first peoples and Traditional Owners and custodians of the land and waterways on which we live and work. We honour and pay our respects to Elders past, present and emerging.

Aboriginal and Torres Strait Islander peoples represent the world's oldest living culture. We celebrate and respect this continuing culture and strive to empower Aboriginal and Torres Strait Islander peoples.

This research was conducted in partnership with Traditional Custodians from the region. We would like to thank the following ranger groups for their contributions to this project: Dabu Jajkial, Jabalbina, Yirrganydji, Gunggandji, Gunggandji-Mandingalbay Yidinji and Mandubarra.

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Ports North contributed data in-kind for Cairns Harbour and Trinity Inlet from the Ports North Long-Term Seagrass Monitoring Program.

Drone imagery and data from reefs in the region were collected and supplied by Johnny Gaskell.

The Cape York Water Partnership provided assistance during this project, and Christina Howley helped with fieldwork. The partnership also provided additional data on seagrass presence from the region in 2024.

The Reef Authority's Marine Monitoring Program provided seagrass data through Len McKenzie from TropWATER.

Executive summary

Tropical Cyclone (TC) Jasper made landfall in December 2023 as a Category 2 system, followed by record-breaking rainfall and extensive regional flooding across Far North Queensland. These extreme conditions caused severe and widespread impacts to inshore estuarine and marine habitats, including mangroves, coral reefs, and seagrass meadows along the coast between Cooktown and Cairns, with additional impacts observed as far south as Kurrimine Beach. This report presents the findings of two years of rapid on-ground and remote sensing surveys carried out in 2024 and 2025; the first coordinated regional-scale assessment of the post-TC Jasper condition of these ecosystems. The work was conducted in collaboration with Traditional Custodians and integrates new field surveys with long-term monitoring datasets and in-kind contributions from partners. Together, these surveys provide updated information on inshore coastal habitats within a historically data-deficient region, improve understanding of the impacts of TC Jasper, and provide an important evidence base to inform future monitoring and management of coastal and marine ecosystems.

The near-total absence of pre-event baseline data for inshore coral reefs and seagrass in this region means the true scale of impact cannot be fully determined. However, opportunistic drone data, Traditional Owner ranger monitoring programs (in-kind data provided by GMYPPBC and Mandubarra) and some long-term monitoring programs provided the only comparable pre/post data, demonstrating the critical value of sustained monitoring programs for regional ecological assessments.

Mangroves

- Extensive damage to mangrove ecosystems was observed across multiple estuarine systems, particularly in the Daintree and Bloomfield Rivers. Climate-natural stressor scores from aerial surveys peaked sharply after TC Jasper.
- Shoreline erosion, tree slumping, root burial, and sediment deposition were widespread, leading to significant tree mortality, including patches of mature standing dead mangroves not previously recorded in the region.
- Satellite-derived mangrove extent declined by 18% at the Daintree (31.9 to 26.1 km²) and 27% at the Bloomfield (3.3 to 2.4 km²) between 2023 and 2024.
- Sediment from collapsed root systems presents an ongoing threat to downstream ecosystems, particularly to surviving mangroves, seagrass and coral habitats.
- While aerial surveys identified some early signs of ecological recovery (e.g. seedling recruitment and reduced stressor scores), satellite-derived mangrove extent showed little measurable recovery during the study period.

Seagrass

- Nine seagrass species were recorded during on-ground surveys for this project covering ~3,532 ha in 2024-25 and ~21,033 ha in 2025.
- A greater area of seagrass was recorded in the second year of surveys. This somewhat reflects increases in deep-water seagrass where surveys were carried out at the peak of the growing season. However, some meadows did have increased biomass and percent cover in 2025, indicating early signs of recovery and resilience.
- These surveys substantially improved knowledge of the regional distribution and extent of seagrass habitats, despite uncertainty regarding the magnitude of TC Jasper impacts resulting from limited pre-event baseline data.

Coral

- Inshore fringing reefs across the survey region were heavily impacted by floodwaters. Prolonged periods of freshwater input with high levels of sediment deposition caused significant coral mortality, with little to no live coral recorded during surveys. Although some of these sediment-smothered reefs were unlikely to be alive prior to TC Jasper, many showed evidence of recent mortality consistent with impacts from TC Jasper and associated flooding.
- Drone imagery showed extensive coral loss at healthy sites with 74 – 87% coral prior to TC Jasper, but almost no live corals afterwards, confirming direct cyclone and freshwater flooding dieback.
- Recovery of reefs where sediment is still present will depend on the redistribution or removal of deposited sediment. Persistent sediment and turf algae cover is likely to inhibit coral recruitment and settlement.
- Live coral was recorded at the Hope Islands, Snapper Island, Low Isles and Double Island on field surveys. However, the long-term Marine Monitoring Program (MMP) showed significant declines in coral cover were due to TC Jasper, particularly at Snapper Island, which was in the direct path of Daintree River floodwaters.

This report presents the first coordinated regional assessment of TC Jasper's impacts across all three habitat types, together with two years of early recovery data. It establishes a critical reference point for understanding how inshore coastal ecosystems respond to compound disturbance events that are projected to increase in frequency and intensity under future climate trajectories.

Recommendations

Continue monitoring to track recovery

Annual or biennial repeat surveys at priority sites; MMP sites, drone survey reefs, Cairns Harbour meadows, and ranger-monitored locations are needed to detect whether habitats are recovering, stabilising or declining further. Formal integration of Traditional Owner ranger data into regional habitat reporting, with sustained resourcing of those programs is a priority.

No active coral restoration is recommended under current conditions

Sediment clearance is a prerequisite for coral recruitment and cannot be accelerated at this scale. If smothering conditions improve at specific subtidal reef sites, targeted surveillance of natural recruitment using ROV or drone technology would be an appropriate next step.

Allow natural regeneration of mangroves and seagrass to proceed

Early recruitment signals in both habitats are encouraging and no established restoration technique exists at the scale required here. Where mangrove rehabilitation trials are being considered across the 1,776 ha of shortlisted area, elevation surveys and sediment assessment should precede any intervention. Seed bank condition and seedling recruitment in the Daintree and Bloomfield estuaries are the most useful early indicators of regeneration trajectory and warrant targeted monitoring. Research should be prioritised to understand the most effective seagrass restoration techniques in all of the tropical species across a range of habitats, to provide the tools to assist recovery following disturbance events.

Invest in catchment-scale sediment management

Reducing ongoing sediment input, including stabilisation of active landslide areas, is the most impactful available lever for supporting long-term seagrass and coral recovery and operates upstream of the estuarine and marine system itself.

Summary flyers

The following flyers summarise key findings of this project and are intended to provide a snapshot of findings as well as additional information from locations of interest. These can be shared with Traditional Owner partners and their communities and with the public more broadly.



Understanding the impact of Cyclone Jasper on coastal marine habitats



Summary

Cyclones can cause significant, lasting damage to the coastal habitats that marine life and coastal communities depend on. This project surveyed over 150 km of the hardest-hit coastline to understand the impacts of, and recovery from TC Jasper.

How did we survey coastal marine habitats?
Surveys were carried out in 2024 and 2025 in partnership with Traditional Owner groups, providing two years of data since TC Jasper.

Mangroves were surveyed by helicopter, boat and with satellite remote sensing.

Seagrass meadows were surveyed by helicopter at low tide, and with a submersible camera from a boat.

Corals were surveyed by helicopter, boat and using a drone.

Tropical Cyclone Jasper

Tropical Cyclone (TC) Jasper made landfall north of Port Douglas in December 2023. It became the wettest tropical cyclone in Australian history, breaking rainfall records and triggering severe flooding and an unprecedented number of landslides. Such flooding with fresh water and extreme sediment loads can damage coastal habitats.

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Dabu Jajikal
Jabalbina
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Mangroves

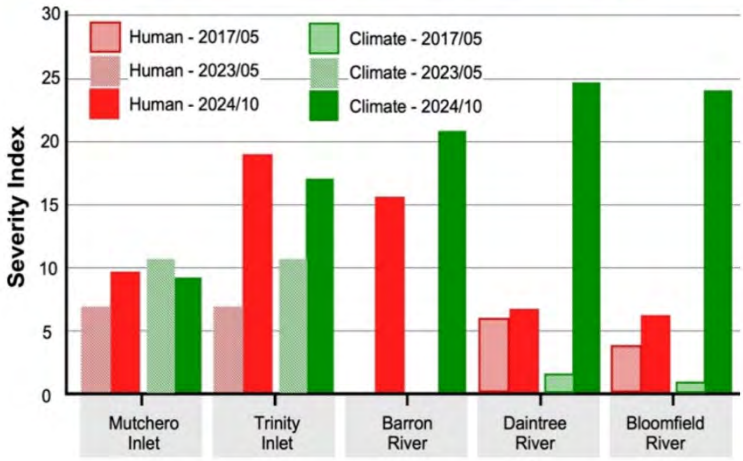
Methods

There was good data on mangrove condition pre TC Jasper. Helicopter surveys updated this information throughout the region in 2024. In 2025 there was a targeted survey focusing on the areas with the most damage and including on ground sediment surveys. Satellite data was also compared pre and post TC Jasper.



Impacts on mangrove ecosystems in the region

Aerial surveys and change indicator assessments carried out br Dr Adam Canning and Dr Norm Duke revealed extensive and, in some cases, unprecedented damage to mangrove ecosystems following TC Jasper. Across the region, satellite imagery analysis identified ~19 km^2 of mangrove lost or severely damaged in the period immediately following TC Jasper, compared with the preceding four months. Approximately half of this damage was located within the Daintree River system.



Visual indicators of flood related stress

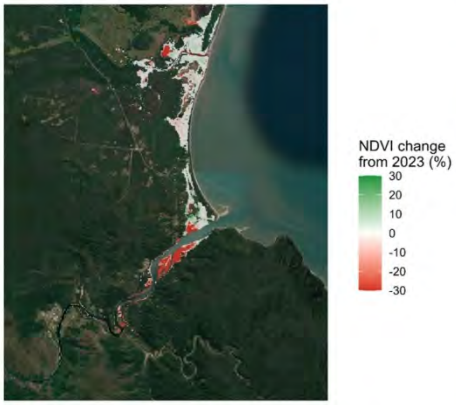
The graph to the left shows the human derived stressors in red and climate derived stressors in green before and after TC Jasper. the largest increase in stressors was climate driven stressors caused by the cyclone in both the Daintree and Bloomfield rivers. There was also an increase in both human and climate indicators in the Trinity Inlet.

Analysis of satellite imagery pre and post TC Jasper

Satellite imagery showing the area of mangroves in estuaries before TC Jasper and after TC Jasper, with losses in area detected in the Daintree and Bloomfield estuaries



Daintree River
5.8km^2 lost (18%)



Bloomfield River
0.9km^2 lost (27%)

Mangroves

Daintree and Bloomfield Rivers

As the Daintree and Bloomfield mangrove ecosystems were identified as the most severely damaged in the 2024 surveys, these were surveyed again in 2025 to understand what processes were driving declines and whether there was any evidence of recovery. Helicopter and boat surveys along with analysis of satellite imagery fed into these surveys.



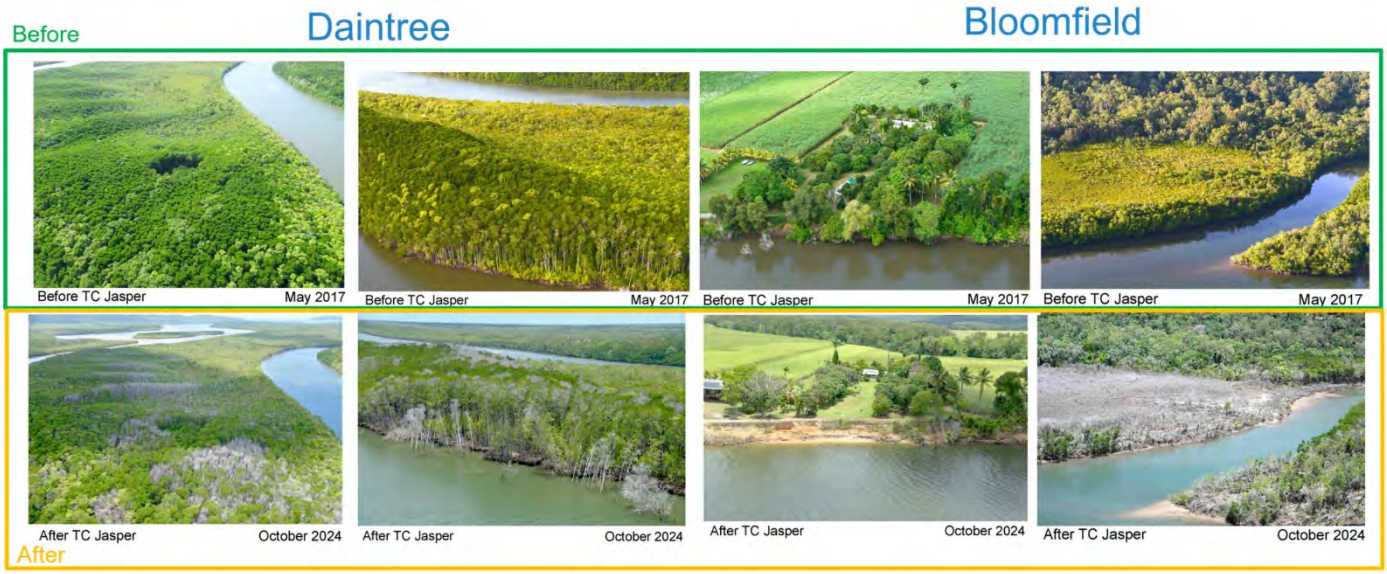
Sediment deposition

Mangroves in the Daintree were impacted by sediment deposition, these sediments buried mangrove roots so they were unable to breathe. The bands of dead mangroves in the photo above had heavily deposited sediment wheras live areas have less sediment. As mangrove roots decompose the seiment level drops and becomes inundated, making recovery harder.

Summary

Both the Daintree and Bloomfield River mangrove ecosystems suffered severe damage and mangrove loss due to the sediment laden floodwaters post TC Jasper. There has been limited evidence of recovery in both catchments so far, although seedlings have been observed, their survival has been limited.

Before and after TC Jasper images from the Daintree and Bloomfield rivers



The Daintree River (left) was immediately impacted by flood destruction and high levels of sediment burial whereas the Bloomfield was largely impacted by direct physical destruction from flood damage (right). There was some saplings colonising in the Daintree and seedling survival remained high in 2025.

What did we find about seagrass in the region?

Seagrass





Prior to TC Jasper, there was limited data on seagrass meadows in the region, making it hard to understand the cyclone's direct impacts. In our second year of surveys, we found seagrass had started to recover in some locations.

Key seagrass findings in the region

Our surveys found extensive seagrass in the region — including species never previously recorded here. We also documented flowering of endemic species and active dugong feeding grounds, both positive signs of ecosystem health and recovery.

Seagrass cover increased between 2024 and 2025 on the reef tops, in deeper water and in coastal meadows.



More deep-water seagrass
Throughout the region in 2025



Enhalus acaroides
At Cooya Beach



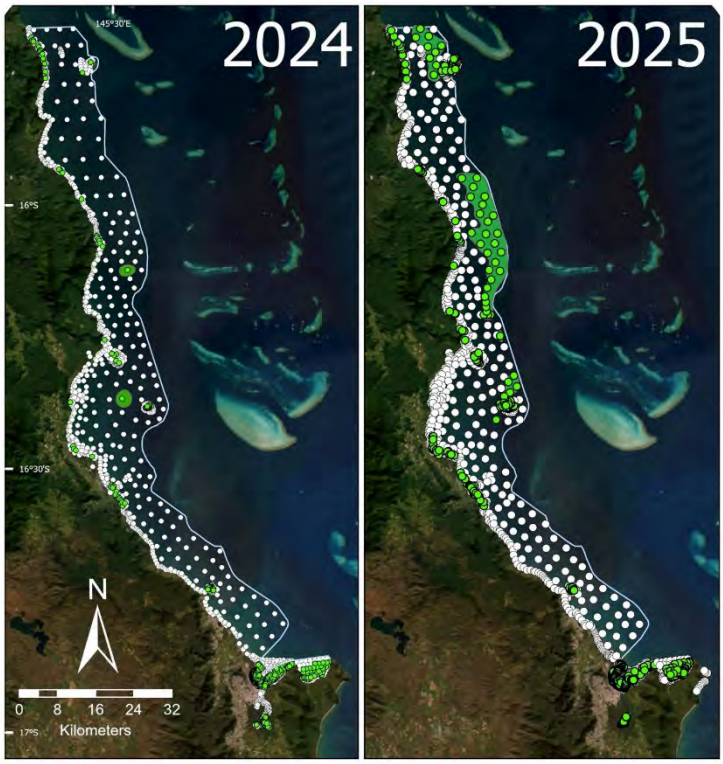
Dugong feeding trails
Near Port Douglas



Flowering *H. tricostata*
Recorded off Snapper Island

Summary

Nine seagrass species were recorded in the region, filling an important historical data gap. The area of mapped seagrass increased from around 3,532 ha in 2024 to around 21,000 ha in 2025, with seagrass biomass also increasing in the second year of surveys. There was an additional 500 ha mapped within Cairns Harbour. This new data helps inform seagrass predictive models valuable for management. The map on the right shows data collected in both years.



GMYPPBC Rangers · Gunggandji Aboriginal Corporation · Yirrganydji Land and Sea Rangers · Jabalbina · Dabu Jajikal

JCU · TropWATER · Ports North · Cape York Water Partnership

TropWATER · JCU · James Cook University Australia

Deep-water seagrass

Seagrass surveyed in 2024 and 2025

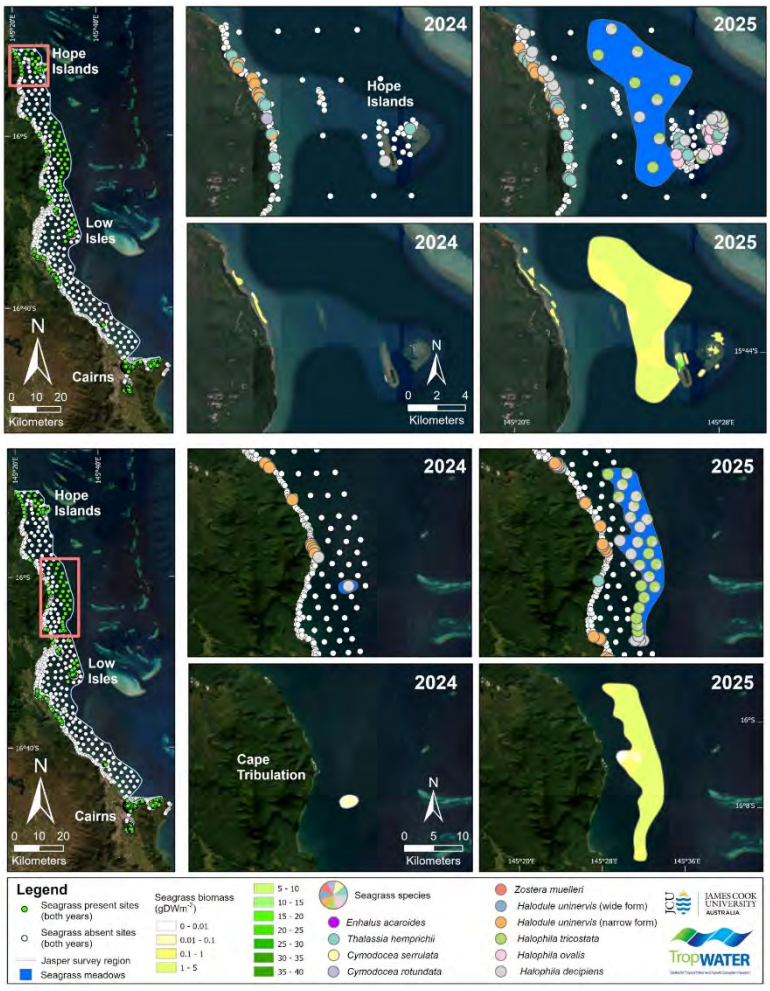
Deep-water seagrass species recorded



Deep-water seagrass in the region

The maps below show the seagrass species and biomass (weight) of seagrass in the main deep-water meadows recorded in 2024 and 2025. Two species of deep-water seagrass were recorded shown right.

- In 2024 only two deep-water seagrass sites were recorded offshore.
- A *Halophila tricostata* meadow was mapped off Snapper Island in 2024 and was still present in 2025.
- In 2025 a large deep-water meadow was mapped north of the Hope Islands (top map), covering ~3,910 ha. This meadow was dominated by *Halophila tricostata* with cover ranging from 1-30%.
- A second large deep-water meadow was mapped in 2025 off the Daintree (bottom map), covering ~13,090 ha. Both deep-water species were recorded here with cover ranging from 1-35%.
- Increases in seagrass cover between years may partly reflect 2025 surveys being carried out earlier in the growing season than in 2024, in the peak season for these species.





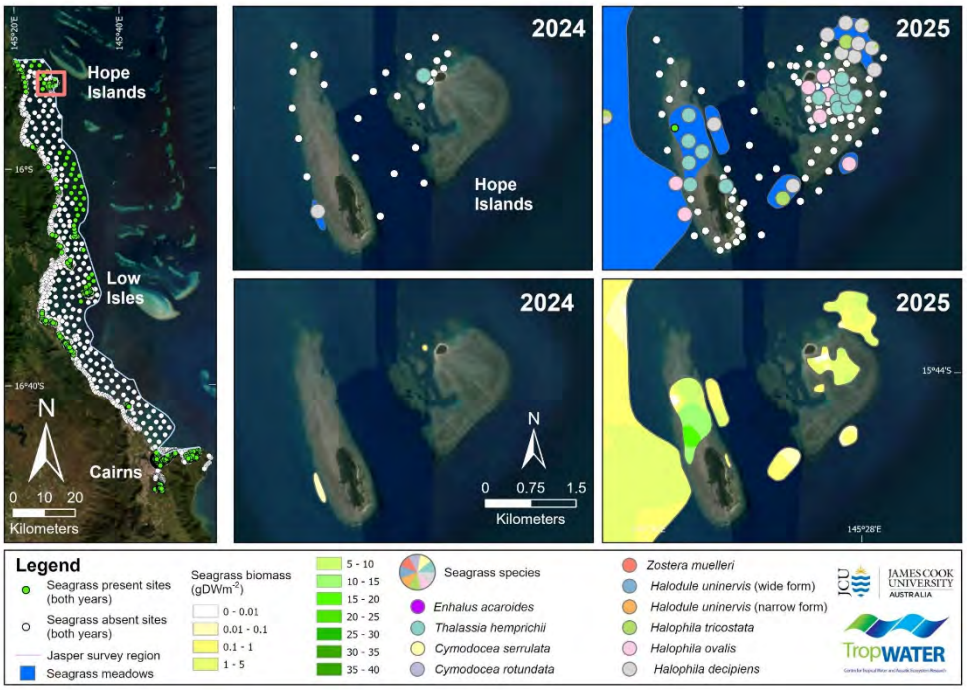


There was very little data on deep-water seagrass in the region prior to TC Jasper, so this new data fills an important gap in our understanding. The endemic species *Halophila tricostata* (left image) was recorded in extensive deep-water meadows in 2025 and was also flowering.

Hope Islands

Seagrass surveyed in 2024 and 2025

The Hope Islands were surveyed by boat in partnership with Dabu Jajikal and Jabalbina Rangers in both 2024 and 2025 to map the seagrass meadow here.







The Hope Islands were surveyed in both years, but better tides and weather allowed more boat sites to be surveyed on the reef flat in 2025. There were seagrasses recorded on the reef-top, around the islands and in deeper waters in the area.

The maps above show the seagrass species and biomass (weight) of seagrass in the meadow in 2024 and 2025.

- In 2024 only 2 of 26 sites had seagrass present.
- In 2025, 116 sites were surveyed, with 35 recording seagrass at 1-12% cover across seven meadows.
- Reef-top meadows were dominated by *Thalassia hemprichii* and subtidal meadows were dominated by *Halophila decipiens* with *Halophila ovalis* and *Halophila tricostata* also present.



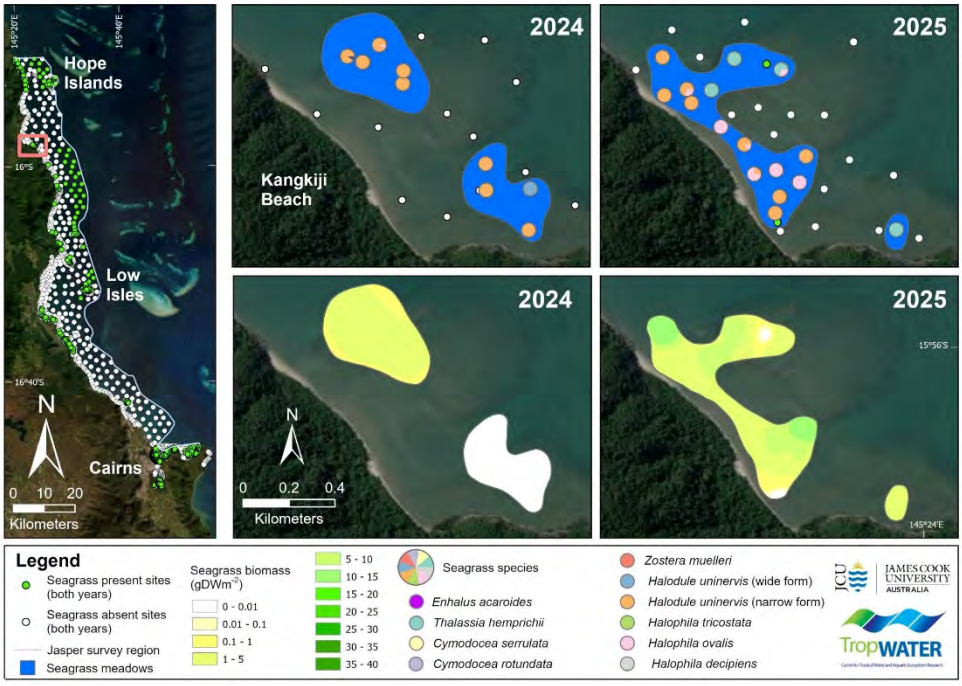
Changes in Hope Islands seagrass

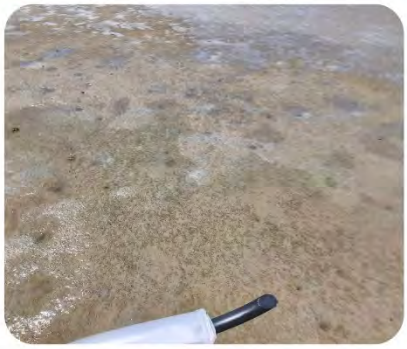
There was very little data from this meadow prior to TC Jasper, so this data fills an important gap in our understanding of seagrass here. The endemic species *Halophila tricostata* (left) was recorded here in 2025 and extensively in the deep-water area north of the Hope Islands. The big jump in seagrass detected between years mostly reflects improved survey access in 2025, rather than sudden meadow growth.

Kangkiji Beach

Seagrass surveyed in 2024 and 2025

Kangkiji Beach was surveyed by boat and helicopter in partnership with Dabu Jajikal and Jabalbina Rangers in both 2024 and 2025 to map the seagrass meadow here.







Kangkiji Beach seagrass meadow is an important grazing area and we saw dugong feeding here on our surveys. This is a diverse reef-top seagrass meadow with three seagrass species recorded.



The maps above show the seagrass species and biomass (weight) of seagrass in the meadow in 2024 and 2025.

- In 2024, the meadow covered about 23 ha in area, ranged in cover from 1-25% and had a relatively low biomass (~1 $gDWm^{-2}$).
- In 2025, the meadow covered a similar area of (~24 ha), but biomass increased to ~4 $gDWm^{-2}$ and some areas had up to 45% cover.
- This meadow was dominated by *Halodule uninervis* in both years, with more *Halophila ovalis* and *Thalassia hemprichii* present in 2025.

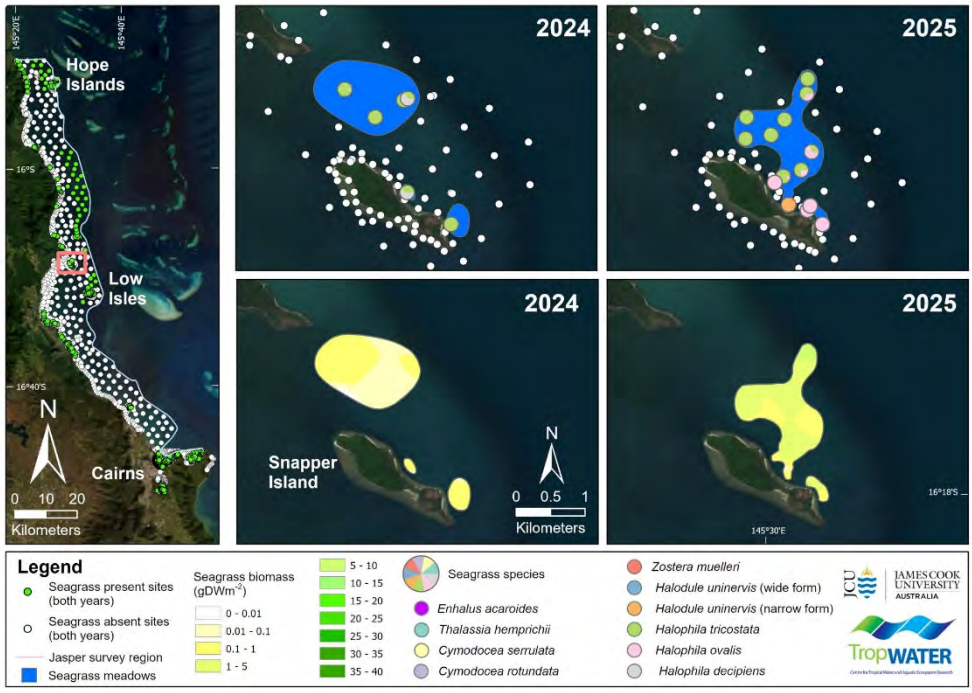
Changes in Kangkiji Beach seagrass

There was very little data from this meadow prior to TC Jasper, making it challenging to understand changes. Seagrass biomass and percent cover increased between 2024 and 2025, showing some improvement post TC Jasper. TropWATER and Dabu Jajikal Rangers will continue to monitor this meadow in 2026 and 2027.

Snapper Island

Seagrass surveyed in 2024 and 2025

Snapper Island was surveyed by boat in partnership with Jabalbina Rangers in both 2024 and 2025 to map the seagrass meadow here.







Snapper Island has seagrass present both on the shallow reef flat and in the deeper channel. This meadow contains the deep-water endemic seagrass species *Halophila tricostata* (image below).

The maps above show the seagrass species and biomass (weight) of seagrass in the meadow in 2024 and 2025.

- In 2024, the large deep-water meadow covered ~121 ha with a biomass of just ~0.1 gDWm^{-2} and only 1% cover of *Halophila tricostata* and Halophila *decipiens*.
- In 2025, this meadow covered a similar area (~108 ha) but biomass increased to ~2.4 gDWm^{-2}, with cover increasing to up to 35% and two new species (*Halodule uninervis* and *Halophila ovalis*) present.



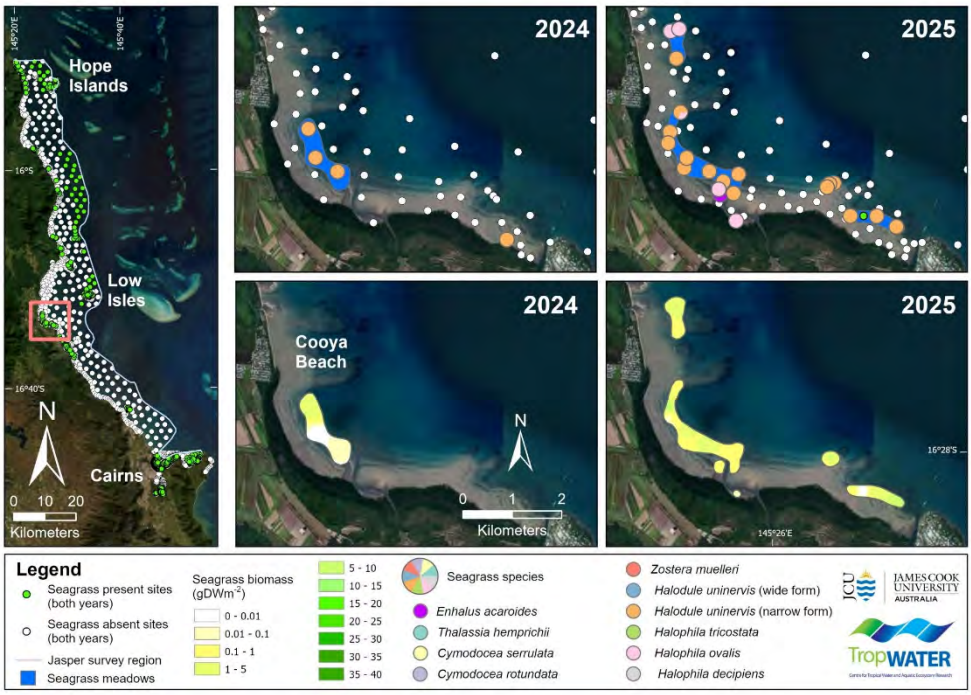
Changes in Snapper Island seagrass

Prior to this survey there was only one seagrass data point from Snapper Island from 1985. This survey recorded endemic *Halophila tricostata* with flowering also observed (left). There was an increase in seagrass biomass in 2025 which may indicate recovery post TC Jasper, but could also be due to the time of year the 2025 survey was conducted.

Cooya Beach

Seagrass surveyed in 2024 and 2025

Cooya Beach was surveyed by boat and helicopter in partnership with Jabalbina Rangers in both 2024 and 2025 to map the seagrass meadow here.







Cooya Beach may be an important feeding ground for dugongs. In 2025, we recorded evidence of dugong feeding near Muddy Creek. This is also one of two locations in the survey area where the larger seagrass species *Enhalus acaroides* has been found, validating anecdotal historical records.

The maps above show the seagrass species and biomass (weight) of seagrass in the meadow in 2024 and 2025.

- In 2024, four sites here had seagrass (*Halodule uninervis*) with 1–20% cover, forming one meadow that covered ~60 ha.
- In 2025, 22 sites had seagrass with up to 40% cover, forming four meadows covering ~140 ha, dominated by *Halodule uninervis* and *Halophila ovalis*.
- A small additional patch of *Enhalus acoroides* (photo above) was recorded for the first time in 2025.


Dugong feeding trails at Cooya Beach

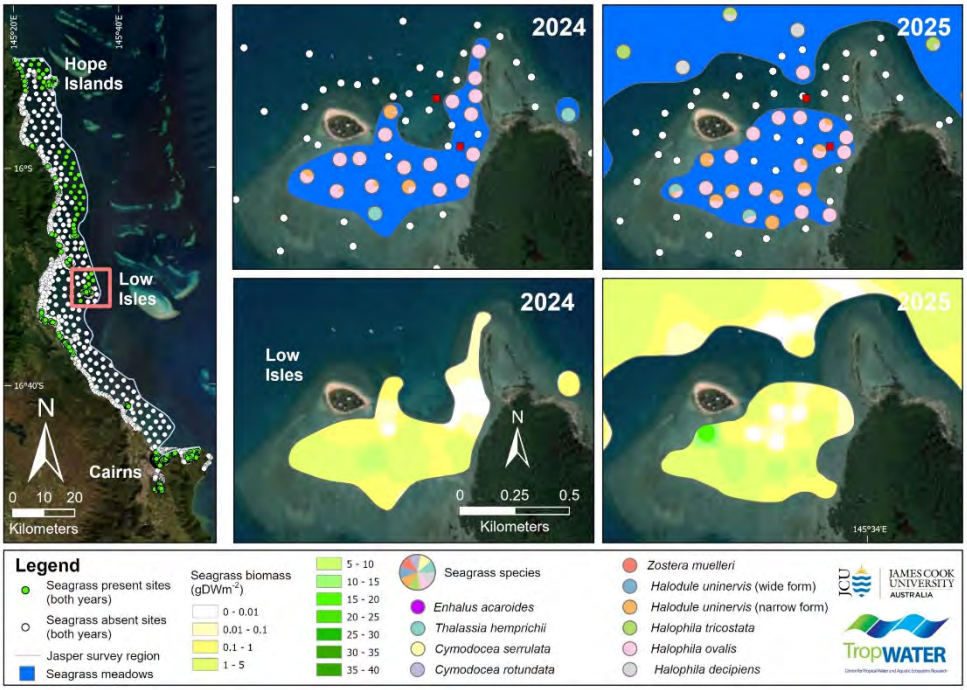
Changes in Cooya Beach seagrass

Seagrass area and biomass/percent cover increased substantially at Cooya Beach in 2025, with a new species recorded for the first time. There was very little data from this meadow prior to TC Jasper which makes it challenging to understand changes, however this likely represents a recovery post cyclone. TropWATER and Jabalbina Rangers will continue to monitor this meadow in 2026/27 and will work with Biopixel Oceans Foundation to understand food web links.

Low Isles

Seagrass surveyed in 2024 and 2025

Low Isles was surveyed by boat and helictoper in partnership with Jabalbina Rangers in both 2024 and 2025 to map the seagrass meadow here.







Low Isles has a reef-top seagrass meadow with deep-water seagrass north of the islands and off the reef flat. This location is also monitored by the Marine Monitoring Program (sites shown by red squares in maps above). This is an important feeding ground for green turtles.

The maps above show the seagrass species and biomass (weight) of seagrass in the meadow in 2024 and 2025.

- In 2024, the meadow covered ~31 ha with a biomass of ~1.4 gDWm^{-2} and 1–20% cover, dominated by *Halophila ovalis*.
- In 2025, the meadow covered a similar area (~31 ha), but biomass increased to ~2.3 gDWm^{-2} with cover also increasing up to 40%, and the meadow shifted to being dominated by *Halodule uninervis*.
- In 2025, a large *Halophila tricostata* (photo below) deep-water meadow north of Low Isles was mapped covering ~1,608, whereas in 2024 there was only one seagrass site here.



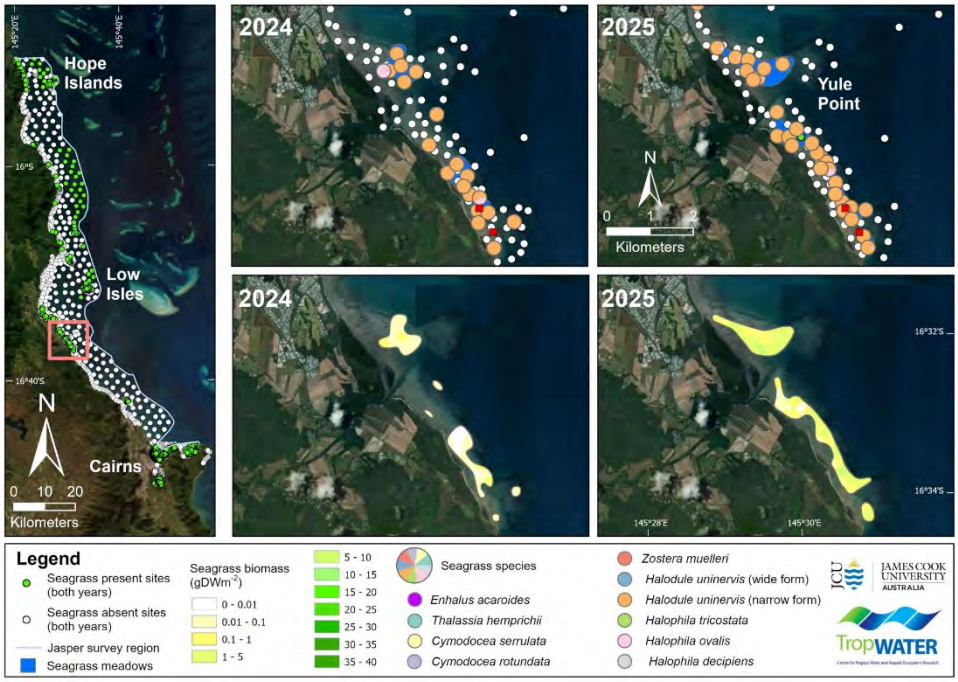
Changes in Low Isles seagrass

The two long-term MMP monitoring sites at Low Isles recorded a decline in seagrass at both sites. At the subtidal site this was directly after TC Jasper, whereas the intertidal site declined in September 2024. There was some recovery documented by MMP surveys, and our data also showed recovery in seagrass biomass and percent cover here.

Yule Point

Seagrass surveyed in 2024 and 2025

Yule Point was surveyed by boat and helicopter in partnership with Yirrganydji Rangers in both 2024 and 2025 to map the seagrass meadow here.







Yule Point is an intertidal seagrass meadow on a dynamic sand bank which has two Marine Monitoring Program (sites shown by red squares in maps above). The meadow is an important dugong grazing area with dugong feeding trails observed here.

The maps above show the seagrass species and biomass (weight) of seagrass in the meadow in 2024 and 2025.

- In 2024, 19 sites had seagrass (1–50% cover), forming a meadow of ~119 ha with a low biomass of ~0.07 $gDWm^{-2}$.
- In 2025, 25 sites had seagrass with cover up to 45% (plus 4 more at Four Mile Beach), and the meadow area increased to ~189 ha with biomass increasing substantially to ~1.7 $gDWm^{-2}$.
- The meadow was dominated by *Halodule uninervis* in both years, with *Halophila ovalis* also present.



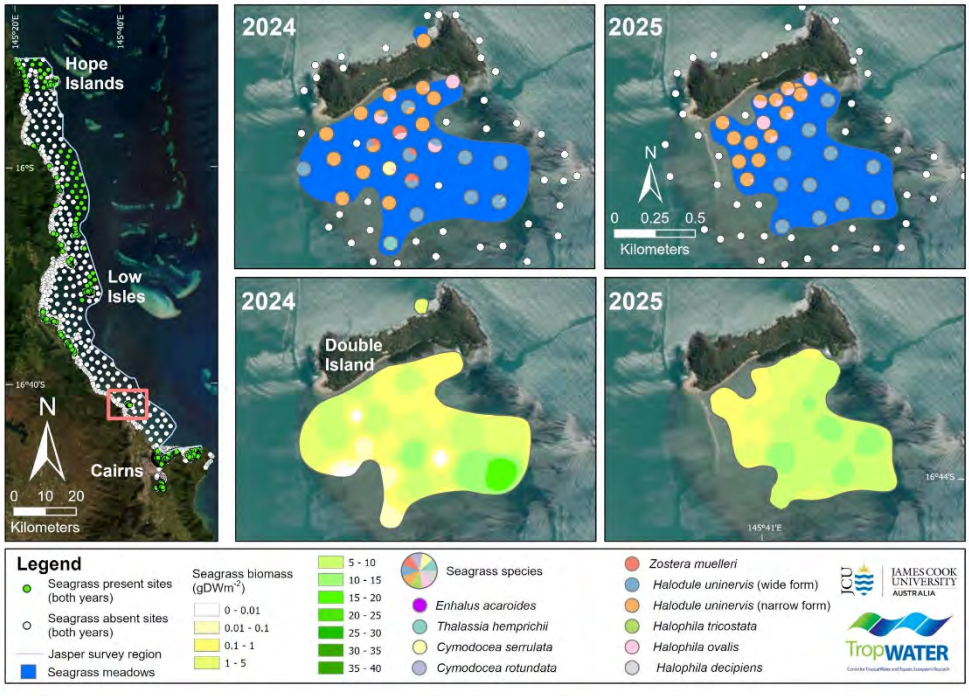
Changes in Yule Point seagrass

There are two Marine Monitoring Program (MMP) monitoring sites at Yule Point, this long-term data shows a reduction in seagrass cover of over 75% post TC Jasper. Both our data and MMP data show some recovery of this meadow in 2025 in terms of increases in meadow area and seagrass biomass/cover. MMP data shows patterns of decline and recovery in this meadow after previous cyclones.

Double Island

Seagrass surveyed in 2024 and 2025

Double Island was surveyed by boat and helicopter in partnership with Yirrganydji Rangers in both 2024 and 2025 to map the seagrass meadow here.







The reef flat at Double Island has a diverse mix of seagrass species. This is an important feeding ground for green turtles and habitat for fish species.

The maps above show the seagrass species and biomass (weight) of seagrass in the meadow in 2024 and 2025.

- In 2024, the meadow covered ~86 ha with a biomass of ~3.7 gDW/m^2 and 1–30% cover.
- In 2025, meadow area decreased to ~66 ha, but biomass increased to ~4.6 gDW/m^2 with cover up to 35%.
- The meadow was dominated by *Halodule uninervis* in both years, with *Thalassia hemprichii* and *Halophila ovalis* also present; *Zostera muelleri* and *Cymodocea serrulata* were additionally recorded in 2024.



Changes in Double Island seagrass

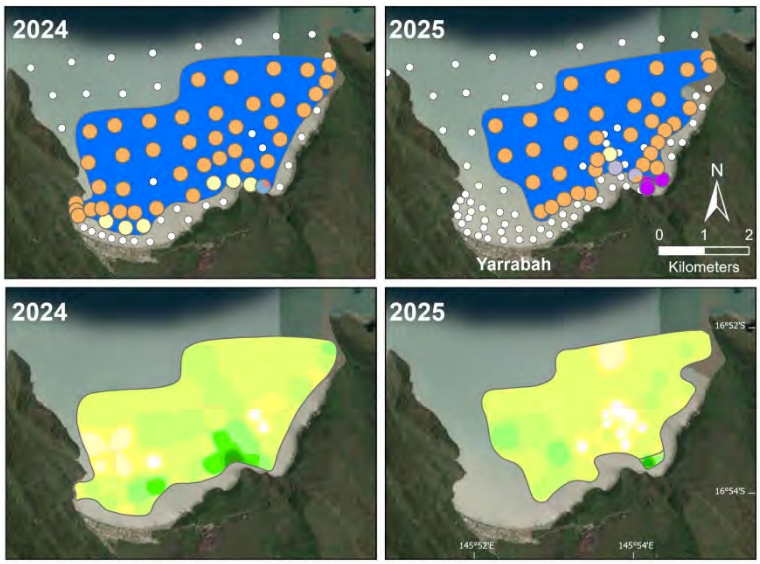
There was very little data from this meadow prior to TC Jasper which makes it challenging to understand changes. Our data shows seagrass biomass increased in 2025 which may indicate recovery. TropWATER and Yirrganydji Rangers will continue to monitor this meadow in 2026/27 and will work with Biopixel Oceans Foundation to understand food web links.

Mission Bay

Seagrass surveyed in 2024 and 2025

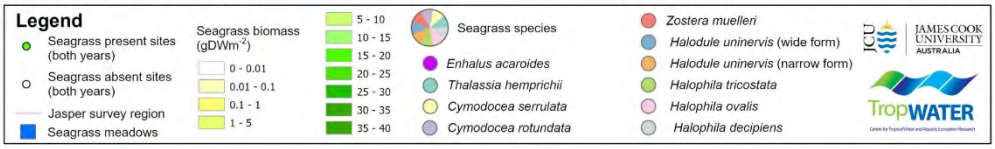
Mission Bay was surveyed by boat and helicopter in partnership with Gunggandji Rangers in both 2024 and 2025 to map the seagrass meadow here.











Mission Bay is an important seagrass meadow that supports turtles and dugong. It is one of two locations in the survey area where the seagrass *Enhalus acaroides* was found. The declines in this meadow show a similar pattern to those in found in the broader Cairns seagrass surveys.

The maps above show the seagrass species and biomass (weight) of seagrass in the meadow in 2024 and 2025.

- In 2024 the meadow covered an area of ~1,387 ha with percent cover ranging from 1 - 40%.
- In 2025 the meadow area was ~1,110 ha with percent cover ranging up to 20%.
- This meadow was dominated by *Halodule uninervis* (narrow), *Cymodocea serrulata*, *Cymodocea rotundata* and *Zostera muelleri* with *Enhalus acaroides* also present in 2025.

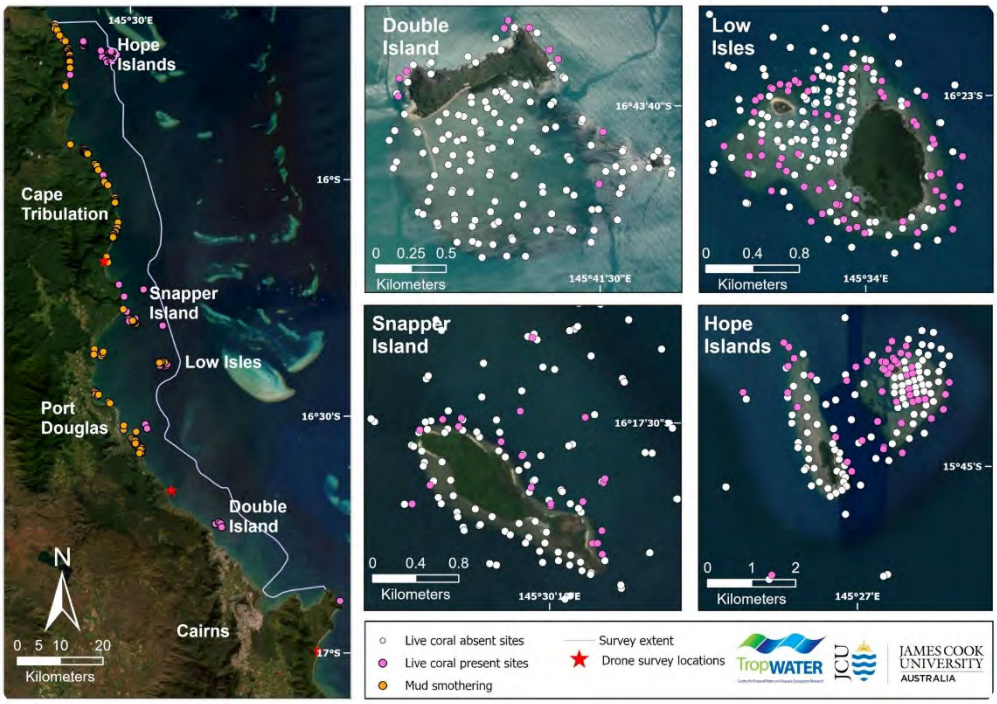


Changes in Mission Bay seagrass

There was very little data from this meadow prior to TC Jasper which makes it challenging to understand changes. However there was a decline in meadow biomass/percent cover and area between 2024 and 2025. This could be due to TC Jasper impacts and sediment resuspension in the region. TropWATER and Gunggandji Rangers will continue to monitor this meadow in 2026.

What did we find about inshore coral in the region?

Helicopter and boat surveys in 2024 and 2025

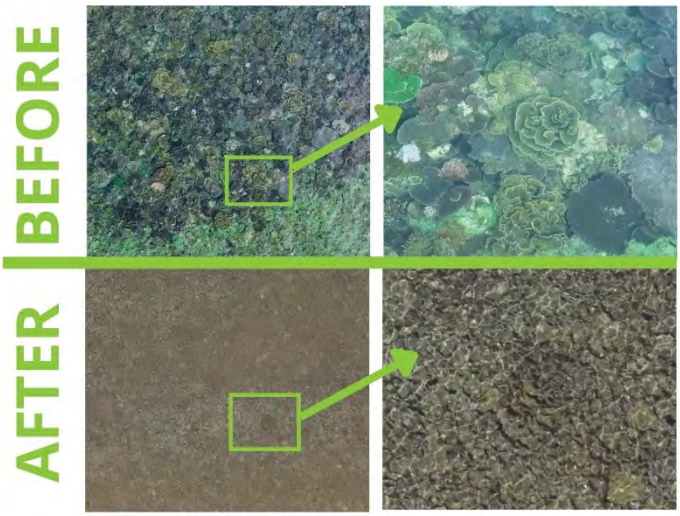


Helicopter and boat surveys found very little live coral on intertidal coastal reefs in the region. There was live coral subtidally largely at islands further offshore. There was limited information about live coral pre TC Jasper, with the exception of Snapper Island and Low Isles where Marine Monitoring Program (Reef Authority) data showed large declines post TC Jasper.

Flood impacts

Large amounts of fresh water and sediments were deposited onto fringing coastal reefs after TC Jasper. This mud has smothered some reefs and flood waters caused corals to die. The orange dots in the map above show where mud smothering was recorded, in many locations this was on reefs that did not have evidence of recent live coral so was unlikely to be due to TC Jasper. However off Cooya Beach (right photo) this damage appeared to be recent and due to the cyclone.





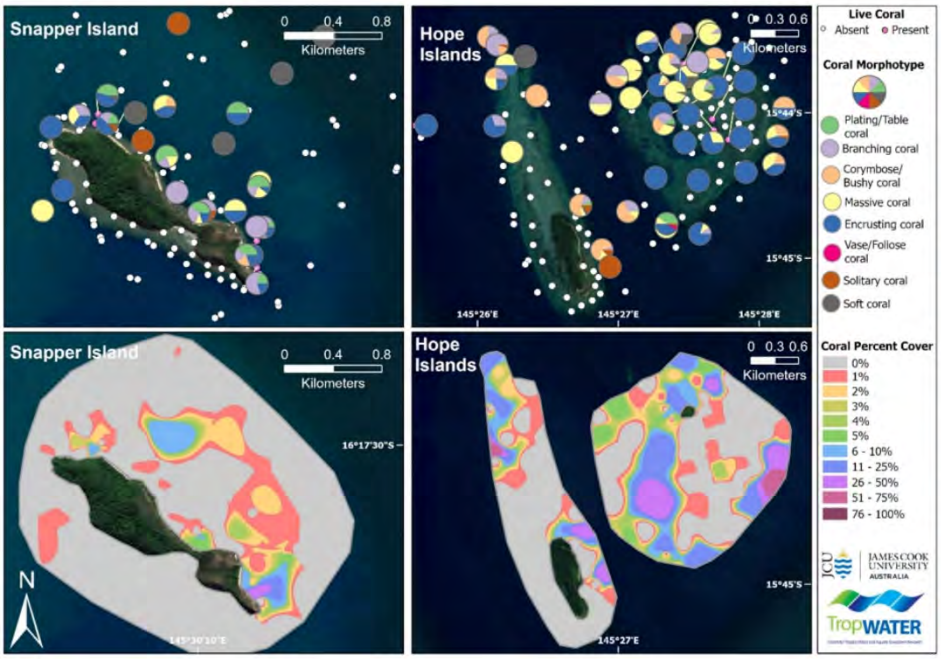
Drone surveys

Drone surveys were carried out by Johnny Gaskell at the three red starred locations in the map above. There was good drone imagery pre TC Jasper at all three locations showing very high live coral cover (74% - 87%). Post TC Jasper there was no coral found at any of these locations. The example on the left shows drone imagery from Unity reef off Wangetti Beach. This data is particularly valuable as it shows extensive live coral before TC Jasper and no live coral after TC Jasper.

GMYPPBC Rangers · Gunggandji Aboriginal Corporation · Yirrganydji Land and Sea Rangers · Jabalbina · Dabu Jajikal · JCU · TropWATER

Northern sector corals

Snapper and Hope Islands

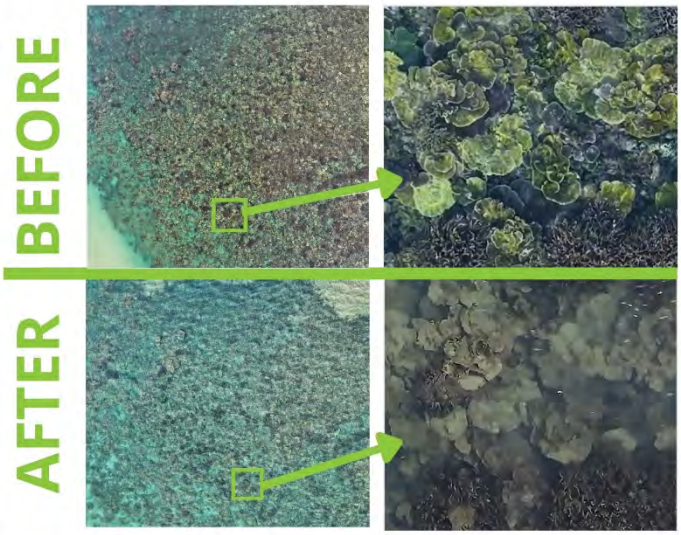


Boat surveys found live coral between 1-16m depth around Snapper and Hope Island. Average hard coral cover at Hope was 12.6% and at Snapper was 5.7%. Both sites had a diversity of coral morphotypes present. The southern side of Snapper Island was impacted by the flood plume from the Daintree and had much lower coral cover. These declines were also documented by MMP (Reef Authority) long-term monitoring data.

Flood impacts

Although there were large areas of damaged and mud smothered coral recorded along the coast in the northern sector (see map on previous page), this sediment was largely on top of reefs which were already eroded and appeared to have died some time ago (see right photo). In contrast, drone surveys (images below) showed evidence that Struck Island had also been impacted by flood waters, resulting in a dramatic decline in coral cover.



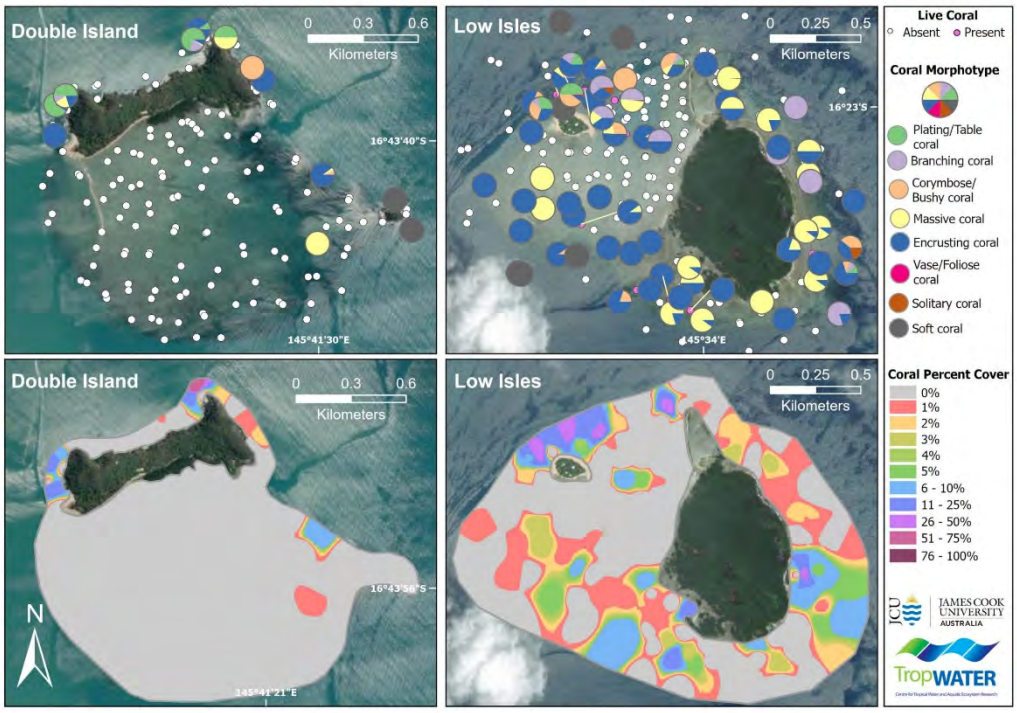


Drone surveys - Struck Island

Drone surveys were carried out by Johnny Gaskell at Struck Island off Thornton Beach (left) in this sector. This imagery showed very high coral cover (87%) prior to TC Jasper. After the cyclone there were no live corals found in the drone imagery, helicopter surveys only found one live coral here. This data is particularly valuable as it shows extensive live coral before TC Jasper and demonstrates the impact of flood waters.

Southern sector corals

Double Island and Low Isles



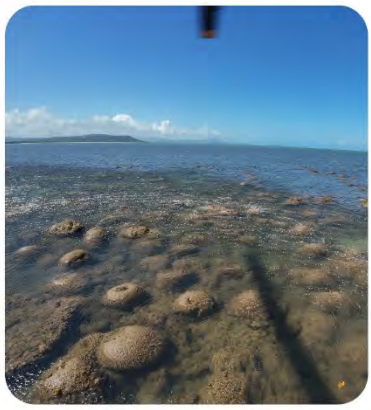
Helicopter and boat surveys found very little live coral on intertidal coastal reefs in the region. There was live coral subtidally largely at islands offshore. There was limited information about live coral pre TC Jasper, with the exception of Snapper Island and Low Isles where MMP (Reef Authority) data showed large declines post TC Jasper.

Flood impacts

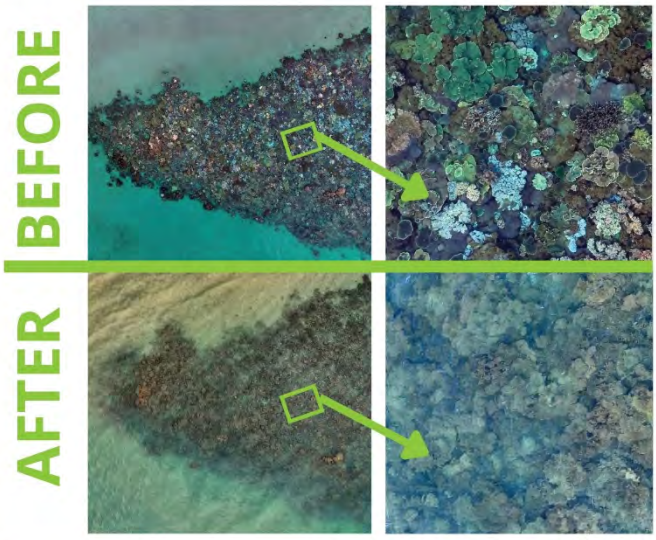
Large amounts of sediment laden floodwater impacted inshore coastal reefs after TC Jasper, this fresh water has caused corals to die and become smothered in mud. There was evidence of recently damaged reefs off Cooya Beach and drone imagery also showed associated coral loss after TC Jasper at both Unity Reef and Ganyjira Reef (see below and coral summary page).



Live coral at Low Isles



Mud smothered corals off Cooya Beach



Drone surveys

Drone surveys were carried out by Johnny Gaskell at Unity Reef off Wangetti Beach (see summary page) and Ganyjira off Yarrabah (left) in this sector. This imagery showed very high coral cover of 74% at both sites prior to TC Jasper. After the cyclone there were no live corals found in the drone imagery. This shows that the impacts of TC Jasper and associated flooding on inshore coral reefs extended further south than our survey area.



Conclusions

Overall summary

The key challenge in understanding how TC Jasper impacted coastal habitats was the lack of data prior to the cyclone for seagrasses and inshore corals. This shows the value of long-term monitoring such as MMP, Ports monitoring and Traditional Owner led projects.

What did we find?

Our data fills an important information gap and represents a new post cyclone baseline data set for the region. Although data from prior to TC Jasper was limited, we were able to understand how the cyclone affected coastal habitats in the region.

The impact of TC Jasper

The impacts of TC Jasper were driven by intense rainfall leading to flooding and landslides. The sediment laden floodwater caused severe damage to mangrove, seagrass and inshore coral reef habitats at a scale not previously documented for a single disturbance event on the Great Barrier Reef.

Mangroves were severely damaged by floodwaters and sediment depostition, particularly in the Daintree and Bloomfield Rivers. Aerial stressor scores were very high after the cyclone, but did decline in the second year of surveys.

Seagrass meadows had particularly limited data from the region prior to TC Jasper. Nine seagrass species were recorded across two survey years with over 20,000 ha of seagrass mapped in 2025. There was low density seagrass present even in the areas most affected by TC Jasper. Long-term monitoring showed declines in seagrass throughout the region.

Inshore coral reefs suffered losses in coral cover with some reefs that had 74 - 87% cover prior to TC Jasper damaged by flood waters and smothered by sediment with very little coral remaining. Snapper Island corals were particularly impacted by the flood plume whereas Low, Double and Hope Islands retained meaningful coral communities.

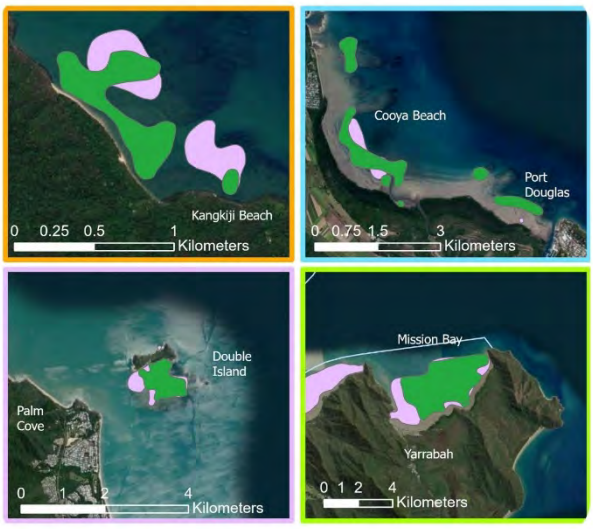
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National Environmental Science Program
Australian Government
Queensland Government



Next steps and recommendations

Next steps

Based on the data collected as part of this project we will be working with Traditional Owner Land & Sea Rangers to monitor seagrass meadows at Kangkiji Beach, Cooya Beach, Double Island and Mission Bay. This work will be connected to food web studies with our partners, Biopixel Oceans Foundation, to understand which species rely on these habitats.



Recommendations

- **Continued monitoring** to track recovery and detect declines. This will also allow managers to identify areas which may require management measures or interventions.
- **Testing techniques** for seagrass and mangrove restoration to be ready to intervene.
- **Invest in catchment scale sediment management** to reduce ongoing sediment input.



Seagrass restoration trials in Mourilyan Harbour with Mandubarra Rangers.

Acknowledgements

This research was jointly funded by the Commonwealth-State Disaster Recovery Funding Arrangements (DRFA) and the Australian Government under the National Environmental Science Program (NESP).

Fieldwork was conducted in partnership with Traditional Custodians from the region. We would like to thank the following Ranger groups for their contributions to this project, Jabalbina, Yirrganydji, Gunggandji, Gunggandji-Mandingalbay Yidinji and Mandubarra.

We would like to thank other partners who provided data for the project; Cape York Water Partnership, The Reef Authority's Marine Monitoring Program, Johnny Gaskell and Ports North.

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Dabu Jajikal

Jabalbina

National Environmental Science Program

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1. Introduction

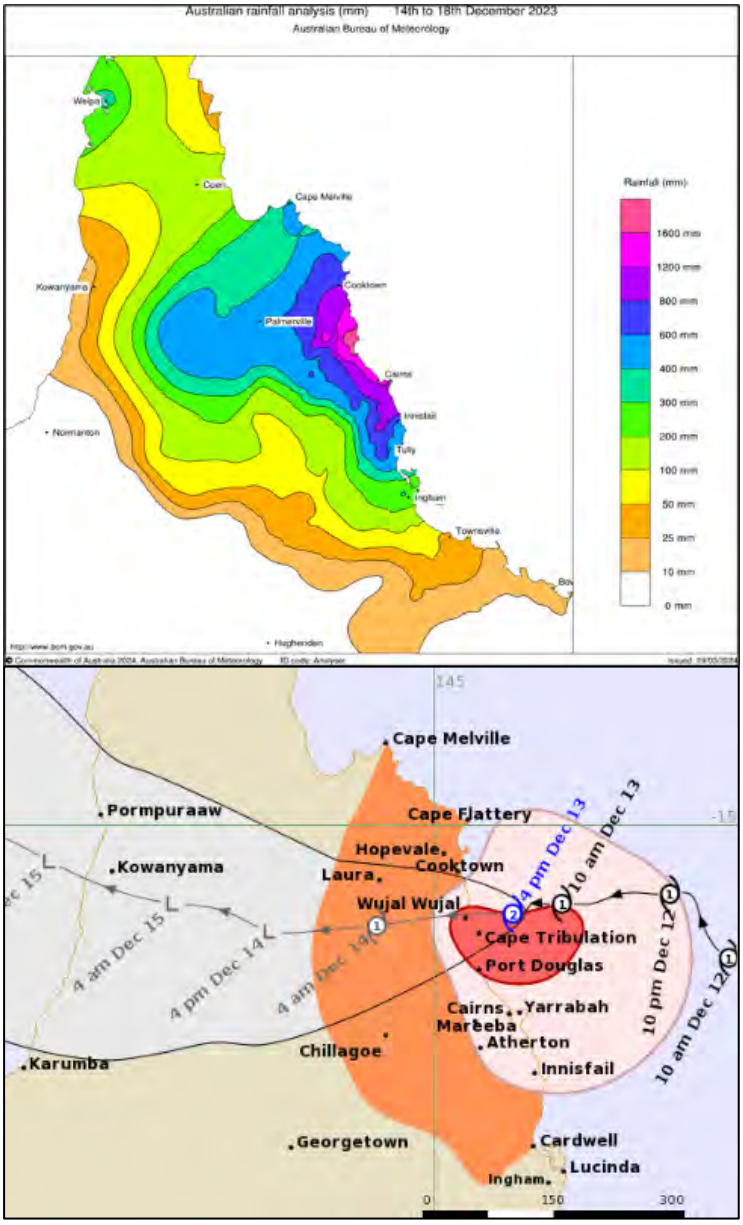


Figure 1: A) Five-day rainfall distribution ending 0900 AEST 18 December 2023. b) Forecast track map on 13 December 2023. Source Prasad et al. (2024)

Tropical Cyclone (TC) Jasper crossed the north Queensland coast as a Category 2 system close to Wujal Wujal (north of Port Douglas) on 13 December 2023 (Figure 1b). TC Jasper then weakened to a tropical low-pressure system and became slow moving over the Cape York Peninsula before dissipating on 17 December 2023 (Prasad et al., 2024). High winds accompanied landfall, with maximum wind speeds reaching 114 km/hr (Prasad et al., 2024). The sustained rainfall after TC Jasper crossed the coast broke many records, including the highest reliable 24-hour rain total ever recorded in Australia (975 mm from Black Mountain TM station located between Kuranda and Port Douglas) (Prasad et al., 2024). Five-day rainfall totals in the region were very high, particularly between Innisfail and Cooktown (Figure 1a). There were 34 stations in the region that recorded five-day totals of over 1,000 mm and three locations in the Daintree that recorded five-day rainfall totals over 2,000 mm (Prasad et al., 2024). Multiple community members in the Annan and Bloomfield catchments recorded rainfall totals exceeding 3,000 mm over the same period (Howley et al., 2024). This unprecedented rainfall caused widespread flooding in the region, with record-breaking flood levels in the Annan, Bloomfield, Barron and Daintree Rivers (Howley et al., 2024; Lim et al., 2024). Sediment loads were high in these floodwaters, and sediment-laden flood plumes extended to the outer Great Barrier Reef (GBR) (Howley et al., 2024).

Cyclones and flooding have been identified as key drivers of ecosystem change for marine habitats in the region. Wind, waves and storm surges can cause substantial physical damage by uprooting mangroves and seagrasses, and dislodging corals (Woolsey et al., 2012; Sippo et al., 2018; Mellin et al., 2019; Correia and Smee, 2022; Srinivasan et al., 2026). Extreme flooding can also cause significant damage to inshore marine ecosystems, for example, sedimentation in mangroves due to

flooding can limit oxygen supply to roots (Sippo et al., 2018), prolonged freshwater exposure and reduced water quality can drive declines in hard coral cover on inshore reefs on the GBR (Wegner et al., 2016), and reductions in underwater light availability associated with floodwaters can drive declines in seagrasses (Lambert et al., 2021; Shepherd et al., 2026). Collectively, these processes indicate that the ecological impacts of TC Jasper were driven not only by cyclone winds, but by the combined effects of prolonged flooding, freshwater exposure and sediment-laden flood plumes that affected coastal ecosystems for an extended period following landfall.

Understanding the impacts of TC Jasper on coastal habitats is important as extreme climatic events are projected to become more frequent and intense, increasing the likelihood of habitat loss, biodiversity decline and changes to ecosystem function (Wolff et al., 2018). Coastal ecosystems play a critical role in the health and resilience of the GBR. For example, mangrove root systems stabilise coastlines and trap sediments, preventing erosion and reducing the flow of nutrients and pollutants into coastal waters (Barbier, 2015; Reis et al., 2017; Sandilyan and Kathiresan, 2015). This is vital for maintaining water clarity and protecting nearby coral reefs and seagrass meadows. All these connected coastal ecosystems also serve as breeding and nursery grounds for many marine species, supporting food webs that extend from estuaries to offshore reef systems (Carrasquilla-Henao and Juanes, 2017). Their ecological connectivity enhances biodiversity and underpins commercial and cultural fisheries (Barbier, 2015; zu Ermgassen et al., 2020). Maintaining these ecosystems is therefore essential not only for coastal protection but also for sustaining the ecological function and integrity of the GBR, including maintaining feeding grounds for dugongs and green turtles, while adjacent coral reefs provide food, habitat and shelter for diverse marine communities. This project provides an opportunity to evaluate any potential ‘downstream’ or longer-term impacts of habitat change on key species such as dugongs and turtles.

Following TC Jasper, there was no regional-scale on-ground assessment of adjacent coastal habitats (seagrass, mangroves, inshore reefs) to assess the extent of impact that TC Jasper and its subsequent record flooding had on these habitats. The principal post-event field assessment was undertaken by Cape York Water Partnership in early 2024, and documented some of the most acute impacts in localised catchment areas near Cooktown and Bloomfield. These surveys recorded extensive landslides and debris flows, changes to rainforest creeks and burial of mangroves (Howley et al., 2024).

This project addresses the lack of regional-scale information on the impacts of TC Jasper on inshore coastal habitats through a combination of field surveys, drone imagery and satellite remote sensing. Where possible, observations were compared with recent historical datasets.

Specifically, these assessments aimed to:

- Identify the extent and location of mangrove damage caused by TC Jasper and its associated flooding, using helicopter surveys to identify stressors and their severity, and Sentinel-2 satellite imagery to quantify the extent of mangrove loss and degradation.
- Map the extent and condition of seagrass and inshore coral habitats using boat-based and aerial habitat surveys. Where possible, survey findings are compared to pre-TC Jasper datasets, noting the paucity of information on these ecosystems in this region.
- Assess changes in coral condition at selected inshore reefs using detailed pre- and post-TC Jasper drone imagery.

The survey results are intended to inform local management responses, support recovery of inshore coastal ecosystems and identify priority areas where future rehabilitation or restoration may be appropriate. This report also provides recommendations developed in consultation with local Traditional Custodians for ongoing monitoring, opportunities to accelerate recovery, rehabilitation and restoration, and actions to reduce further habitat loss.

This research was jointly funded by the Commonwealth-State Disaster Recovery Funding Arrangements (DRFA) and the Australian Government under the National Environmental Science Program (NESP). All work was undertaken in collaboration with Traditional Custodians across the region, who contributed to project planning, participated in fieldwork and were involved in the interpretation of results, reporting and discussions on future monitoring and management priorities.

Together, these surveys represent the first coordinated regional assessment of post-TC Jasper condition across inshore coastal habitats between Cooktown and Cairns and provide a foundation for evaluating ecosystem recovery, resilience and future responses to extreme weather events.

2. Methods

Field surveys were undertaken between Yarrabah (near Cairns) and the Hope Islands, with additional in-kind datasets extending the spatial coverage south to Kurrimine Beach (Figure 2). Field surveys were focused on inshore coastal benthic habitats from the mangroves to within five nautical miles of the coastline, inside the 'GBR Waterbodies Open Coastal Zone'. Low Isles was also included in the survey footprint following local reports of TC Jasper impacts on coral and seagrass communities. Methods are presented separately for mangrove assessments and marine benthic habitat surveys (seagrass and coral).

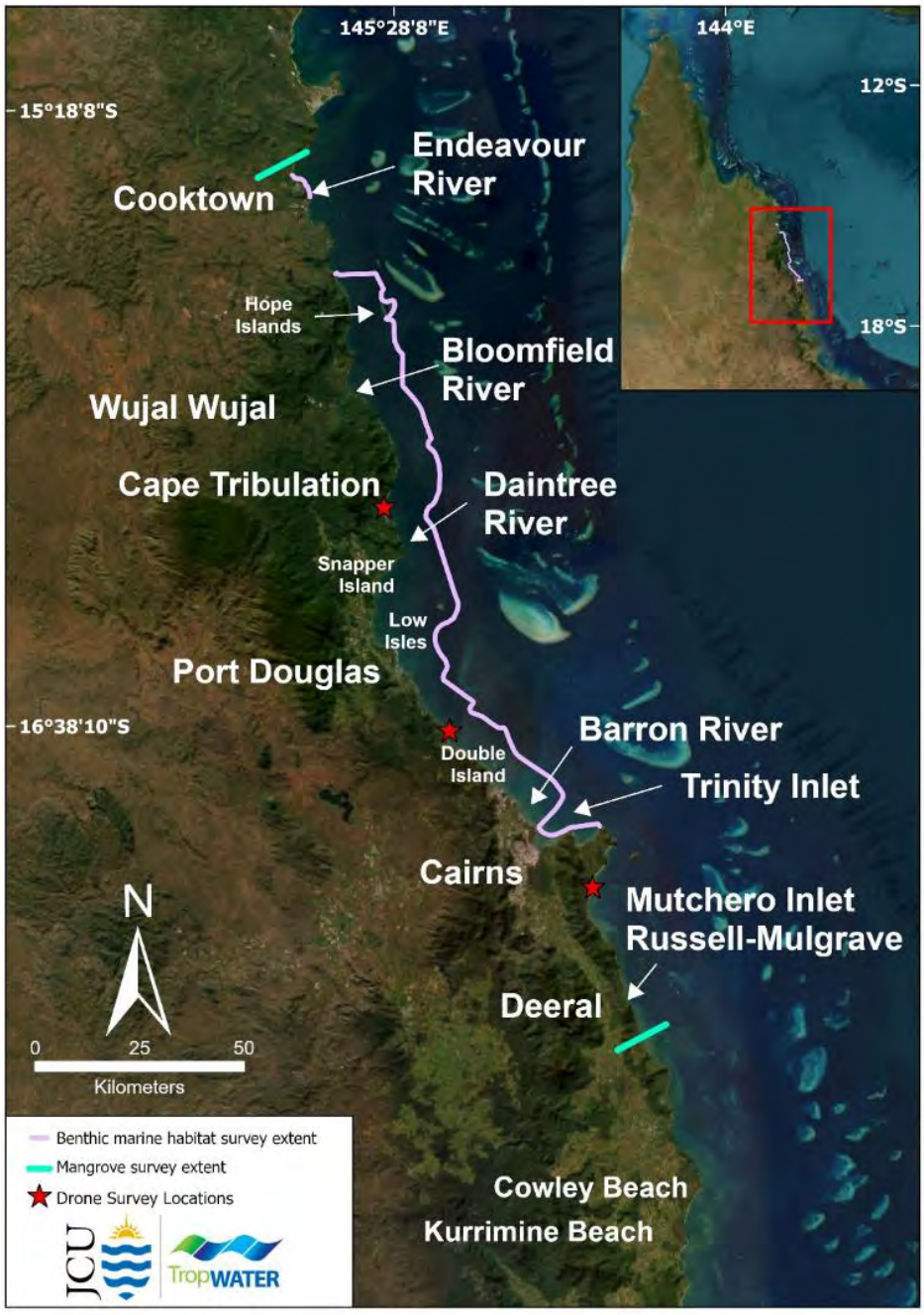


Figure 2: Survey region for benthic marine habitats with drone survey locations shown. Mangrove assessments carried out from the Mutchero Inlet to the Bloomfield River. In-kind seagrass data also provided down to Cowley and Kurrimine Beach.

Mangrove surveys

Field surveys, satellite remote sensing, and sediment transects were combined to assess mangrove condition in the Daintree and Bloomfield River systems following TC Jasper. Mangrove habitats are affected by a range of environmental stressors operating across different spatial scales and time periods, which can be grouped into 1) those related to direct human activities and 2) those related to climate and climate change, and can be identified and quantified through observable indicators on the ground (Duke, 2014; Duke et al., 2019). Aerial coastline surveys were conducted in October 2024 from Deeral to Cooktown to assess TC Jasper impacts across the broader survey region (Figure 2), with a follow-up survey in October 2025 focused on the Daintree and Bloomfield Rivers where damage was most severe, to assess recovery. Satellite imagery was used to quantify changes in mangrove extent and vegetation condition relative to the 2023 pre-cyclone baseline, building on comparable surveys undertaken in 2017 and 2024. Sediment deposition transects were established in October 2025 to investigate root burial as a potential driver of mangrove mortality, following observations of suspected sediment impacts during the 2024 survey.

Coastline surveys

Mangroves are influenced by a range of environmental stressors that can lead to visible impacts, such as dieback or changes in coverage. These stressors operate across different spatial scales and time periods and can be grouped into 1) those related to direct human activities, and 2) those related to climate and climate change. By observing and scoring established visual indicators linked to these drivers, the nature and severity of change can be rapidly assessed in the field.

For both surveys, continuous georeferenced photographs (~20-30% overlap) were captured from a Robinson 44 helicopter flying at ~30 m altitude and ~100 m from the shoreline at speeds of 70-100 km/h, providing a manoeuvrable platform for identifying and scoring shoreline habitat condition indicators (Table 1 and

Table 2) linked to threats such as cyclones, rising temperatures, sea-level rise, pollution, and reclamation. This approach has been applied extensively along the northern Australian coastline from Gladstone to Broome (e.g., Canning & Duke, 2023; Duke & Mackenzie, 2018; Duke et al, 2010).

For each system, a suite of human-related and climate-natural stressors were rated in terms of their extent and severity across the surveyed coastline (Figure 3; Table 1 and

Table 2). The product of these two ratings, normalised to a scale of 0 to 5, yielded an overall stressor score for each indicator. Summing scores within each category provided an aggregate human-related and climate-natural index for each system, enabling comparison between the 2024 and 2025 surveys as well as an earlier survey conducted in 2017.

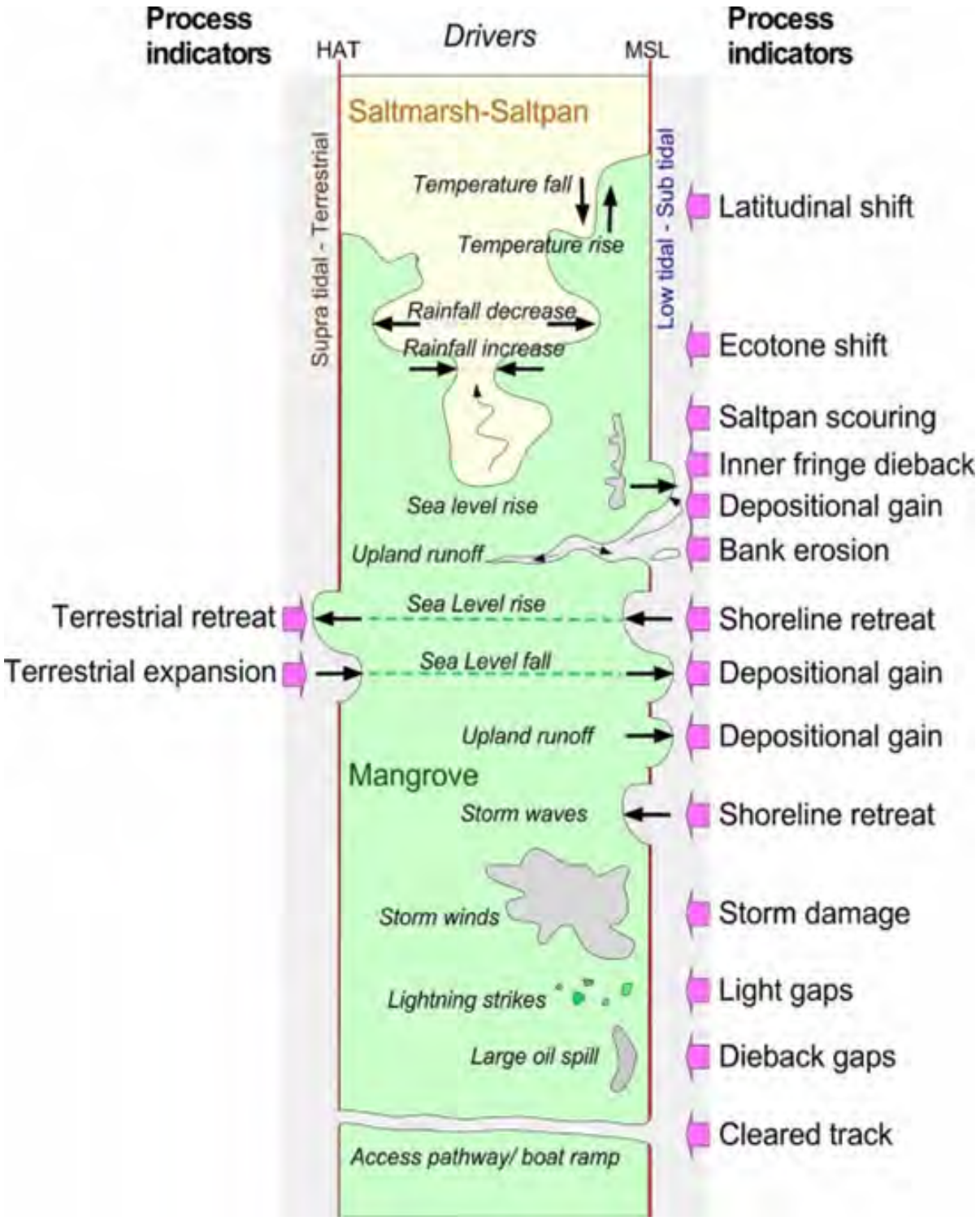


Figure 3: An illustrative schematic of tidal wetland habitat (shaded green and pale yellow) and degraded habitat (grey shading) showing process-response indicators associated with respective drivers (pink arrows) acting at specific ecotone locations across the tidal profile between land (left) and sea (right).

Table 1: Human-derived stressors (except climate change) and climate-natural stressors (including climate change) and visual indicators appraised during coastal surveys.

Category	Stressor	Visual indicator
Human-derived	Structure Loss	The presence of constructed features such as rock walls, wharves, ramps, and roads.
	Direct Loss	The absence of trees due to direct removal, including clearing or landfill.
	Altered Hydrology	The alteration of tidal hydrology due to the presence of tidal bunds, drains, or impounded areas.
	Encroachment	The absence of a buffer between coastal ecosystems and human settlement or loss due to conversion along tributaries for human settlement.
	Access Tracks	The presence of observable damage due to vehicle and foot tracks.
	Stock Impact	Observable impact from the direct presence, or track indication of recent presence, of livestock such as cattle, horses, and goats.
	Feral Pig Damage	Observable impact from the direct presence of feral pigs or indication of recent presence including tracks, wallows and diggings.
	Pollutant Impact	The presence of oil spill, scum, a dumpsite, or dieback from a known pollutant including herbicide runoff.
	Nutrient Excess	The presence of pervasive algal growth or enhanced vegetation growth relative to neighbouring areas.
	Fire Scorch	The presence of fire damage to vegetation.
	Weed Smother	The presence of weeds and weed smothering.
Climate-natural	Storm Damage	The presence of broken trees and forest damage from high winds, a cyclone track may be visible.
	Shore Erosion	The presence of fallen trees along the shoreline and steep banks where land has eroded.
	Root Burial	The presence of roots covered in sediment or dieback with signs of recent sediment deposition.
	Inner Fringe Collapse	As sea level rises, the seaward mangrove fringe becomes excessively submerged, or drowns, causing dieback known as ‘inner fringe collapse’, often observed as canopy gaps or irregular dieback.

	Channel Bank Erosion	The presence of fallen trees along tidal channels and steep channel banks where land has eroded.
	Pan Scouring	The presence of sheet erosion in salt pans or missing saltmarshes.
	Ecotone Negative Shift	The presence of lines and linear patches of dead and stressed mangrove vegetation along upper saltmarsh transition zones within tidal wetlands.
	Ecotone Positive Shift	The presence of lines and linear patches of young mangrove vegetation along transition zones within tidal wetlands and encroachment upon fringing terrestrial ecosystem.
	Depositional Gain	The presence of young trees on recently expanded banks and edges where sediment has deposited.
	Terrestrial Retreat	As sea level rises, terrestrial vegetation parallel to the landward mangrove fringe becomes excessively submerged, or inundated with salt, causing back edge dieback known as 'terrestrial retreat', and often accompanied by scouring erosion.
	Light Gaps	A circular gap in canopy cover, may show dieback or incineration, from lightning strikes.
	Altered Hydrology.	Dead or dying trees accompanied with a naturally arising impoundment.

Table 2: Estuarine survey image point assessment criteria and classification for tidal wetland habitat and environmental condition descriptors.

Extent of impact on tidal wetland area	The extent of tidal wetlands impacted determined by the proportional area showing impact	Impact extent 0. Non-mangrove 1. 1 – 10%. Relatively unaffected. 2. 10 – 30% – Minor. 3. 30% – 60% – Moderate. 4.60% – 90% – Severe. 5. >90% – Extreme.	*Extent score* – extent of impact (% of coastline length) where tidal wetlands occur.
Severity of impact on tidal wetland area	The severity of tidal wetlands impacted as determined by the degradation state observed.	Impact severity 0. No impact 1. Minimal – present but no observable effect 2. Minor – recovery within less than one year 3. Moderate – recovery over 1–2 years 4. Major – recovery over 2–10 years 5. Severe – recovery unlikely – collapse/replace	*Severity score* – severity of impact to tidal wetland.

Satellite imaging change detection

This study aimed to quantify changes in mangrove extent and condition across the Daintree and Bloomfield Rivers following TC Jasper, using a time series of Sentinel-2 satellite imagery. Sentinel-2 surface reflectance imagery was processed via Google Earth Engine (GEE) using a Python-based workflow to prepare and export imagery, with imagery then processed further using an R-based workflow. In GEE, Level 2A surface reflectance imagery was cloud-masked using the QA60 band, retaining only pixels free of cloud and cirrus contamination, and filtered to scenes with less than 20% cloud cover. Annual dry-season composites (June to September) were produced for 2023, 2024 and 2025 using median pixel values. Eight spectral indices were calculated per composite alongside raw Sentinel-2 bands (Table 3), and elevation data from the SRTM DEM was included as a covariate. An elevation mask restricted classification to pixels between 10 and 20 m to exclude upland false positives. The performance of spectral indices for mangrove classification varies considerably across geographic regions owing to differences in species composition, tidal regime, and background land cover, meaning no single index reliably transfers between sites. Multiple indices were therefore calculated and compared to identify the most appropriate classifier for this region.

Classifier selection was based on 5-fold cross-validation with Cohen's Kappa as the performance metric, evaluated against 800 georeferenced reference points manually assigned across the Daintree and Bloomfield regions, with 400 mangrove and 400 non-mangrove points distributed to achieve broad spatial coverage. Points were selected by visual interpretation of 2020 high-resolution aerial imagery in Google Earth, representing pre-impact conditions, and validated against a 2020 Sentinel-2 composite. Candidate approaches fell into two categories. First, single-index threshold classifiers were evaluated for each spectral index individually, assessing the ability of each index to discriminate mangrove from non-mangrove pixels. Second, Random Forest models (100 trees) were evaluated using either spectral indices or raw Sentinel-2 bands as predictors, each supplemented with the SRTM DEM. The best-performing approach was then applied across all years to produce annual mangrove extent maps.

Classified rasters exported from GEE were further filtered in R v4.4.3 using the terra package (Hijmans, 2026; R Core Team, 2025) to retain only pixels with NDVI greater than 0.6 and EVI greater than 0.2, reducing commission errors in the final extent maps. Mangrove area was calculated per region by summing qualifying pixels and converting to hectares. Change detection was performed relative to a 2023 pre-cyclone baseline, with each pixel classified as one of four categories: non-mangrove, gained, maintained, or lost. NDVI percent change relative to 2023 was also calculated across all pixels classified as mangrove in either year, providing a continuous indicator of vegetation condition change.

Identifying potential rehabilitation sites

Aerial survey observations and satellite-derived change detection maps were combined to manually delineate discrete parcels of mangrove loss or damage across the Daintree and Bloomfield Rivers as potential rehabilitation targets. Mangroves are effective natural colonisers and dispersers, and damaged areas often show strong natural recovery where hydrological and sediment conditions remain suitable. Allowing one to two years post-disturbance before committing to active intervention therefore allows areas of natural recovery to become apparent, reducing the risk of unnecessary intervention and focusing resources on areas where unaided recovery is unlikely. Mapping was consequently focused on areas showing little or no recovery in the October 2025 aerial and satellite surveys, approximately two years after TC Jasper. For each parcel, the primary stressor was assigned from aerial survey indicator scores where this could be determined with confidence or flagged for further on-ground assessment where the cause of damage remained unclear.

Sediment deposition survey

To investigate the relationship between sediment deposition and mangrove mortality, on the 2nd of October 2025, two 50 m transects were established at a dead patch in the south arm of the Daintree River, each crossing the interface between dead and living mangrove (Figure 4). Transects were positioned so that the first 25 m fell within the dead stand and the remaining 25 m within the adjacent living stand, allowing direct comparison of conditions either side of the mortality boundary.

Sediment deposition depth was measured at 10 m intervals along each transect using a graduated rod inserted to the pre-disturbance sediment surface, identified by a distinct stratigraphic boundary between recently deposited material and the underlying substrate. All mangrove trees within 2 m of the transect tape were recorded, with height, stem diameter measured between the highest prop root and the first branch, and living or dead status noted for each individual. The proportion of living seedlings relative to total seedling count was also recorded within the same 2 m buffer, providing an indication of recruitment potential across the deposition gradient.

Table 3: Spectral indices calculated from Sentinel-2 imagery for mangrove classification.

Index	Description	Formula	Reference
NDVI Normalised Difference Vegetation Index	Normalised ratio of the NIR and Red bands.	$NDVI = \frac{NIR - Red}{NIR + Red}$	Rouse et al (1973)
EVI Enhanced Vegetation Index	Reduces influence of atmospheric conditions and decouples canopy background signal from vegetation.	$EVI = 2.5 \times \frac{NIR - Red}{NIR + 6 \cdot Red - 7.5 \cdot Blue + 1}$	Liu & Huete (1995)
NDWI Normalised Difference Water Index	Normalised ratio of the Green and NIR bands, used to identify areas of water.	$NDWI = \frac{Green - NIR}{Green + NIR}$	McFeeters (1996)
MNDWI Modified Normalised Difference Water Index	Normalised ratio of the Green and SWIR bands, used to identify areas of water.	$MNDWI = \frac{Green - SWIR1}{Green + SWIR1}$	Xu (2006)
NDMI Normalised Difference Moisture Index	Normalised ratio of the NIR and SWIR bands.	$NDMI = \frac{NIR - SWIR}{NIR + SWIR}$	Gao (1996)
MVI Mangrove Vegetation Index	Contrasts NIR and green reflectance relative to SWIR; sensitive to mangrove canopy structure.	$MVI = \frac{\lvert NIR - Green \rvert}{\lvert SWIR - Green \rvert}$	Baloloy et al (2020)
CMRI Combined Mangrove Recognition Index	Combines NDVI and NDWI to enhance mangrove discrimination.	$CMRI = NDVI - NDWI$	Gupta et al (2018)
MMRI Modular Mangrove Recognition Index	Combines NDVI and MNDWI to enhance mangrove cover contrast.	$MMRI = \frac{\lvert MNDWI \rvert - \lvert NDVI \rvert}{\lvert MNDWI \rvert + \lvert NDVI \rvert}$	Diniz et al (2019)

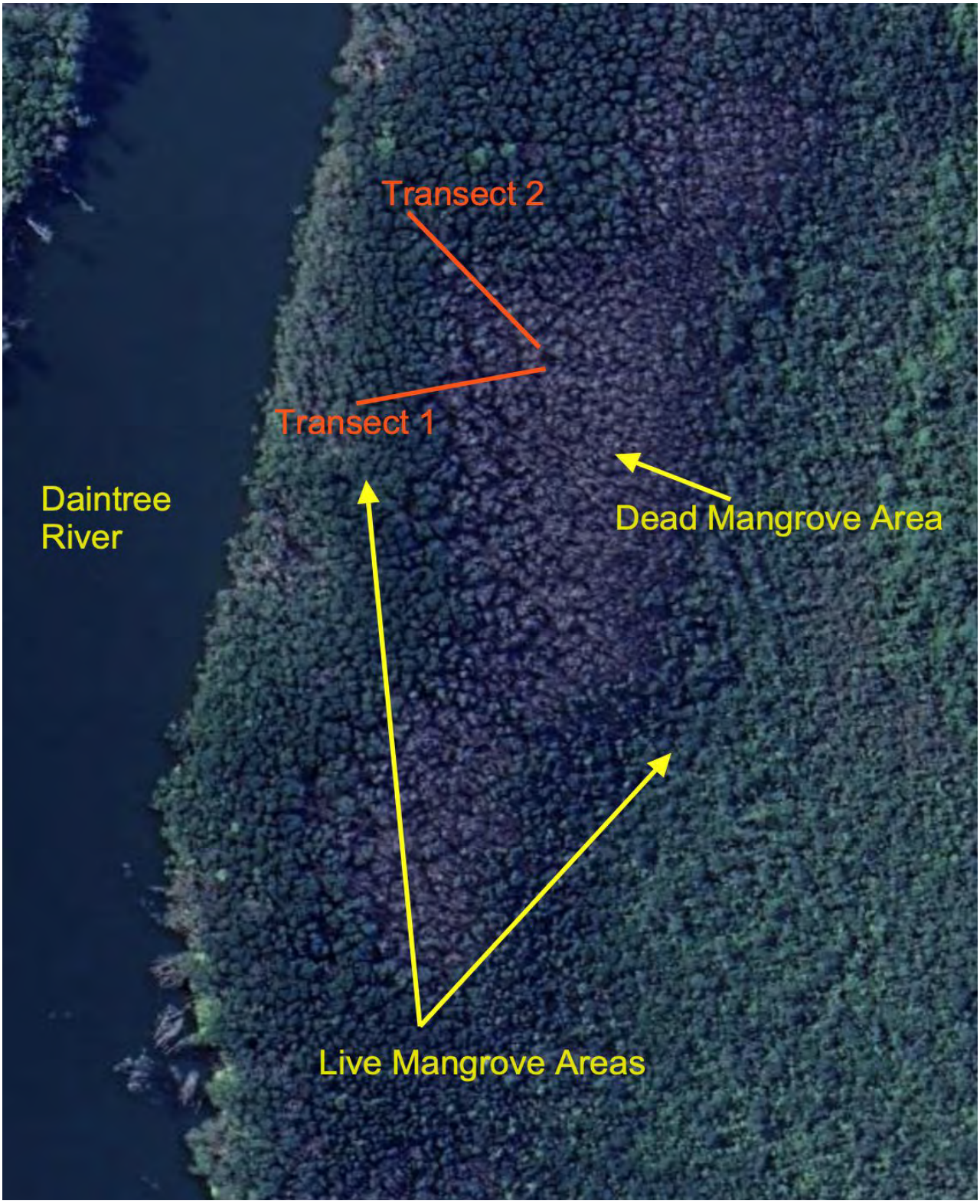


Figure 4: Positions of two transects at a dead mangrove patch in the Daintree River south arm (Transect 1 starting location: -16.28071, 145.41475, EPGS: 4326) to assess deposited sediment depth and tree status.

Benthic marine habitat surveys

Benthic habitat surveys targeting algae, coral and seagrass were carried out between Yarrabah in the south and Cooktown in the north, with additional in-kind data south to Kurrimine Beach using the same methodology. These surveys were focused on inshore coastal habitats from the mangroves to within five nautical miles of the coastline, inside the 'GBR Waterbodies Open Coastal Zone'. In addition to this, we also surveyed Low Isles due to reported impacts on corals after TC Jasper.

Benthic surveys to record the types of habitats present (i.e. seagrass, coral etc.) and the condition of these habitats were carried out from a helicopter at spring low tide, and deeper areas were surveyed from a boat using an underwater real-time camera. A waypoint was recorded at each site and an assessment of the percent cover of all benthic communities (hard coral, soft coral, algae, seagrass, sponges, oysters, etc.) and their condition was recorded.

Sediment type was recorded with the dominant sediment type listed first (e.g. sand, mud, rock, shell, rubble, reef, gravel). The percent of sediment with no benthic habitat cover at the site was recorded, and the percent cover of rubble was also recorded separately.

Helicopter surveys recorded percent cover of benthic habitats at a radius of 15 m from the helicopter and subtidal camera sites used three camera drops at each site to determine an overall percent cover for benthic habitats.

Algae

Total algae cover was further broken down into main functional groups; erect macroalgae, erect calcareous algae, filamentous algae, turf mat and encrusting algae. Where rubble was present and covered in algae, this was recorded as rubble and a note made of the algae cover.

Hard coral

Hard coral cover was further broken down into: plating coral, branching coral, corymbose coral, massive coral, encrusting coral, vase corals and solitary corals. Information about coral condition was also recorded, such as damage due to crown-of-thorns starfish, disease, smothering and bleaching. Where reefs were dead and smothered in mud, this was also recorded as mud smothering.

Seagrass

Where seagrass was observed, overall percent cover was recorded at the site. Three 0.25 m^2 quadrats were also haphazardly placed at the site and both percent cover and a visual estimate of seagrass biomass (as described by Kirkman 1978 and Mellors 1991) were recorded for each 0.25m^2 quadrat. Observer measurements are calibrated against biomass values from quadrats harvested and dried to determine mean above-ground biomass in grams dry weight per square metre (g DW m^{-2}) at each site. The percentage contribution of each seagrass species to total biomass within each quadrat also was recorded. For subtidal sites, a Van Veen grab was used to confirm species of seagrass present.

Enhalus acoroides presence: The dry weight biomass for *E. acoroides* is substantially higher than other tropical seagrass species and dominates the average above-ground biomass calculations of a meadow where it is present. Because of this, *E. acoroides*-dominated areas of a seagrass meadow get partitioned from the main meadow extent and treated as a separate meadow for analysis (see section 3.3.2 – Mission Bay as an example). Where isolated patches of *E. acoroides* occur within a larger mapped meadow, they are excluded when calculating the meadow average biomass and species composition metrics to be able to track the dynamics of the morphologically smaller dominant species in the meadow.

Drone surveys

Drone mapping for reef top habitats was carried out at three sites in the survey area; Struck Island (Thornton Beach), Unity Reef (Wangetti Beach) and Ganyjira Reef (Yarrabah) (Figure 5). Low-level, high resolution drone imagery was collected from these reefs before and after TC Jasper. To analyse these images, the drone photographs were divided into equal quadrats. Quadrat size depended on image resolution and zoom level of individual images. Quadrat size was minimised while maintaining sufficient image resolution for reliable coral identification. Quadrats with significant sun glare were excluded, as were quadrats which did not contain more than 80% reef flat. These quadrats were uploaded to CoralNet for analysis using a 16-point intercept analysis with a label set which distinguishes various morphotypes (Table 8). The post-TC Jasper images were not of sufficient resolution to analyse in this way; we were only able to make an overall assessment of percent cover at the site.

Habitat mapping and geographical information system

All survey data were entered into a GIS platform for presentation of benthic habitat spatial data. In the field, waypoints were marked in Arc Field Maps, and data were analysed using ArcPro® 3.6.4.

Site layer

The site (point) layer contains data collected at each site, including:

- Site number.
- Temporal details – Survey date and time.
- Spatial details – Latitude and longitude.
- Habitat information – Sediment type; seagrass information including presence/absence, above-ground biomass (total and for each species) and biomass standard error (SE); site benthic cover (percent cover of algae, seagrass, benthic macro-invertebrates, open substrate).
- Sampling method and any relevant comments.

Seagrass meadow layer

The seagrass meadow (polygon) layer provides summary information for all sites within each meadow, including:

- Meadow ID number – A unique number assigned to each meadow to allow comparisons among surveys.
- Temporal details – Survey date.
- Habitat information – Mean meadow biomass + standard error (SE), meadow area (hectares) + reliability estimate (R), number of sites within the meadow, seagrass species present, meadow density and community type and meadow landscape category.
- Sampling method and any relevant comments.

Seagrass meadow boundaries were constructed using GPS-marked meadow boundaries, seagrass presence/absence site data, field notes, and aerial photographs taken during helicopter surveys. Meadow area was determined using the calculate geometry function in ArcPro®. The meadow boundary was assigned a mapping precision estimate (in metres) based on mapping methodology used for that meadow. Meadows were drawn around single dots, either using the surrounding sites where seagrass was absent as a guide to the size of the meadow, or other notes taken on the survey. For intertidal sites with limited information about the size of the seagrass meadow, a diameter of 100 m was used for the meadows. Mapping precision was variable depending on the survey method and distribution of data points. For helicopter surveys where meadows were a single site, this was 5–10 m. For helicopter survey sites within a meadow, this was 20–50 m. For boat surveys with only one data point, this was 20–50 m. For meadows where data points were spread out, this was 100 m; for sites in deeper water with a single data point, this was 200 m. The mapping precision estimate was used to calculate a buffer around each meadow representing error; the area of this buffer is expressed as a meadow reliability estimate (R) in hectares.

Comparisons with historical data

Mangrove change analysis data was compared with previous helicopter surveys carried out in this region in 2017 and 2023.

There was limited available data for corals and seagrasses. Existing seagrass data from 1984–2014 has been synthesised by Carter et al. (2016) and is summarised in Figure 10. Long-term monitoring data was obtained from the Reef Authority's Marine Monitoring Program (MMP) for seagrass and inshore coral reefs in the region, and this is summarised in Leahy et al. (2026). Detailed seagrass methods are available in McKenzie et al. (2026) and detailed coral methods in Thompson et al. (2026). Long-term monitoring is also carried out in the Port of Cairns with methods described in Scott et al. (2026).

In-kind data on seagrass presence before TC Jasper from Gunggandji-Mandingalbay Yidinji Peoples Prescribed Body Corporate (GMYPPBC) and Mandubarra Aboriginal Land & Sea Incorporated was collected using methods consistent with those used in this study.

Together, these complementary datasets provide multiple independent lines of evidence for assessing habitat condition and interpreting the impacts of TC Jasper across the survey region.

3. Results

Overview of field activities

Following Tropical Cyclone Jasper in December 2023, the first year of on-ground surveys was conducted between October 2024 and January 2025. The second year of helicopter surveys was undertaken between October 2025 and December 2025. Targeted drone surveys were undertaken pre-TC Jasper in April and November 2022 and post-TC Jasper in August and October 2024, and January 2025. Additional boat-based assessments were carried out for mangroves in the Daintree River system to assess areas not easily accessible during aerial work in October 2025.

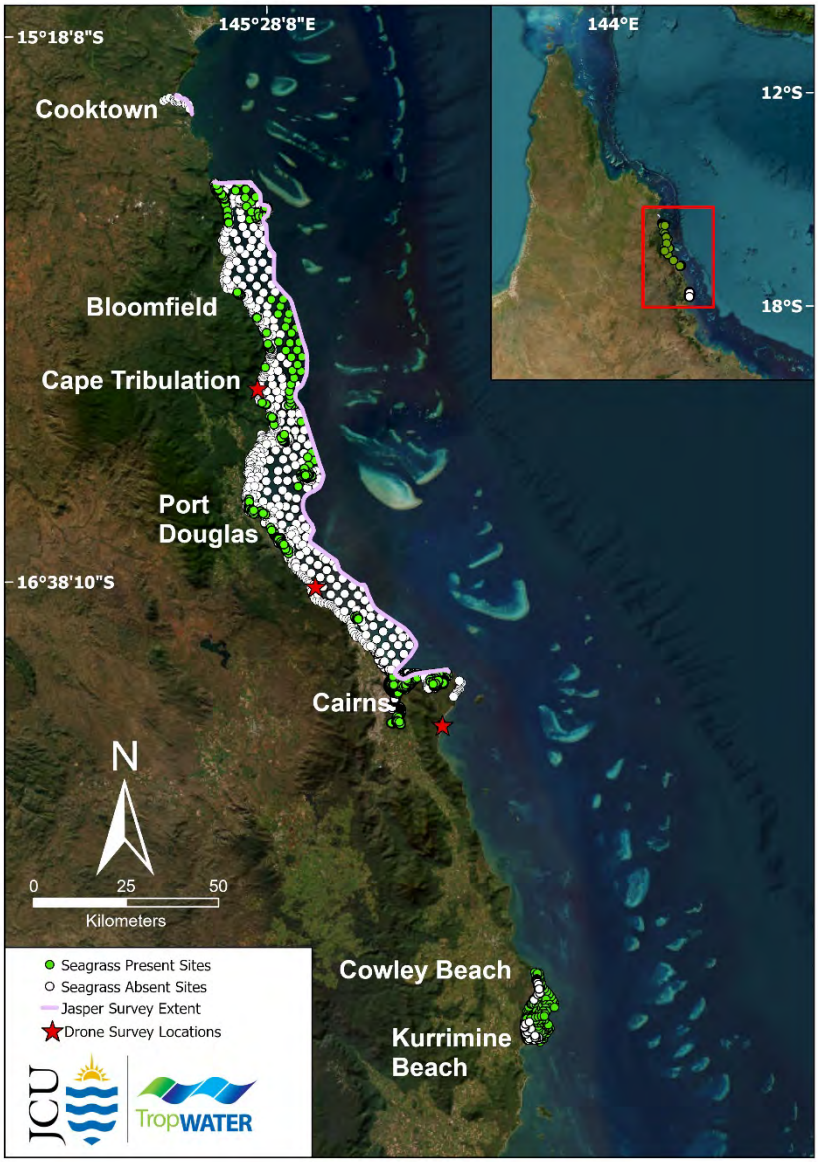


Figure 5: Data from the region collected in 2024 and 2025 showing seagrass presence and absence. Data within the TC Jasper survey region was collected as part of this project. Additional data are provided by Cape York Water Partnership, Gunggandji-Mandingalbay Yidinji Peoples Prescribed Body Corporate, Mandubarra Aboriginal Land & Sea Incorporated and Ports North.

In-kind seagrass data from both pre- and post-TC Jasper periods was provided by partners Gunggandji-Mandingalbay Yidinji Peoples Prescribed Body Corporate (GMYPPBC) and Mandubarra Aboriginal Land & Sea Incorporated. These in-kind datasets extend regional coverage and provide a broader snapshot of seagrass presence across the wider study region.

The coastline between Yarrabah and Cooktown was surveyed, with the exception of the Yuku Baja TUMRA, as we were unable to obtain permission from Traditional Custodians for this project.

A total of 2,727 habitat assessment sites were recorded across the two post-TC Jasper survey years. An additional 1,562 in-kind survey sites contributed to the regional dataset, comprising 1,230 Ports North monitoring sites, 270 Mandubarra sites, 46 GMYPPBC sites and 16 Cape York Water Partnership sites (Figure 5).

Mangrove data

Coastline surveys

Change indicator scores from the 2024 aerial surveys are presented across all seven surveyed systems from Deeral to Cooktown in Table 4. Human-derived indicator scores were highest at Trinity Inlet and the Barron River, driven by encroachment, structural loss, and altered hydrology. The Daintree and Bloomfield Rivers recorded the highest climate-natural scores across all surveyed systems, driven by flood damage, bank erosion, shoreline erosion, and root burial, with both rivers scoring at or near the maximum for these indicators. Climate-natural scores at both sites were low in 2017, but increased sharply by 2024, with the Daintree rising from 1.4 to 24.4 and Bloomfield from 0.8 to 23.8. Visual indicators of flood-related stress were widespread across both systems, including bank and shoreline erosion, tree slumping, and total vegetation loss in some areas. Large patches of standing, dead mature mangrove trees were recorded at both sites, an indicator not previously observed in this region. Sediment mounds were commonly observed throughout both estuaries.

By October 2025, climate-natural scores at both sites had declined, falling to 12.5 at the Daintree and 11.5 at the Bloomfield, though both remained elevated relative to 2017 baseline conditions (Figure 6, Table 4). At Bloomfield, the highest individual scores were recorded for flood damage, shoreline erosion, root burial, and bank erosion. At the Daintree, flood damage and root burial scores were similarly high, with additional impacts recorded for inner fringe collapse, altered hydrology, and light gaps. Human-derived stressor scores were higher in the Daintree (8.25) than Bloomfield (4.3) in 2025.

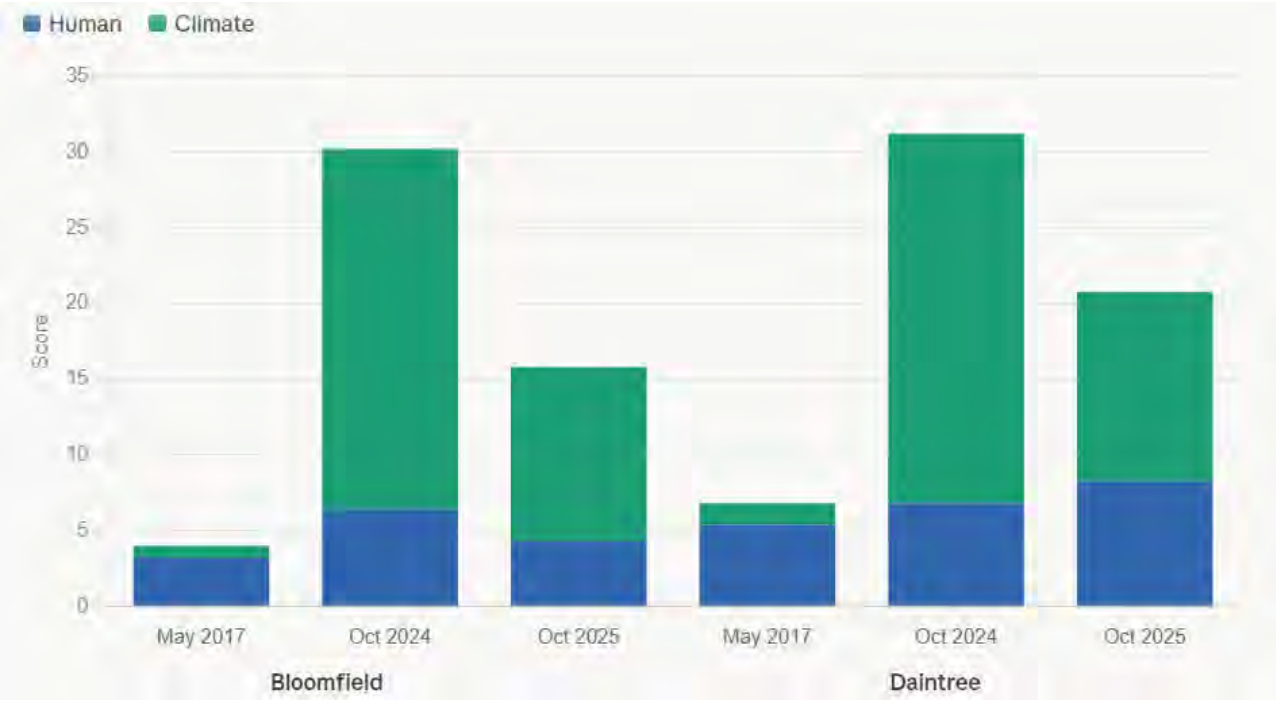


Figure 6: Cumulative human-derived and climate-natural stressor scores for the Daintree and Bloomfield Rivers recorded during aerial surveys in May 2017 (Duke & Mackenzie, 2018), Oct 2024, and Oct 2025, following Tropical Cyclone Jasper (December 2023).

Table 4: Stressor scores for human-derived and climate-natural indicators recorded during aerial surveys of mangrove systems in 2024 (Mutchero Inlet to Cooktown) and 2025 (Daintree and Bloomfield Rivers, shaded blue). Scores are the product of extent and severity ratings, normalised to a maximum of 5. Orange shading indicates scores ≥ 4.

Category	Indicator	2024					2025			
		Mutchero Inlet	Trinity Inlet	Barron River	Daintree River	Bloomfield River	Annan River	Endeavour River	Daintree River	Bloomfield River
Human-derived	Structure Loss	1.6	4	2.4	1.6	1.6	0.8	1.8	1	1.5
	Direct Loss	0	3	2.4	0	0	1.2	1.8	1.6	0
	Altered Hydrology	2.4	3	3	1.6	0	0.8	1.2	1.4	0
	Encroachment	4	4	4	2.4	1.8	0	1.2	1.8	1.5
	Access Tracks	1.6	3	1.2	1.2	1.8	0.8	1.2	0.9	0.2
	Stock Impacts	0	0	0.8	0	1.2	1.2	0	1.2	0
	Feral Damage	0	0	0	0	0	0	0	0	0
	Pollutant Impact	0	0	0	0	0	0	0	0	0
	Nutrient Excess	0	1.8	1.8	0	0	0	0.8	0	0
	Fire Scorch	0	0	0	0	0	2.4	0	0	0
	Weed Smother	0	0	0	0	0	0	0	0	0
	Vessel Damage	0	0	0	0	0	0	0	0.4	0.4
Climate-natural	Storm Damage	0	0	0	0	0	0	0	0	0
	Shoreline Erosion	1.2	2.4	3.2	5	5	3	0.8	0.8	3
	Root Burial	0.8	3.2	1.6	3.2	4	2.4	0.8	4	3.5
	Inner Fringe Collapse	0	2.4	1.8	2.4	2.4	1.8	1.2	0.7	0
	Bank Erosion	2.4	2.4	4	5	5	3	1.8	2.4	3
	Pan Scouring	0	0	0	0	0	2.4	2.4	0	0
	Ecotone Shift -ve	0	0	0	0	0	0	0	0	0

Category	Indicator	2024					2025			
		Mutchero Inlet	Trinity Inlet	Barron River	Daintree River	Bloomfield River	Annan River	Endeavour River	Daintree River	Bloomfield River
	Ecotone Shift +ve	0	0	0	0	0	0	0	0	0
	Depositional Gain	2.4	2.4	2.4	2.4	2.4	2.4	1.8	0.4	0
	Terrestrial Retreat	0	1.2	1.2	0	0	1.2	1.2	0	0
	Light Gaps	1.2	1.2	1.6	2.4	0	0.8	0	0.4	0
	Altered Hydrology	0	0	2.4	0	0	1.8	0	0.6	0
	Flood Damage	1.2	1.8	2.4	4	5	2.4	1.8	4	5

Satellite imaging change detection

Satellite-derived estimates confirmed substantial mangrove losses at the two sites (Daintree and Bloomfield Rivers) most affected by TC Jasper. Mangrove extent was classified using a Random Forest model trained on raw Sentinel-2 bands, which outperformed all alternative classification approaches in cross-validation (Table 3), achieving a mean Cohen's Kappa of 0.897 compared with 0.882 for a Random Forest trained on spectral indices and Kappa values ranging from 0.192 (EVI) to 0.787 (MVI) for single-index threshold classifiers. In the Daintree, mangrove extent decreased from 31.9 km² in 2023 to 26.1 km² in 2024, a loss of approximately 5.8 km² (18%), with little recovery evident by 2025 (26.7 km²). Bloomfield showed a similar proportional decline from 3.3 km² in 2023 to 2.4 km² in 2024 (a loss of approximately 0.9 km², 27%), with a marginal further decline to 2.3 km² in 2025 (

Table 5, Figure 7). Little substantial change in extent was detected across the remaining surveyed systems over the same period. The losses at Daintree and Bloomfield represent the most extensive mangrove dieback documented in this region, with no meaningful recovery in mangrove extent evident at either site within the study period.

Table 5: Extent (km^2) of mangrove forests in different river basins between Deeral and Cairns, assessed using annual composites of Sentinel 2 imagery.

Year	Annan	Barron	Bloomfield	Daintree	Endeavour	Hartley' s	Mowbray	Port Douglas	Trinity Inlet
2023	6.1	9.8	3.3	31.9	9.6	0.4	2.5	11.6	34.7
2024	5.0	9.9	2.4	26.1	12.1	0.4	2.4	11.5	35.6
2025	5.1	9.4	2.3	26.7	11.2	0.3	2.1	11.2	34.5

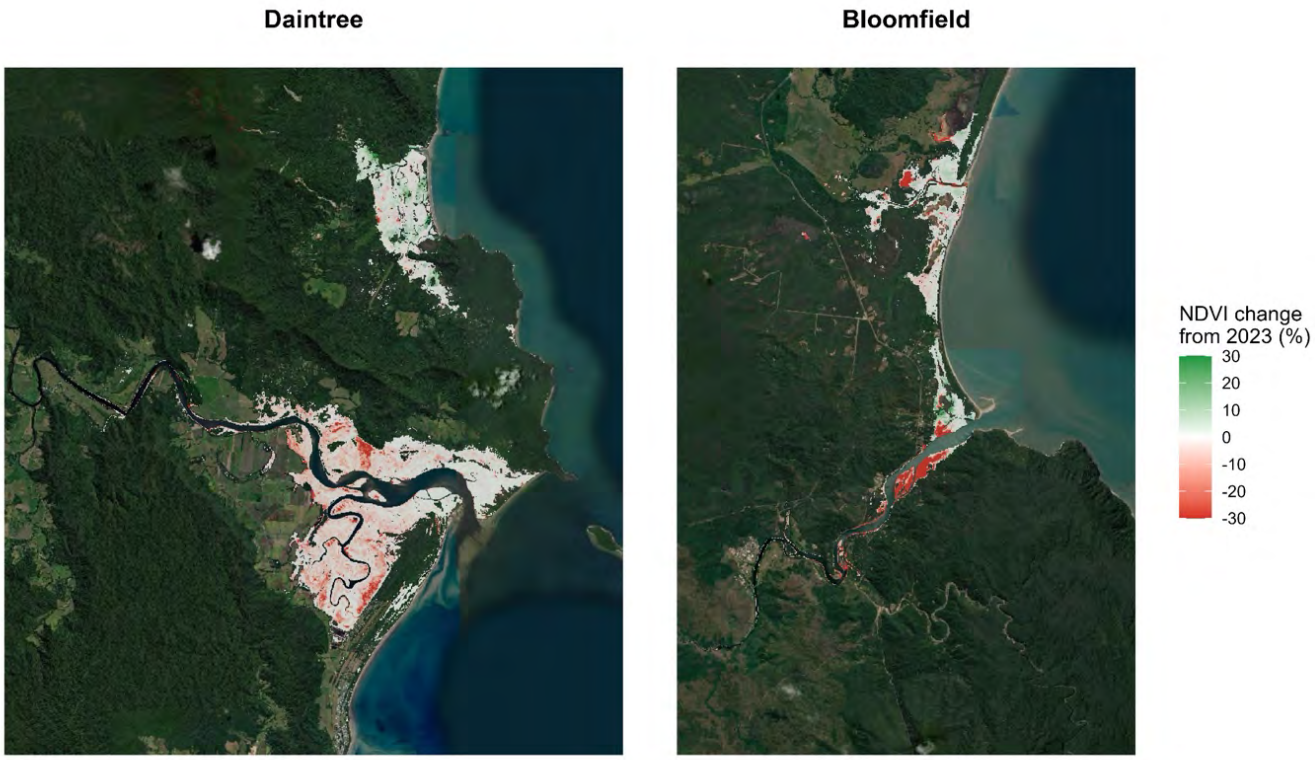


Figure 7: Percent change in NDVI relative to a 2023 pre-cyclone baseline for the Daintree and Bloomfield Rivers in 2025, derived from Sentinel-2 surface reflectance imagery. Red tones indicate vegetation decline relative to the 2023 baseline, while green tones indicate early recovery or expansion.

Targeted sediment deposition surveys

Sediment deposition depth was consistently greater in dead mangrove stands than in adjacent living stands across both transects (Table 6; Figure 8). Mean deposition depth in dead stands averaged 10.9 cm (± 0.9 SE) compared with 6.2 cm (± 0.9 SE) in living stands, indicating that heavier sediment loads were associated with tree mortality in the most severely affected areas. Even relatively modest sediment addition can impair mangrove function by reducing gas exchange through aerial roots or by smothering crab communities whose bioturbation activity is important for sediment aeration and nutrient cycling. The stands were dominated by *Rhizophora* and *Bruguiera* species, which possess large prop roots and buttresses that remained substantially exposed despite partial burial. This suggests that the mechanisms of mortality are likely to be more complex than sediment burial alone and warrant further investigation. Tree size metrics were broadly similar across the live-dead boundary, with mean stem diameters ranging from 18.2 to 21.9 cm and mean heights from 16.6 to 21.4 m, indicating that mortality was not driven by differences in tree size or age structure. The proportion of living trees was markedly lower in dead stands (0% and 33.3% in transects 1 and 2, respectively) than in living stands (72.2% and 55.6%), while seedling survival remained high across both zones (84-100%), suggesting active recruitment is occurring even where the mature canopy has been lost.

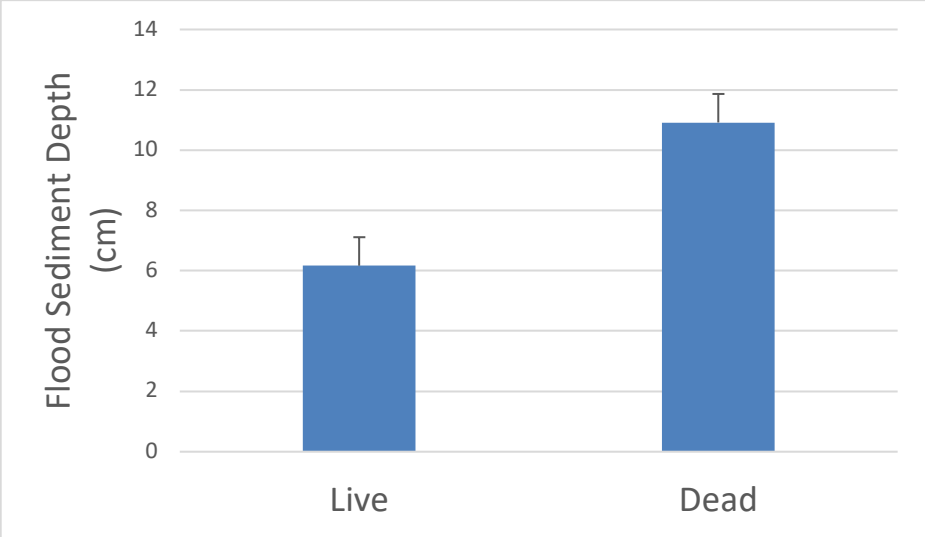


Figure 8: Mean deposited sediment depth (cm; error bars ± 1 SE) in living and dead mangrove stands recorded along two 50 m transects crossing the live-dead interface at a dead patch in the south arm of the Daintree River, October 2025.

Table 6: Sediment deposition depth, mean stem diameter, mean tree height, and proportion of living trees and seedlings recorded along two 50 m transects crossing the live-dead mangrove interface at a dead patch in the south arm of the Daintree River, October 2025.

		Sediment depth (cm)	Mean stem diameter (cm)	Mean tree height (m)	Trees living (%)	Seedlings living (%)
Transect 1	**Live**	6.3	18.2	16.6	72.2	93.1
	Dead	11.7	20.6	21.4	0	91.7
Transect 2	**Live**	6	20.6	17	55.6	84.1
	Dead	10.2	21.9	19	33.3	100

Summary of TC Jasper impacts on mangrove habitats

Extensive mangrove damage was recorded across the Daintree and Bloomfield Rivers following TC Jasper, with impacts consistently identified across all three assessment methods. Climate-natural stressor scores from aerial surveys increased markedly between 2017 and 2024 (pre- and post-cyclone), rising from 1.4 to 24.4 at the Daintree and from 0.8 to 23.8 at the Bloomfield, before declining to 12.5 and 11.5 respectively by October 2025, remaining well above pre-cyclone levels. Satellite-derived mangrove extent declined by 18% at the Daintree (31.9 to 26.1 km²) and 27% at the Bloomfield (3.3 to 2.4 km²) between 2023 and 2024, with little meaningful recovery detected at either site by 2025. Sediment deposition surveys at the Daintree confirmed greater burial depths in dead mangrove stands (mean 10.9 cm) relative to adjacent living stands (mean 6.2 cm).

Potential rehabilitation priority areas

Drawing on the 2025 aerial surveys and satellite change detection, areas showing little or no natural recovery were delineated as potential rehabilitation priority areas across the Daintree and Bloomfield systems. A total of 1,776 ha was identified, representing a range of impact types requiring different management responses (

Table 7; Figure 9). Sediment deposition was the dominant impact category, accounting for 1,068 ha (60% of the total), reflecting the scale of burial-related mortality observed across both systems. Hydrological modification accounted for a further 155 ha, and flood damage with and without associated sediment deposition accounted for 98 ha combined. Erosion-affected areas totalled 27 ha, while terrestrial retreat and non-mangrove riparian loss accounted for 51 ha and 46 ha respectively. A further 215 ha was identified for further on-ground investigation where the dominant impact type could not be confidently assigned from aerial and satellite data alone, and 24 ha exhibited mixed impacts not readily attributable to a single driver.

Table 7: Area (ha) of mangrove and riparian habitat shortlisted for rehabilitation scoping across the Daintree and Bloomfield Rivers, categorised by primary impact type (or where further investigation is required) as determined from 2025 aerial surveys and satellite change detection.

Key impact	**Area (ha)**
Mixed impacts along with a naturally dynamic river mouth	92
Erosion	27
Flood damage	69
Flood damage and sediment deposition	29
Hydrological modifications, such as drains or tidal bunds	155
Further investigation required	215
Mixed impacts	24
Non-mangrove riparian loss	46
Sediment deposition	1068
Terrestrial retreat	51
Total	**1776**

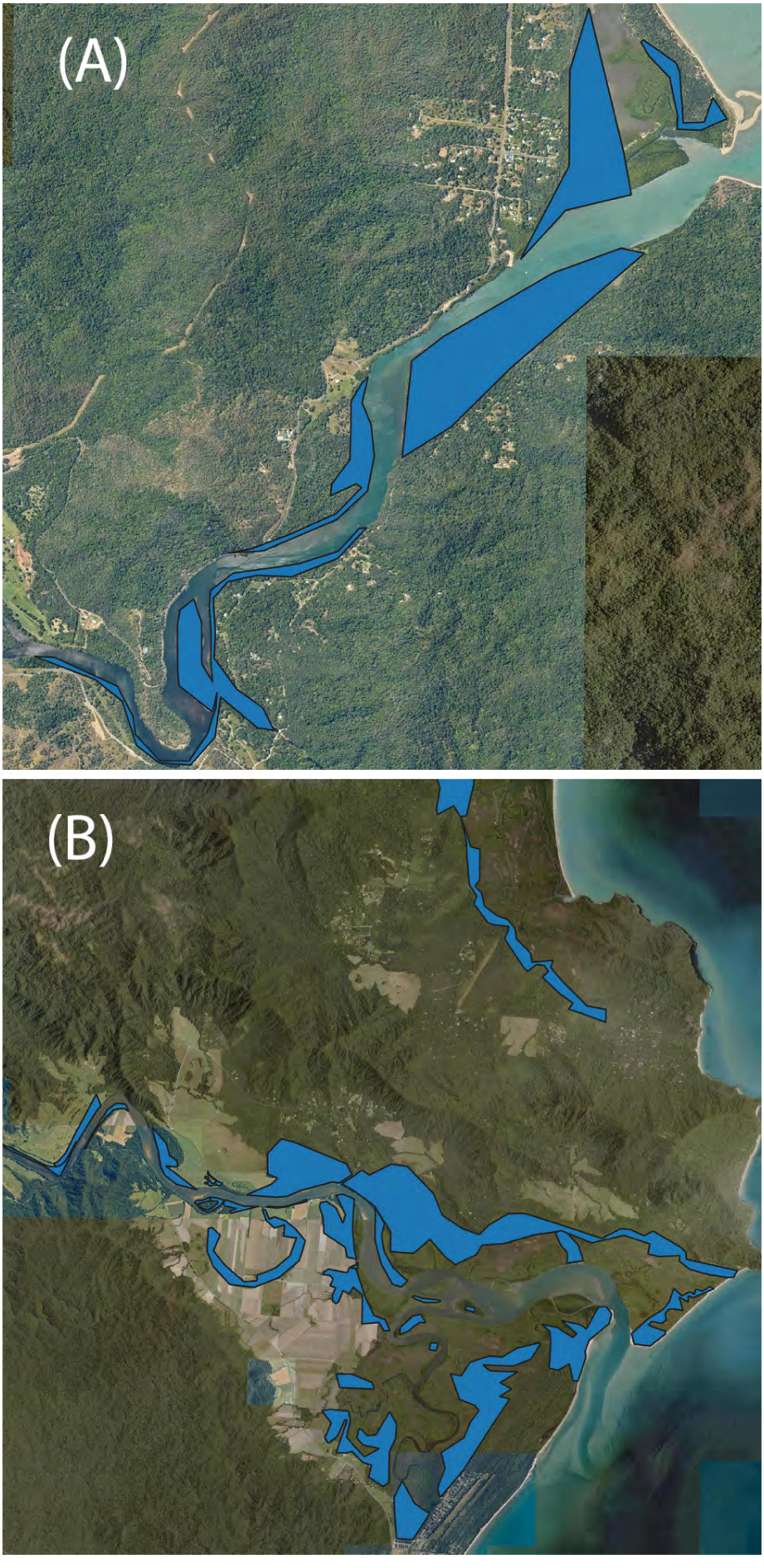


Figure 9: Potential areas where further rehabilitative interventions could be warranted for mangroves across the (A) Bloomfield and (B) Daintree estuaries.

Seagrass data

This section presents the seagrass data recorded as part of this project and puts this in context with the available historical data and long-term monitoring to understand the impacts of TC Jasper on seagrass in the region. Seagrass data pre- and post-TC Jasper has also been provided by GMYPPBC and Mandubarra Aboriginal Land and Sea Incorporated to illustrate the immediate impact of the cyclone to the south of our survey region.

Available regional scale historical data

The NESP seagrass synthesis layer compiles records of seagrass in the GBR from 1984 – 2014 (Carter et al., 2016). This dataset shows extensive data around Cairns Harbour itself as part of an annual monitoring program (see section 0) but quite limited information for the remainder of the Cooktown – Kurrimine Beach region. Only 44 data points were available in the synthesis layer with seven records of seagrass within the post-TC Jasper coastal survey region north of Cairns (excluding Low Isles) (Figure 10). To the south of Cairns, previous surveys in the Yarrabah area of Mission Bay provided 36 data points, of which 24 contained seagrass (Figure 10). The majority of the records from the region were from the 1980s, so the lack of and age of available data limits our understanding of seagrass condition and extent in the region prior to TC Jasper.

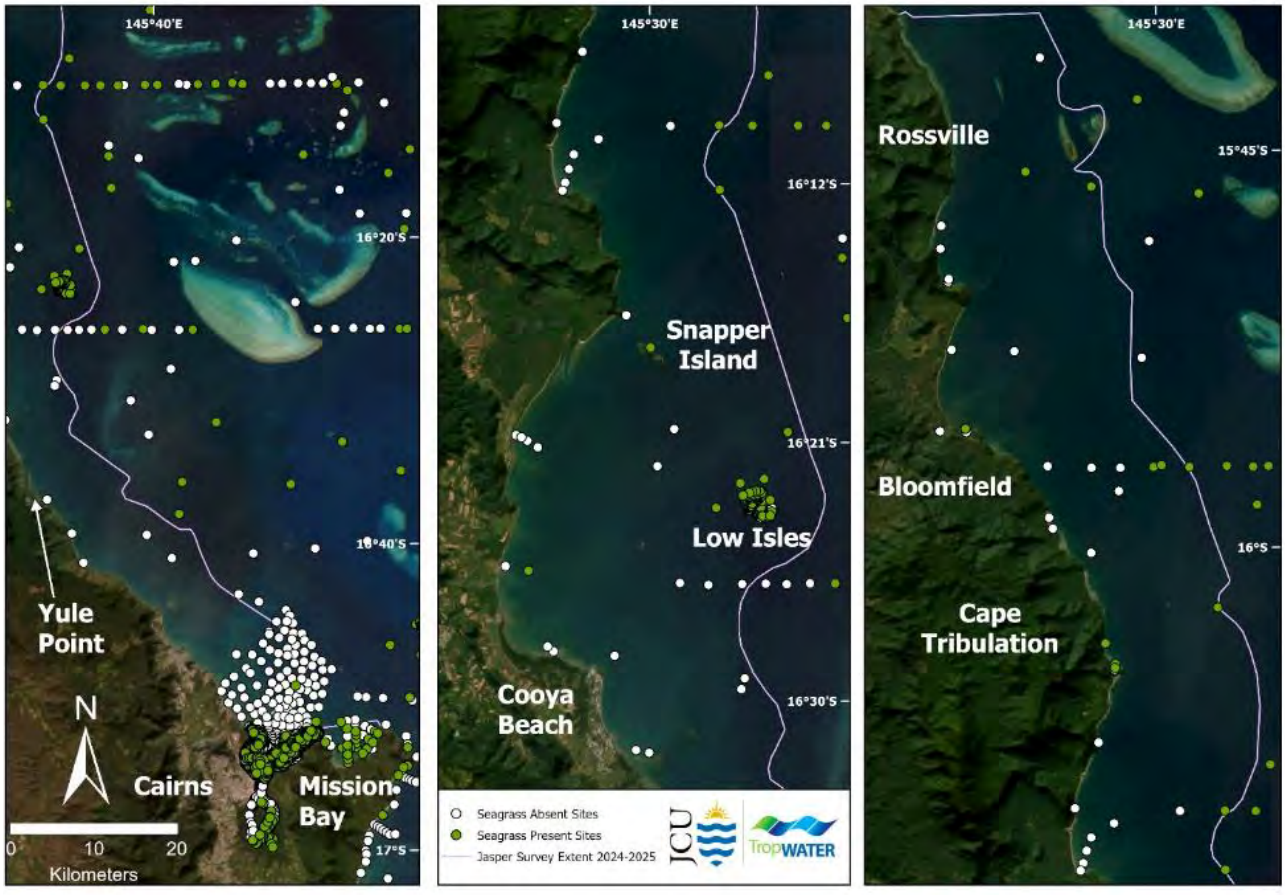


Figure 10: Available data of seagrass presence/absence from 1980 – 2014 in the survey region and synthesised in Carter et al. (2016).

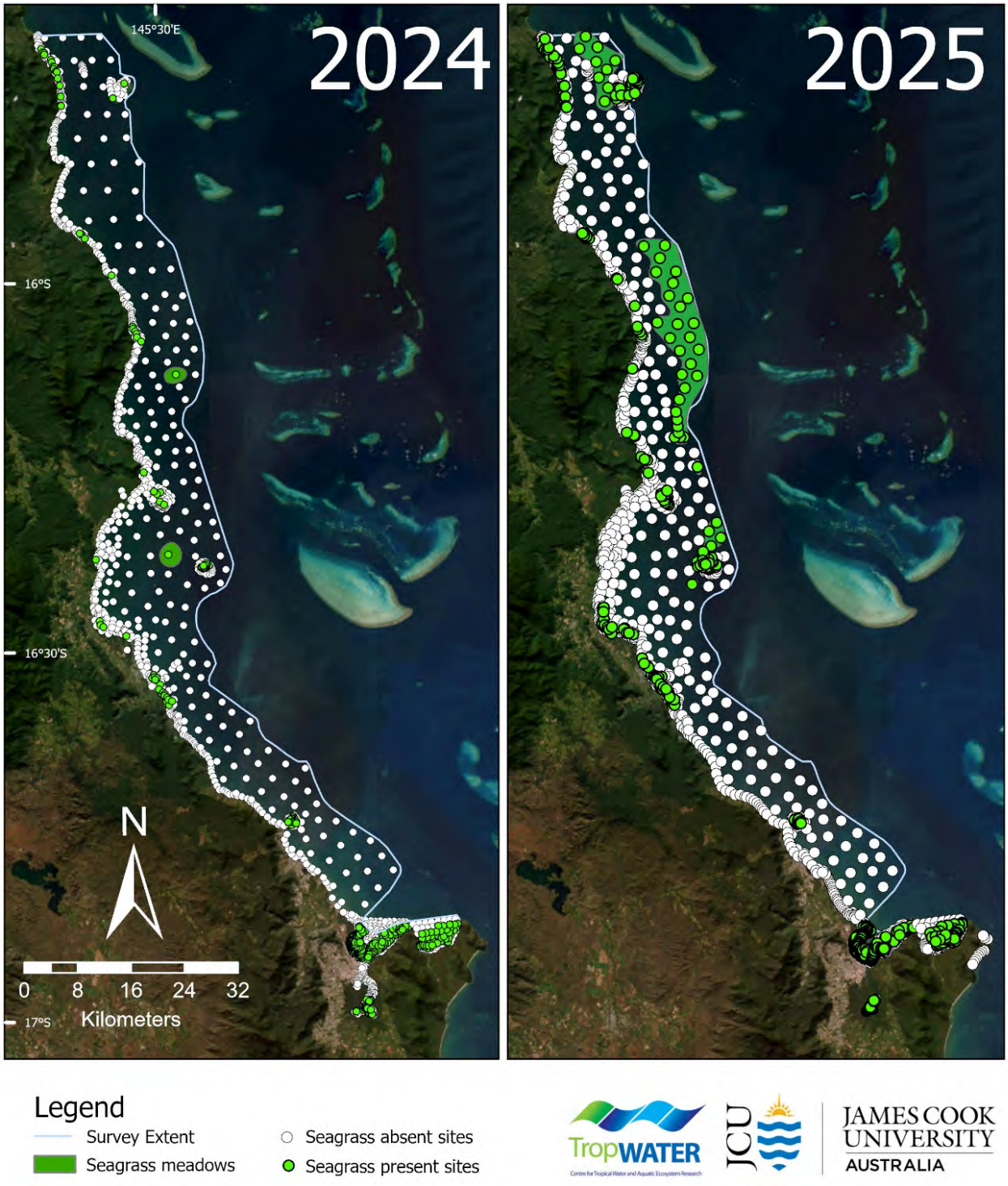


Figure 11: Benthic habitat assessment sites from the 2024 and 2025 surveys following Tropical Cyclone Jasper, showing location of seagrass and seagrass meadows.

Regional scale seagrass data

On-ground surveys were conducted across two years: October 2024 - January 2025 (labelled as 2024) and October – December 2025 (labelled as 2025); these data points are shown in Figure 11 and are discussed in detail below. Aerial and boat-based surveys found seagrass throughout the

survey area, with eight seagrass species recorded in the first year and nine seagrass species in the second year, covering an area of 3,532 ± 785ha in 2024 and 21,033 ± 2114 ha in 2025.

The following summaries compare data from each year for the key mapped areas of seagrass shown above. An additional map from Cape Tribulation is shown in the appendix (Appendix B).

Northern survey region (including deepwater seagrass)

In 2024, 16 of 84 sites along the coastal stretch shown in Figure 12 had seagrass present, ranging from 1 – 15% cover. Whereas in 2025, 33 of 120 sites had seagrass, ranging from 1 – 20% cover. Six seagrass meadows were mapped in 2024 in this sector, covering 100.0 ± 9.7 ha. This increased to eleven meadows covering 154.0 ± 65.7 ha in 2025. These meadows were dominated by narrow leaf *Halodule uninervis*, *Thalassia hemprichii* and *Cymodocea rotundata*, with some subtidal *Halophila decipiens* meadows present near the reef edge in 2025.

No deep-water seagrass was recorded in this area in 2024, but in 2025 a large deep-water meadow was mapped between the Hope Islands and the mainland. This meadow comprised three *Halophila* species, dominated by endemic *H. tricostata* with an average biomass of 1.49 ± 0.17 gDWm^{-2} (between 1 – 30% cover) and with an area of 3910.2 ± 320.8 ha.

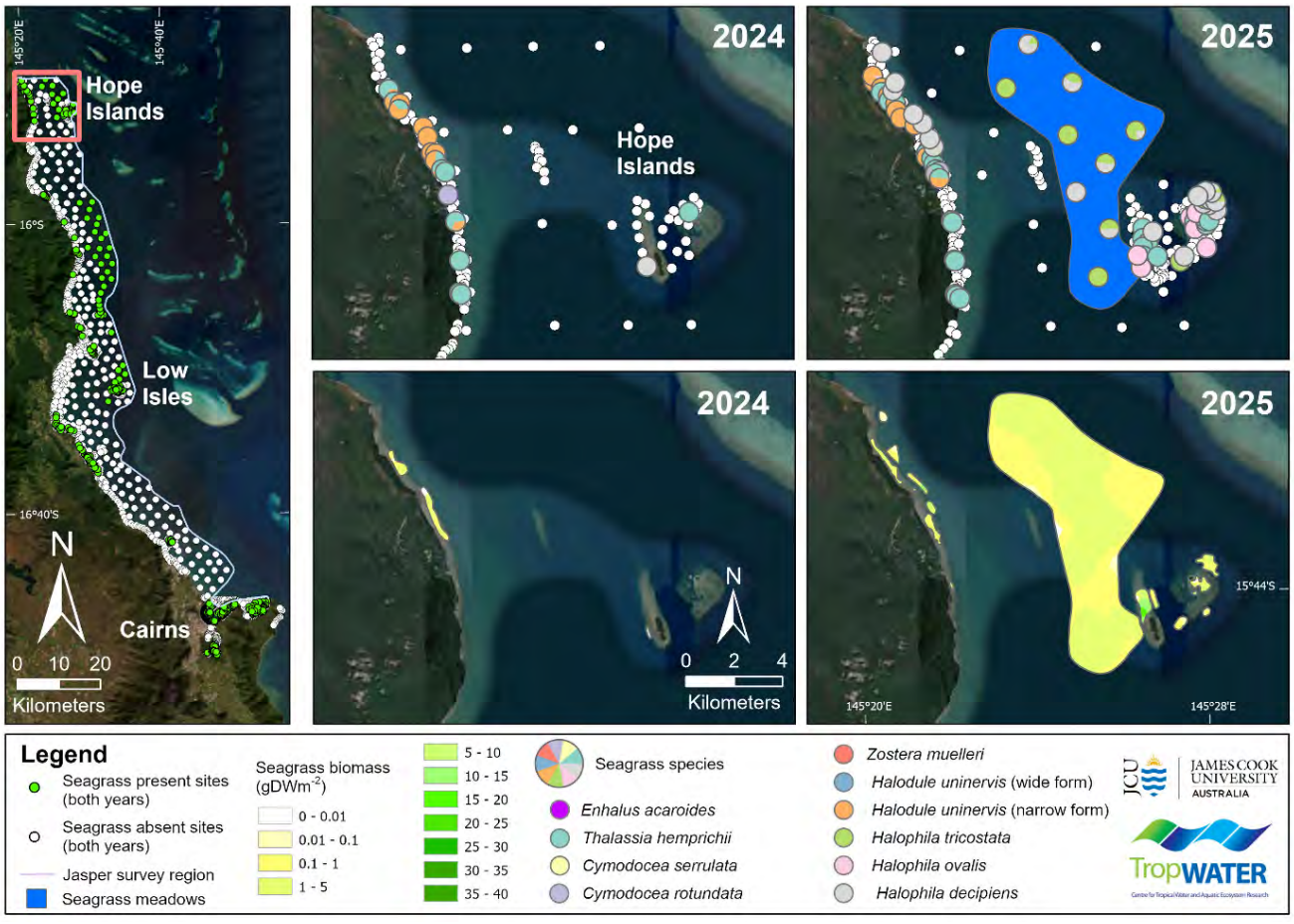


Figure 12: Seagrass species and meadows (top panel) and interpolation of seagrass above-ground biomass (bottom panel) for the northern survey area including deep-water meadows.

Hope Islands

The Hope Islands (Figure 13) were mapped more extensively in 2025 as better tides and weather conditions allowed access to the reef flat for boat-based surveys. In 2024, seagrass was recorded at just two of 26 sites around the Hope Islands. In 2025,116 sites were surveyed, of which 35 had seagrass present, with seagrass cover ranging from 1-12%. Seven distinct meadows were recorded around the islands in 2025, with reef top meadows dominated by *T. hemprichii* and subtidal meadows dominated by *H. decipiens,* with some *H. ovalis* and *H. tricostata* also present.

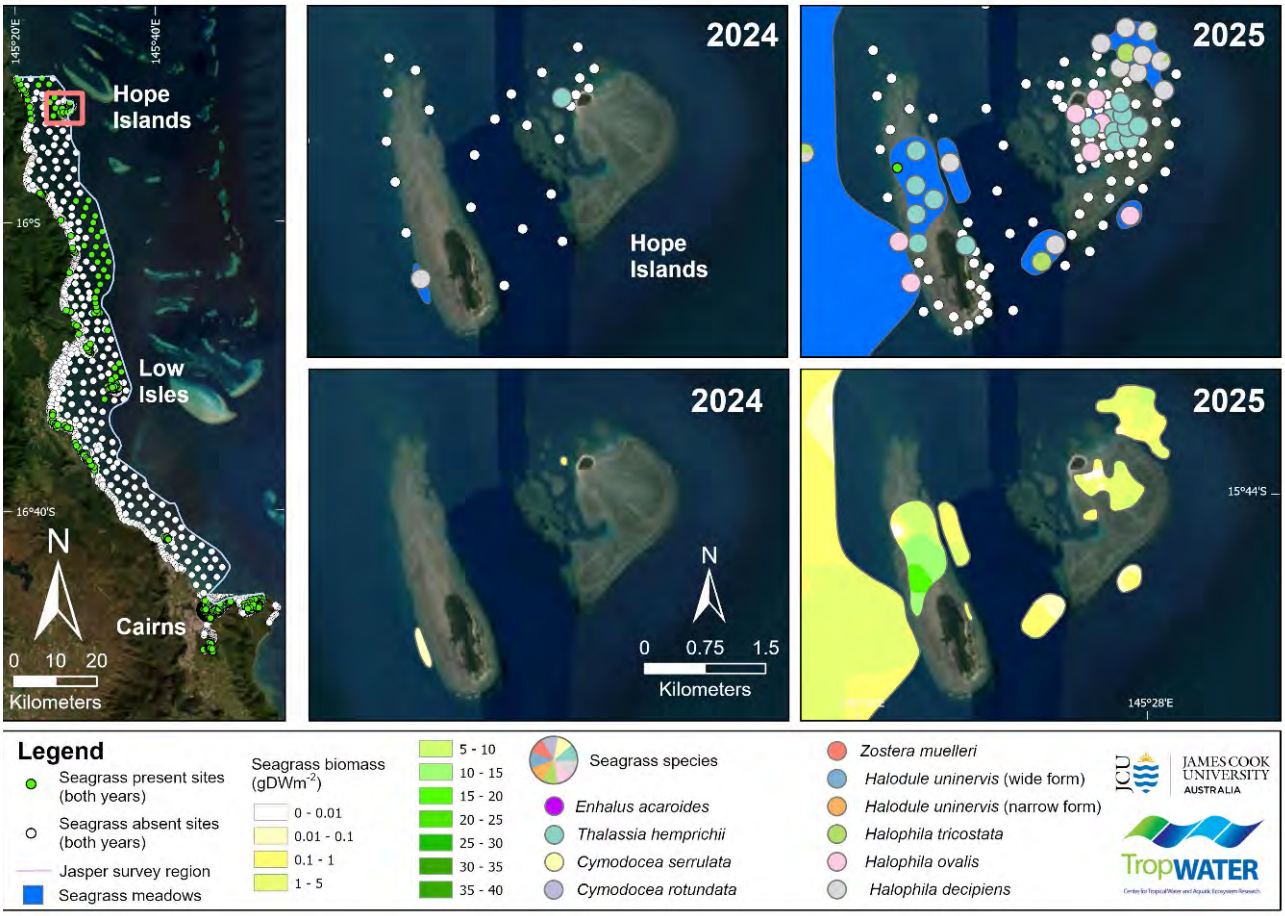


Figure 13: Seagrass species and meadows (top panel) and interpolation of seagrass above-ground biomass (bottom panel) for the Hope Islands including deep water meadows.

Kangkiji Beach

Seagrass meadow area at Kangkiji remained the same between the 2024 and 2025 surveys (~23 ha); however, the footprint changed between surveys. In 2024, the meadow was fragmented into two distinct patches, while in 2025 the northern patch significantly expanded and the southern patch got smaller (Figure 14). Biomass increased from 1.12 ± 0.44 gDWm^{-2} (1 - 25% cover) in 2024 to 4.33 ± 0.99 gDWm^{-2} (1 - 45% cover) in 2025. The meadow was dominated by *H. uninervis* in both years, with more *H. ovalis* and *T. hemprichii* present in 2025.

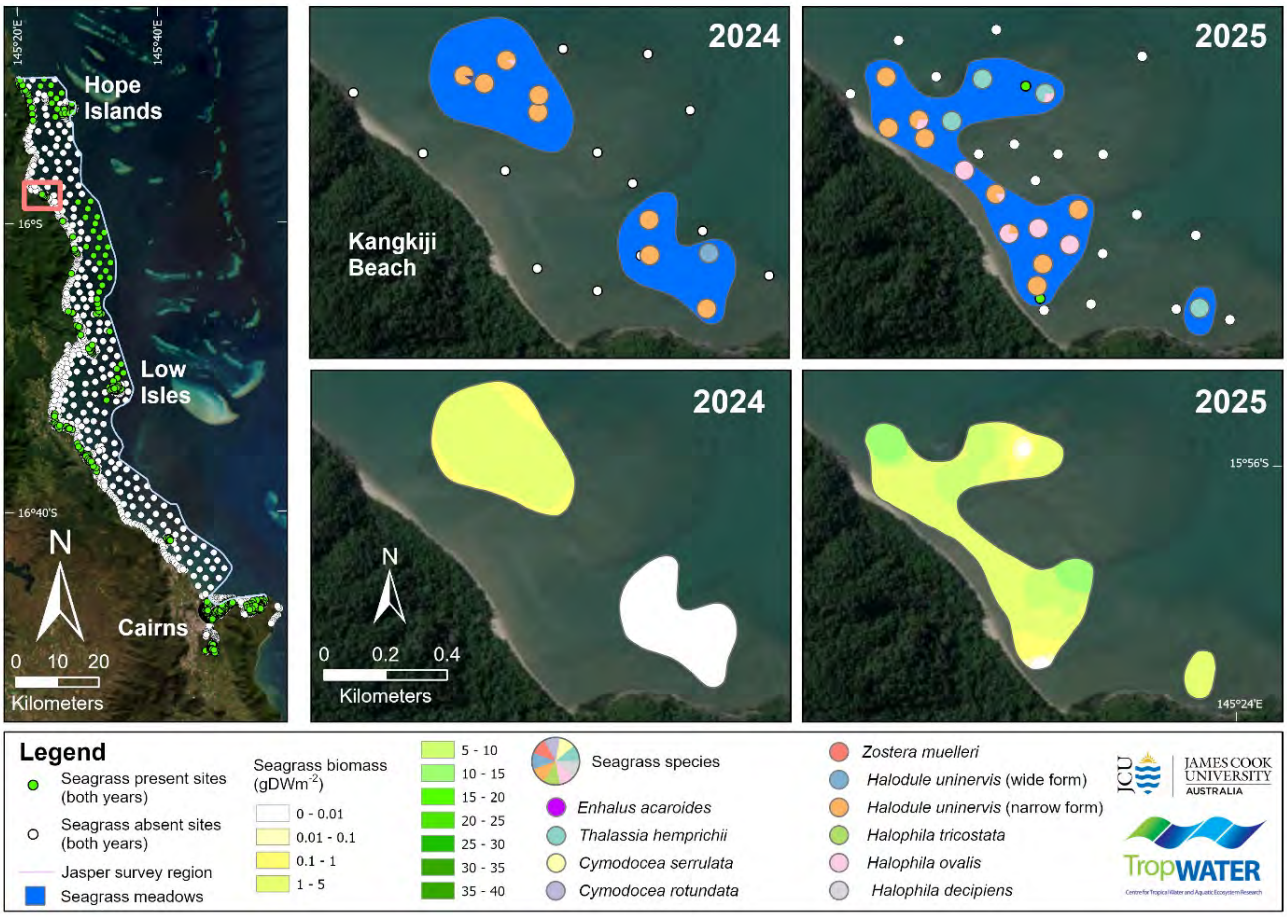


Figure 14: Seagrass species and meadows (top panel) and interpolation of seagrass above-ground biomass (bottom panel) for Kangkiji Beach. Note some 2024 sites were collected by Cape York Water Partnership and do not contribute to the interpolation of above-ground biomass.

Daintree deep water meadows

Only one deep-water site with *H. decipiens* present was recorded in this area in 2024 (Figure 15). In 2025, a large deep-water meadow was mapped covering 13,090.1 ± 759.6 ha. The meadow consisted of *H. tricostata* and *H. decipiens* with seagrass percent cover ranging from 1 – 35%. Along the coastal strip, seagrass was recorded at 29 sites in 2025, comprising *H. ovalis*, *H. uninervis* and *T. hemprichii*, compared with only 11 sites in 2024 where only *H. uninervis* and *H. decipiens* were present.

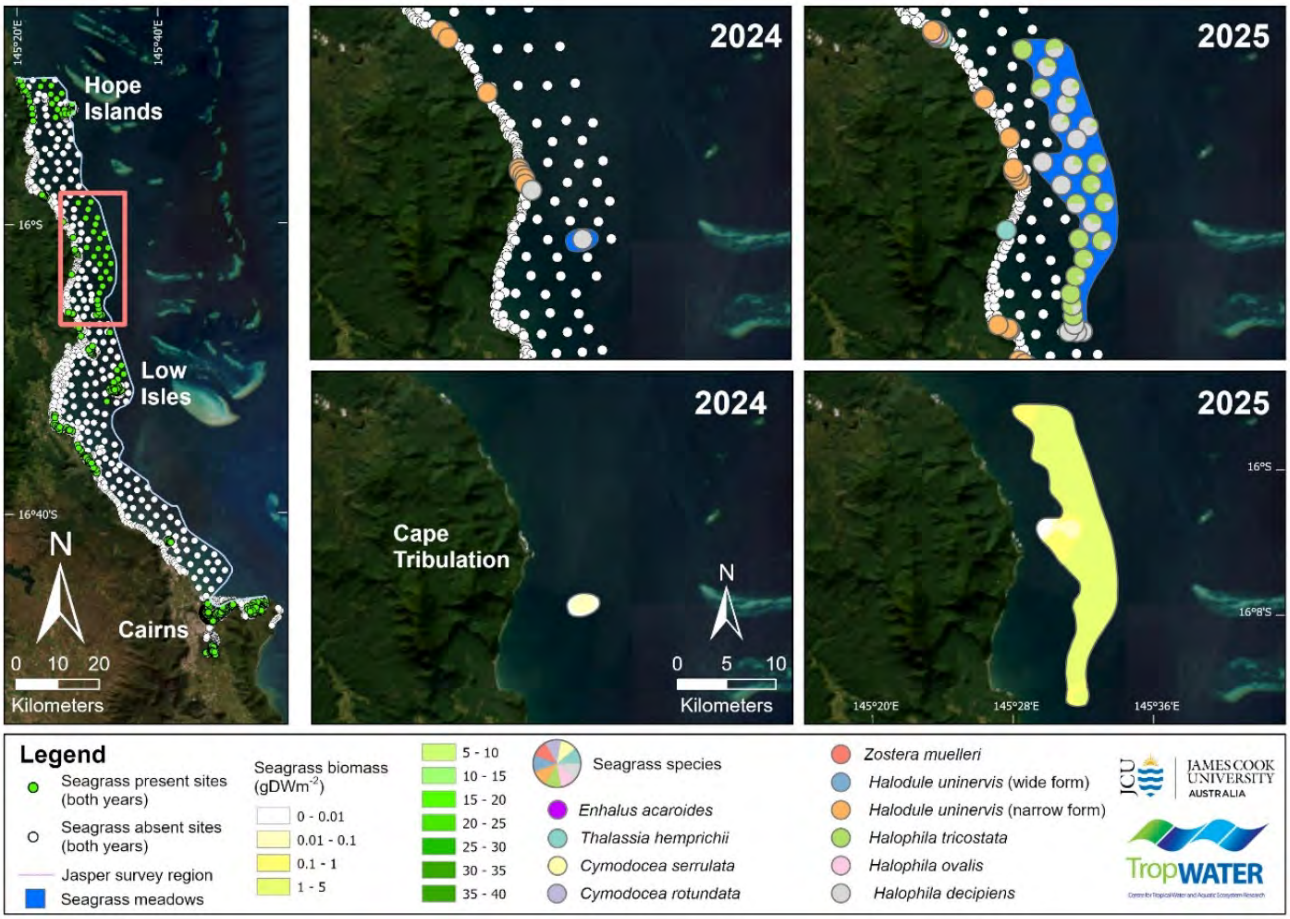


Figure 15: Seagrass species and meadows (top panel) and interpolation of seagrass above-ground biomass (bottom panel) for the Daintree deep water area.

Snapper Island

Three meadows were mapped around Snapper Island in 2024, compared with two meadows in 2025 (Figure 16). The larger deep-water meadow to the north was dominated by *H. tricostata* and *H. decipiens* in both years. In 2024, this meadow covered 121.3 ± 43.9 ha with an average biomass of 0.12 ± 0.06 gDWm^{-2} and all assessment sites recorded only 1% cover. In 2025, this meadow additionally contained *H. uninervis* and *H. ovalis* covering a similar area of 107.5 ± 62.7 ha but with a higher average biomass of 2.4 ± 0.7 gDWm^{-2} and seagrass cover increasing to 1-35%. Two additional single-site meadows containing *H. tricostata* (1-3% cover) were recorded in 2024; in 2025 a small meadow containing *H. ovalis* (1-15% cover) was mapped.

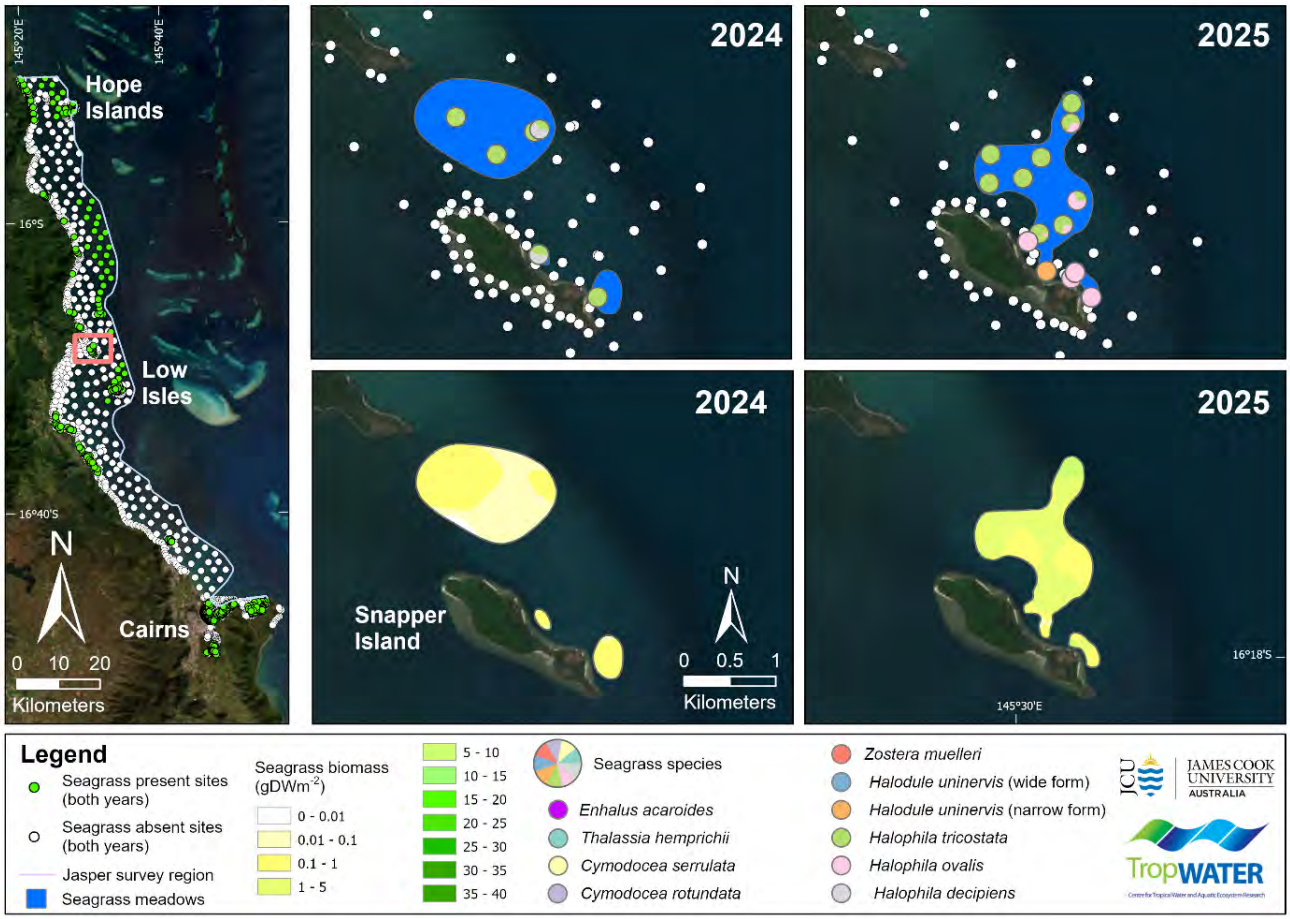


Figure 16: Seagrass species and meadows (top panel) and interpolation of seagrass above-ground biomass (bottom panel) for Snapper Island.

Cooya Beach

In 2024, four assessment sites between Cooya Beach and Port Douglas contained narrow leaf *H. uninervis*. These sites ranged in cover from 1-20% and formed one meadow of 59.6 ± 20.6 ha (Figure 17). In 2025, 22 seagrass sites were recorded (1-40% cover). These sites formed four meadows dominated by narrow leaf *H. uninervis* and *H. ovalis* covering 139.9 ± 50.8 ha. There was also a smaller meadow with *H. ovalis* and patches of *E. acoroides* (1-3% cover) on the bank.

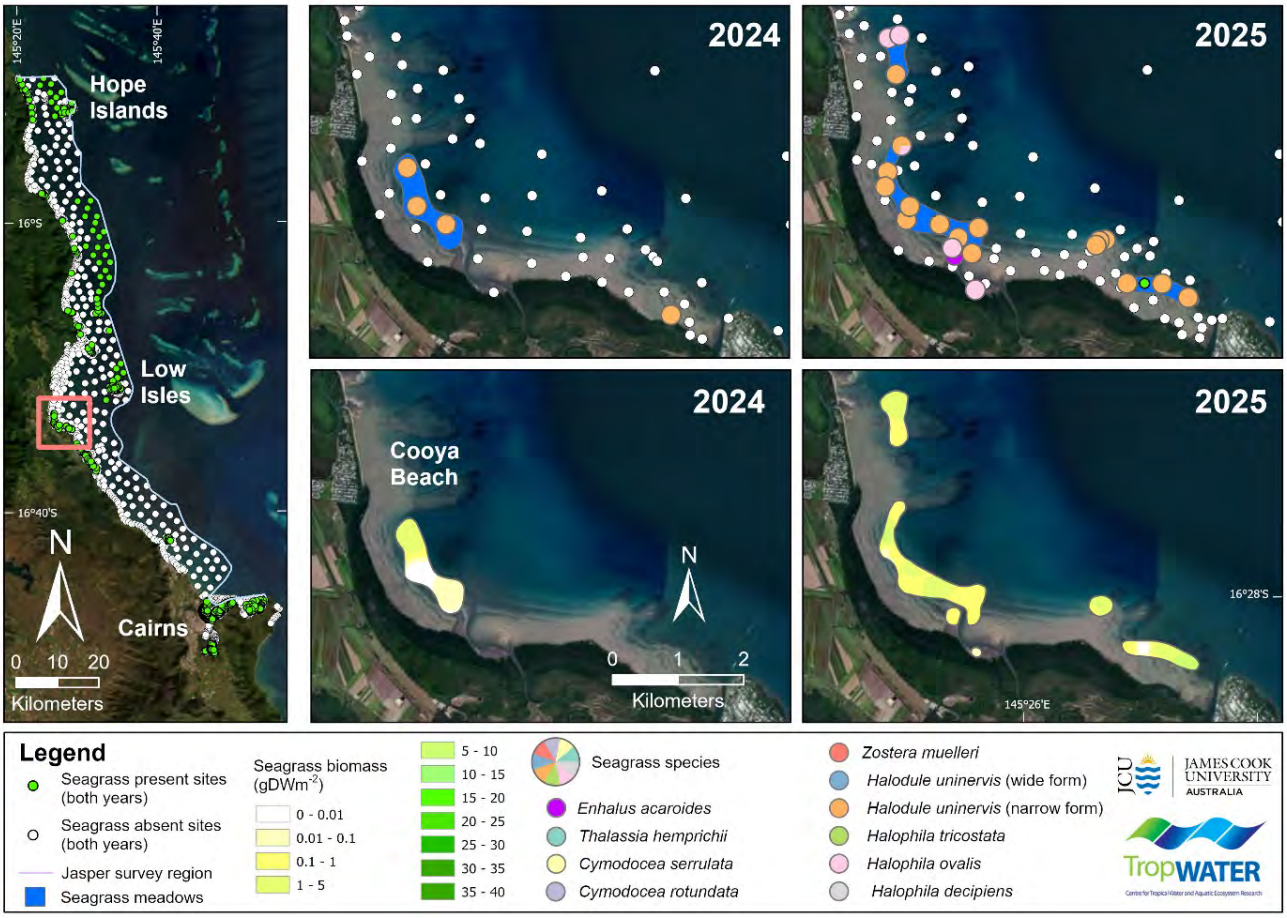


Figure 17: Seagrass species and meadows (top panel) and interpolation of seagrass above-ground biomass (bottom panel) for Cooya Beach.

Low Isles – deep-water

Only one deep-water site recorded seagrass in this area in 2024, with 1% cover of *H. tricostata.* In 2025, deep-water seagrass expanded to a large *H. tricostata* meadow, with *H. ovalis* and *H. decipiens* also present, covering 1607.9 ± 220.4 ha with 1-12 % cover. An additional site with 1% cover of *H. tricostata* was recorded to the south of Low Isles (Figure 18).

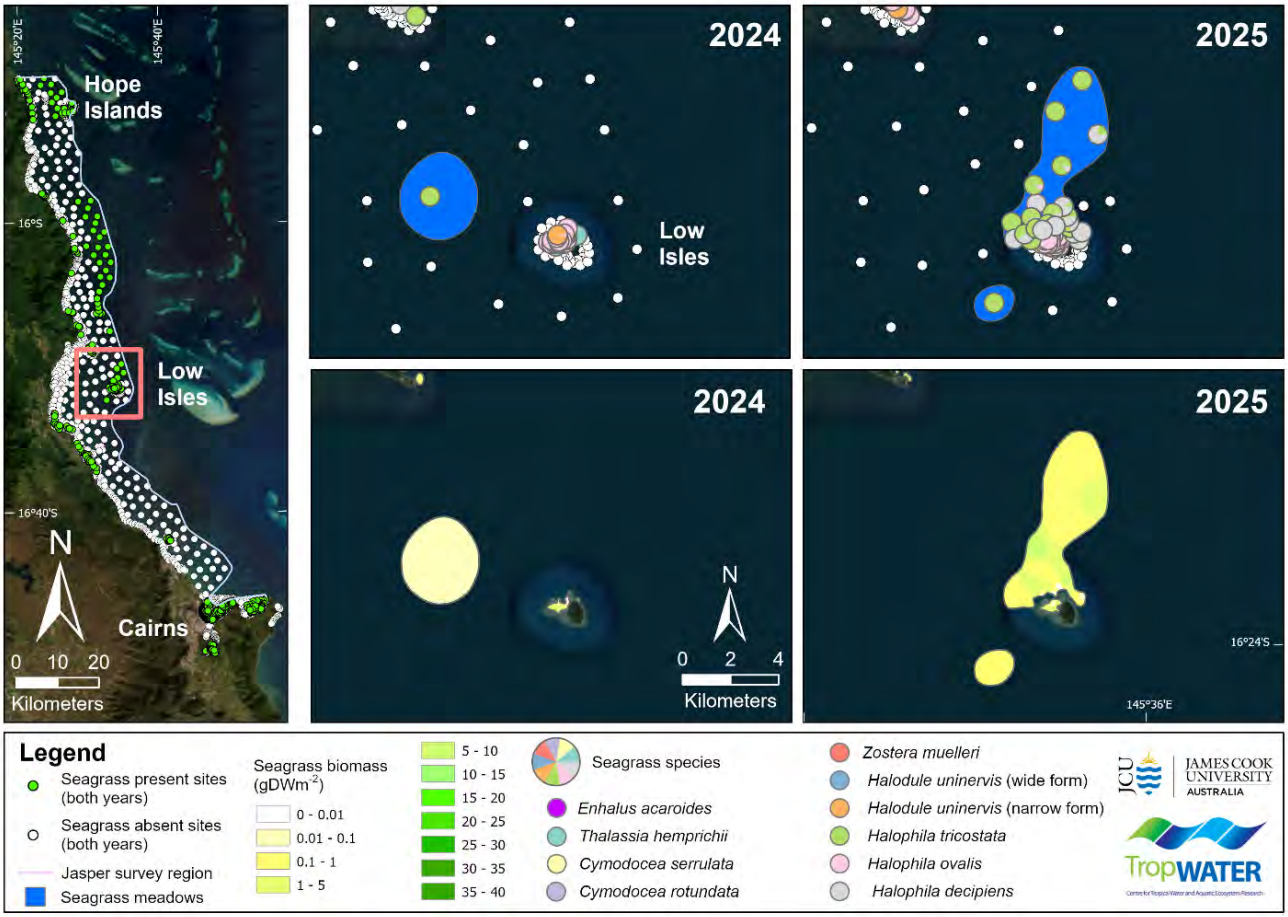


Figure 18: Seagrass species and meadows (top panel) and interpolation of seagrass above-ground biomass (bottom panel) for Low Isles deep water area.

Low Isles – reef top

The main reef top meadow at Low Isles covered 31.1 ± 18.1 ha in 2024, dominated by *H. ovalis* with narrow leaf *H. uninervis* and *T. hemprichii* also present. Meadow biomass was 1.44 ± 1.18 gDWm^{-2} with 1-20% cover (Figure 19). In 2025, the meadow covered a similar area (30.5 ± 13.3 ha) but meadow biomass increased to 2.34 ± 0.72 gDWm^{-2}. Narrow leaf *H. uninervis* dominated the meadow in 2025 with *H. ovalis* and *T. hemprichii* also present, and seagrass cover increased to 1-40%.

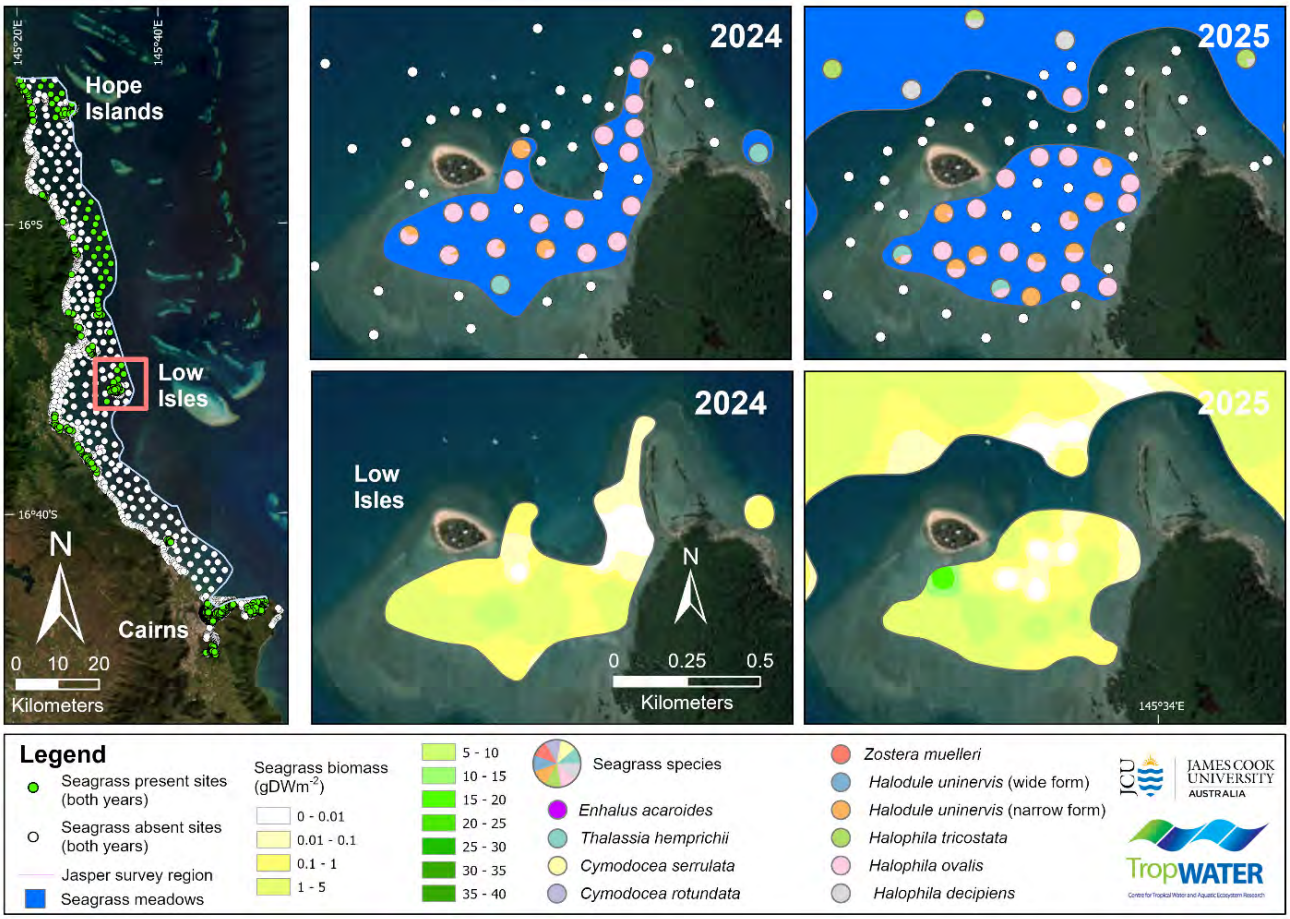


Figure 19: Seagrass species and meadows (top panel) and interpolation of seagrass above-ground biomass (bottom panel) for Low Isles.

Yule Point

Seagrass was recorded at 19 sites at Yule Point in 2024 (1-50% cover), increasing to 25 sites in 2025 (1-45% cover), with a further four sites recorded just outside this map to the north on Four Mile Beach (Figure 20). Both the southern and northern meadows expanded and became denser between 2024 and 2025. The mapped meadow covered 118.8 ± 18.9 ha in 2024 with an average biomass of 0.07 ± 0.2 gDWm^{-2}, increasing to 188.9 ± 47.0 ha and 1.69 ± 0.36 gDWm^{-2} in 2025. The meadow was dominated by narrow leaf *H. uninervis* in both years, with *H. ovalis* also present.

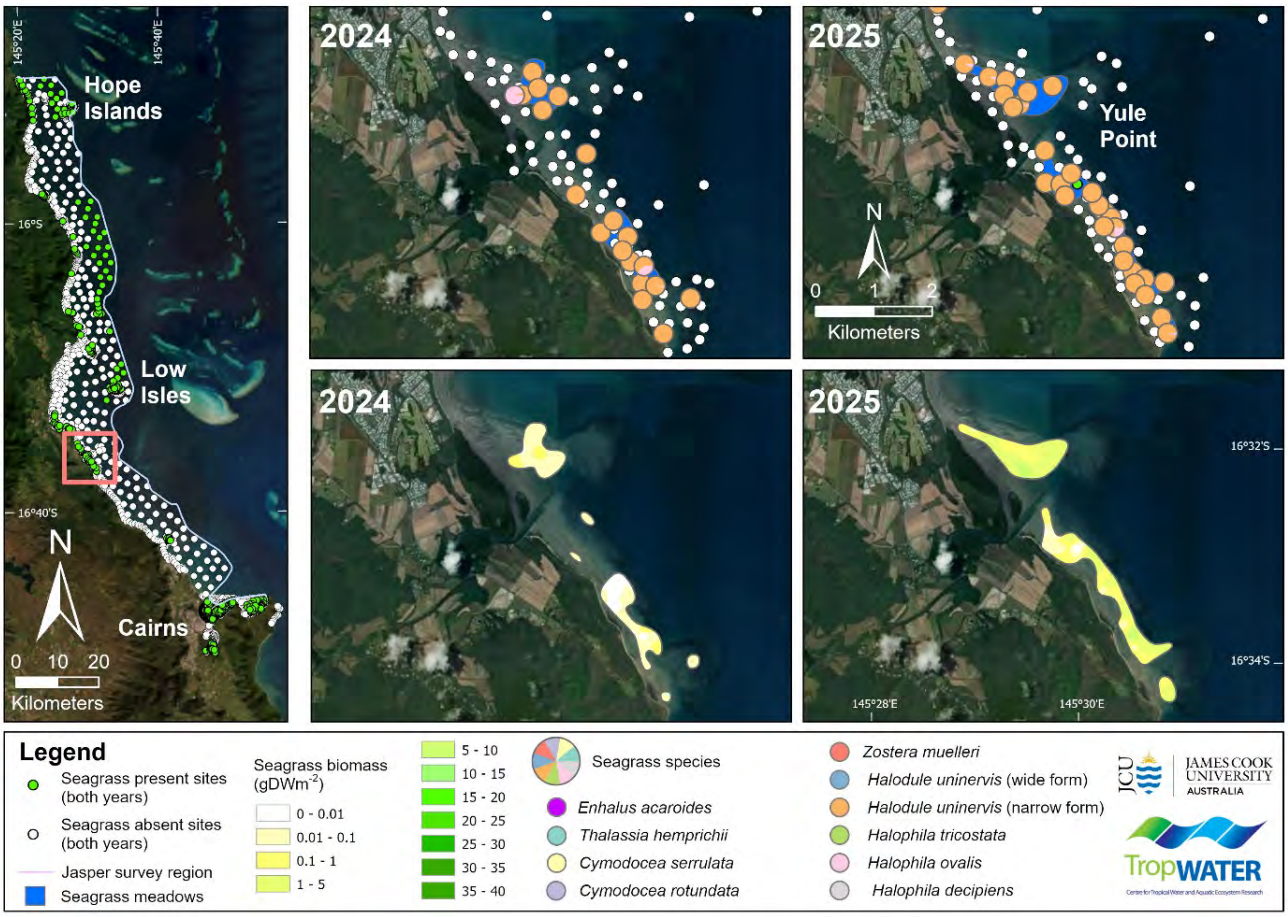


Figure 20: Seagrass species and meadows (top panel) and interpolation of seagrass above-ground biomass (bottom panel) for Yule Point.

Double Island

In 2024, 26 sites with seagrass were recorded in the reef-top meadow at Double Island (1-30% cover), with an average meadow biomass of 3.66 ± 2.65 gDWm^{-2} across 86.2 ± 23.9 ha (Figure 21). In 2025, there were also 26 sites with seagrass recorded (1-35% cover). The seagrass meadow biomass increased to 4.56 ± 0.81 gDWm^{-2}; however, meadow area decreased to 66.3 ± 42.0 ha. In both years, the meadow was dominated by *H. uninervis* (both wide and narrow form), with *T. hemprichii* and *H. ovalis* also present in both years. *Zostera muelleri* and *C. serrulata* were present in 2024, but not 2025.

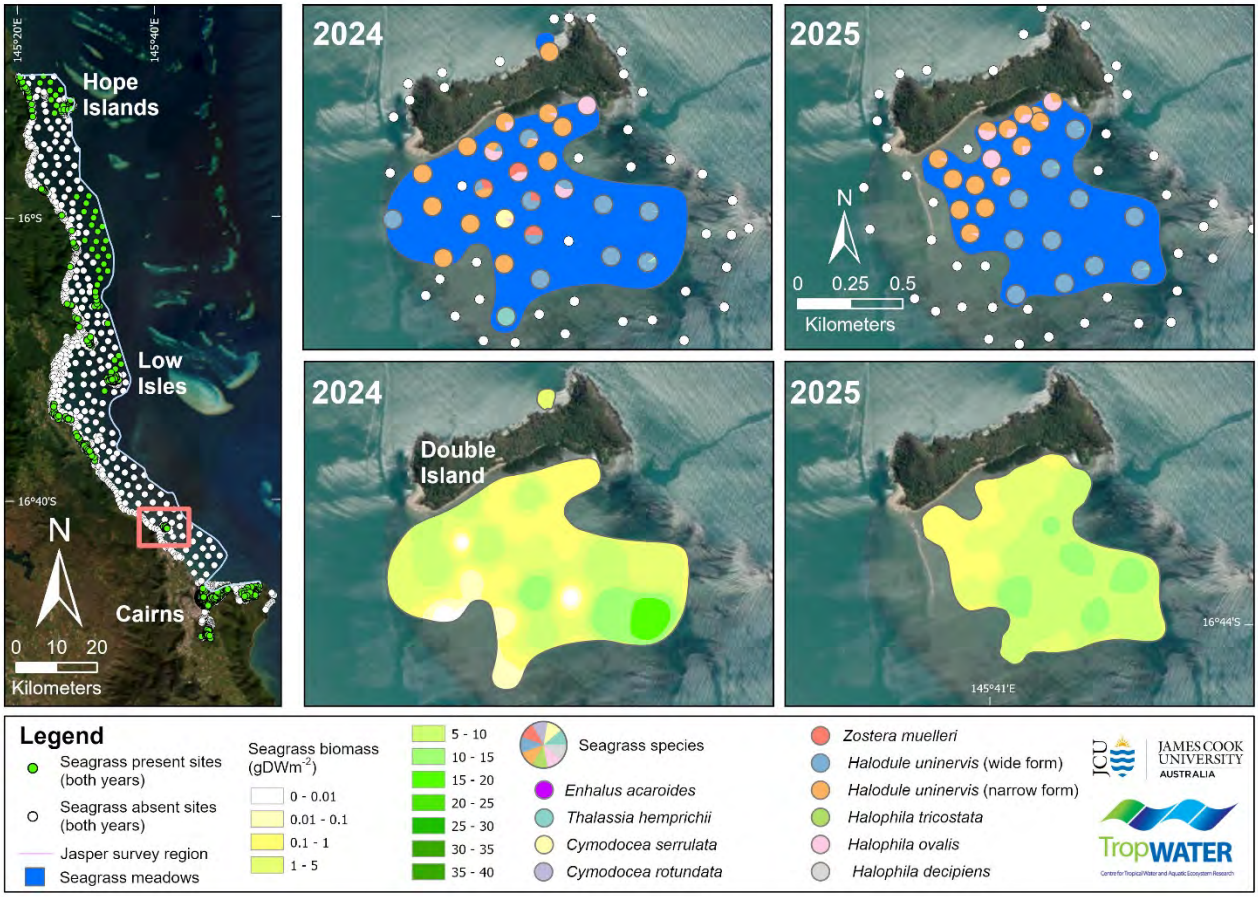


Figure 21: Seagrass species and meadows (top panel) and interpolation of seagrass above-ground biomass (bottom panel) for Double Island.

Mission Bay

In 2024, the seagrass meadow in Mission Bay covered an area of 1387.3 ± 175.8 ha and had a mean biomass of 6.08 ± 0.93 gDWm^{-2} (Figure 22). In 2025, the total seagrass extent across the Bay was slightly less at ~1110 ha. In 2025, the seagrass meadow was mapped as two different meadows based on the presence and dominance of *E. acoroides* in that area of the meadow (Figure 22) (see section 2.3.3 on why *E. acoroides* gets separated from the rest of the meadow). Mean meadow biomass in the main section of the meadow decreased in 2025 to 2.88 ± 0.42 gDWm^{-2}. The *E. acoroides* section of the meadow had a mean meadow biomass of 20.91 ± 4.06 gDWm^{-2}. Seagrass cover ranged from 1-40% in 2024, and from 1-20% in 2025.

The dominant seagrass species in the Bay across both survey years was narrow leaf *H. uninervis*. *Cymodocea serrulata*, *E. acoroides, Z. muelleri*, and wide leaf *H. uninervis* were present in both years, while *C. rotundata* was only recorded in 2025.

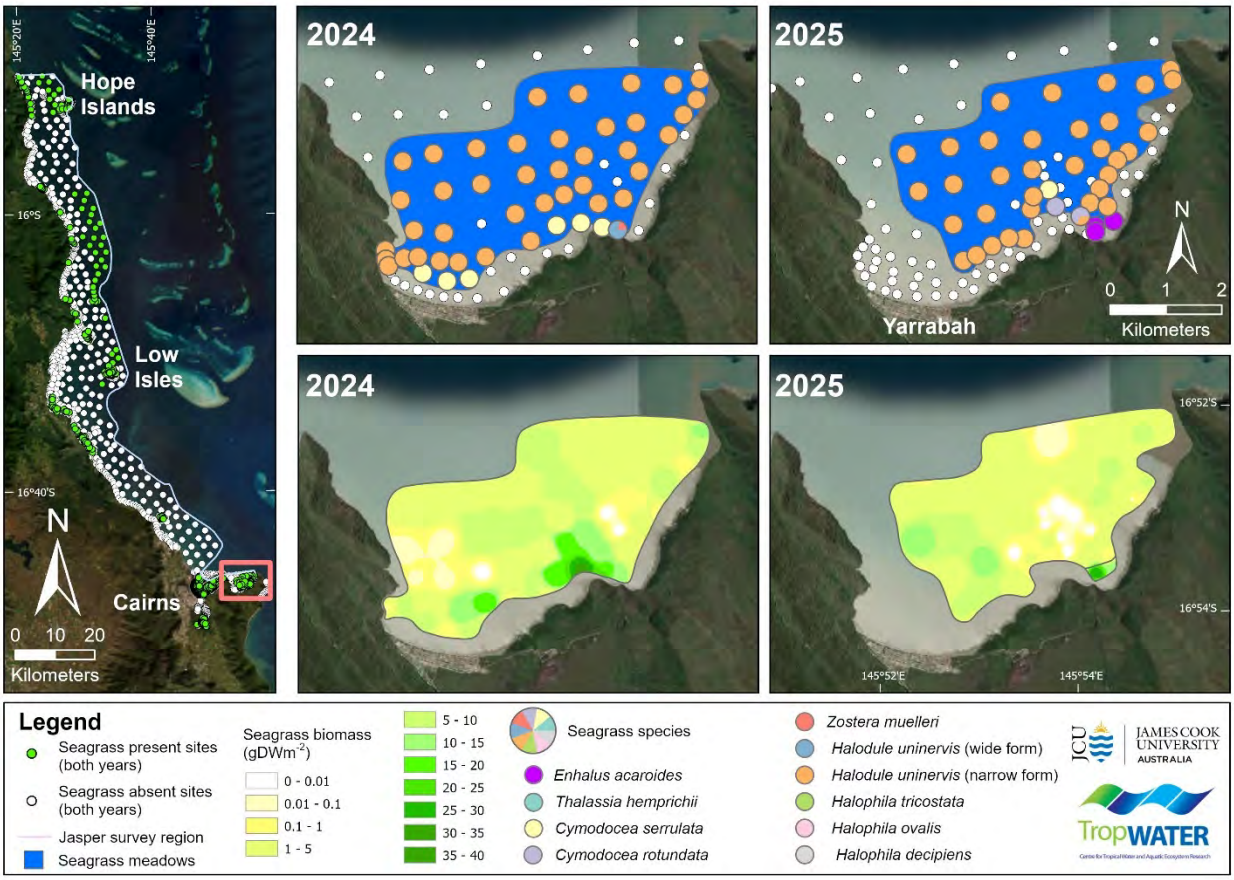


Figure 22: Seagrass species and meadows (top panel) and interpolation of seagrass above-ground biomass (bottom panel) for Mission Bay.

Long-term seagrass monitoring in Cairns Harbour (Ports North funded project)

Seagrasses in the Port of Cairns have been monitored since 2001, with six meadows monitored and a seed bank assessment undertaken in two of these meadows annually (Scott et al., 2026). This long-term dataset enables an assessment to be made of seagrass condition based on seagrass biomass, meadow area and the seagrass species present.

Overall, Cairns meadows declined in area and above-ground biomass between 2023 (pre-TC Jasper) and 2024. For the Bessie Point meadows (Figure 24), the extent of seagrass continued to decline from 2024 to 2025, while for the Esplanade meadow (Figure 23) area remained stable and the biomass continued to decline.

The estuarine meadows in Trinity Inlet also declined in condition (Scott et al., 2026). This change may be due to reduced light levels recorded following TC Jasper. Benthic light monitoring conducted as part of the program showed that the meadows in the inlet received light below their growth requirements, whereas the harbour meadows were subjected to light below their growth thresholds for a short period of time (Scott et al., 2026).

Despite the documented declines, the long-term monitoring data from this program show how these meadows can recover from acute disturbances. In 2014, the meadows had a very small area and low biomass following steady declines from 2010 due to multiple years of La Niña conditions and TC Yasi in 2011. Despite this, both meadows showed significant recovery from 2014 onwards. In contrast, the more isolated Mourilyan Harbour, 75 km to the south of Cairns, was not able to recover from these climatic conditions, likely due to the diminutive seagrass cover remaining in this more isolated inlet after these disturbances and the limited seed bank present for locally driven recovery (Shepherd et al., 2026).

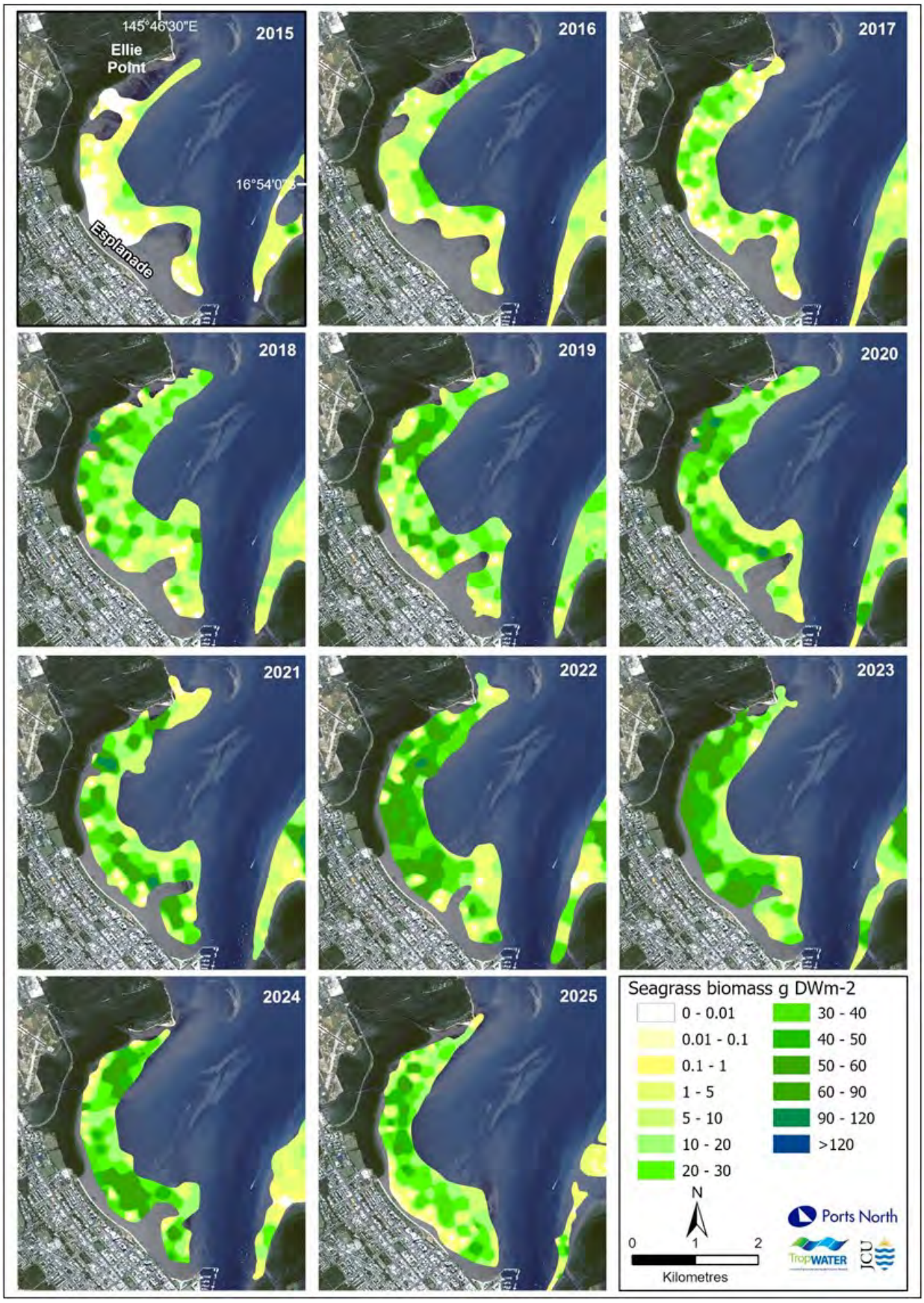


Figure 23: Cairns Esplanade to Ellie Point seagrass monitoring meadows from 2015 to 2025 (Scott et al. 2026). Note this biomass interpolation scale uses a different scale to the preceding figures.

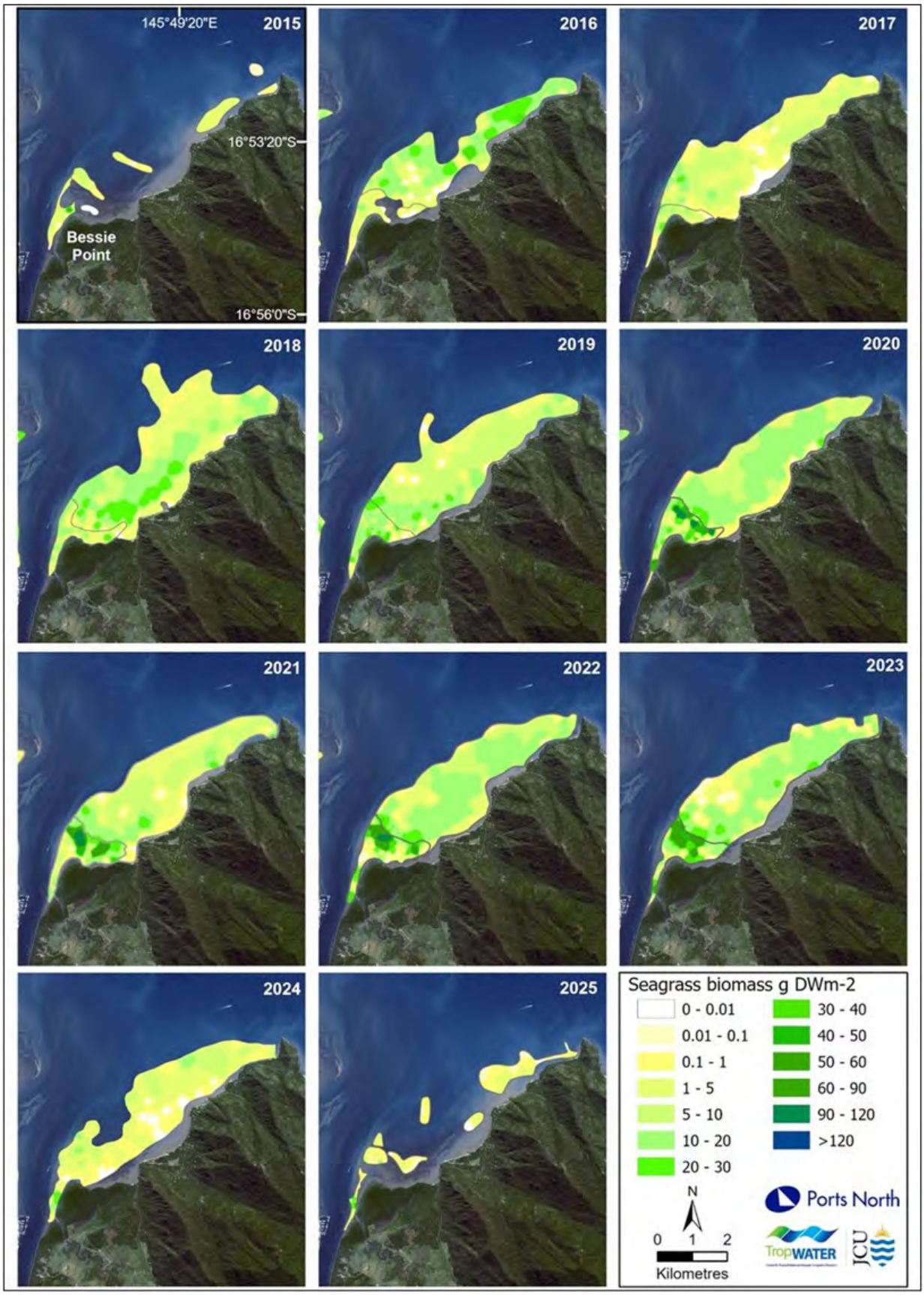


Figure 24: Bessie Point and South Bessie Point seagrass monitoring meadows from 2015 to 2025 (Scott et al., 2026). Note this biomass interpolation scale uses a different scale to the preceding figures.

Long-term Marine Monitoring Program (MMP) seagrass data

Through the Reef Authority's Marine Monitoring Program, JCU TropWATER monitors three locations in the survey region twice a year within a 5 ha area and along fixed transects to track seagrass condition. Data up to September 2025 are available on the Seagrass Watch website (www.seagrasswatch.org/marine-monitoring-program) and in McKenzie et al (2026). The three MMP seagrass locations are Green Island, Yule Point and Low Isles (Figure 25 – Figure 27).

Low Isles

Both MMP sites at Low Isles are dominated by the colonising species *H. ovalis*. The intertidal site at Low Isles (LI1) increased in percent seagrass cover after TC Jasper, from 4.7% in September 2023 to 13% in April 2024 (Figure 25). However, there were large fluctuations between pre- and post-wet season surveys over the past few years, and the most recent September 2025 survey had a similar percent cover (5.3%) to pre-TC Jasper levels. The subtidal site (LI2s) declined from 8.1% cover in October 2023 to 0.5% in May 2024. By September 2025 there was some limited recovery to 4.3%.

Site LI1 was within the meadow mapped as part of the boat and helicopter surveys, whereas LI2s which had a very low seagrass percent cover post-TC Jasper was just outside the mapped meadow in both years.

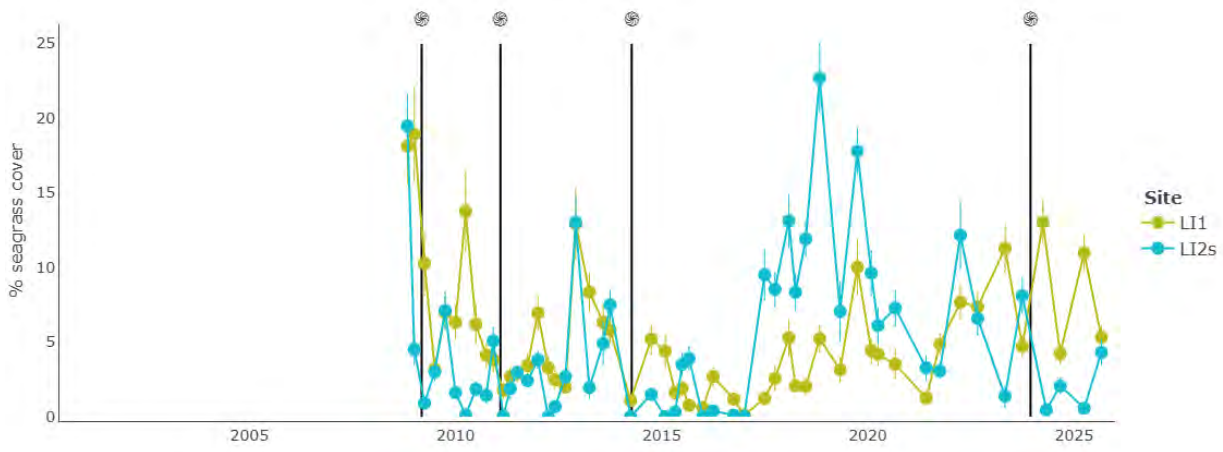


Figure 25: Reef Authority's Marine Monitoring Program long-term seagrass data showing seagrass percent cover at both Low Isles sites. Source: www.seagrasswatch.org/marine-monitoring-program. Vertical lines indicate tropical cyclones.

Yule Point

Both MMP sites at Yule Point are located on the intertidal bank and are dominated by *H. uninervis,* with *H. ovalis* also present. These sites both had a similar pattern with a sharp decline in seagrass percent cover (22.7% at YP1 and 12.2% at YP2) after TC Jasper (Figure 26). By September 2025, YP1 had recovered by 3.4% and YP2 by 2.2%; however, both sites had cover well below that recorded over the past 10 years. This data shows cycles of decline and recovery in this meadow over the duration of the monitoring period.

Site YP1 was outside the meadow mapped by helicopter in this project, whereas site YP2 was inside the mapped meadow. Figure 20 shows this meadow was low biomass with patchy cover over both survey years.

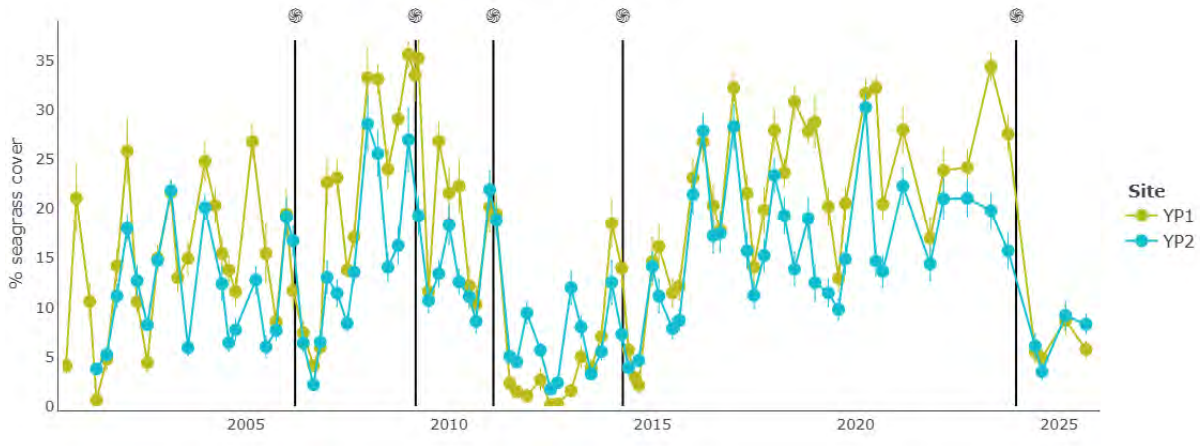


Figure 26: Reef Authority's Marine Monitoring Program long-term seagrass data showing seagrass percent cover at both Yule Point sites. Source: www.seagrasswatch.org/marine-monitoring-program. Vertical lines indicate tropical cyclones.

Green Island

At Green Island off the coast of Cairns there are three MMP sites, GI1 and GI2 are intertidal sites located on the reef flat and are dominated by *C. rotundata* and *T. hemprichii.* GI3 is a subtidal site in the lagoon with a diverse species mix. There was a decline in percent cover at all sites in the surveys leading up to TC Jasper (Figure 27). Both intertidal sites slightly increased in percent cover after TC Jasper and continued a trajectory of improvement over the following surveys. The subtidal site GI3s decreased in percent cover from 26.5% in November 2023 to 21.3% in June 2024; however, this had recovered to pre-cyclone levels by the following survey.

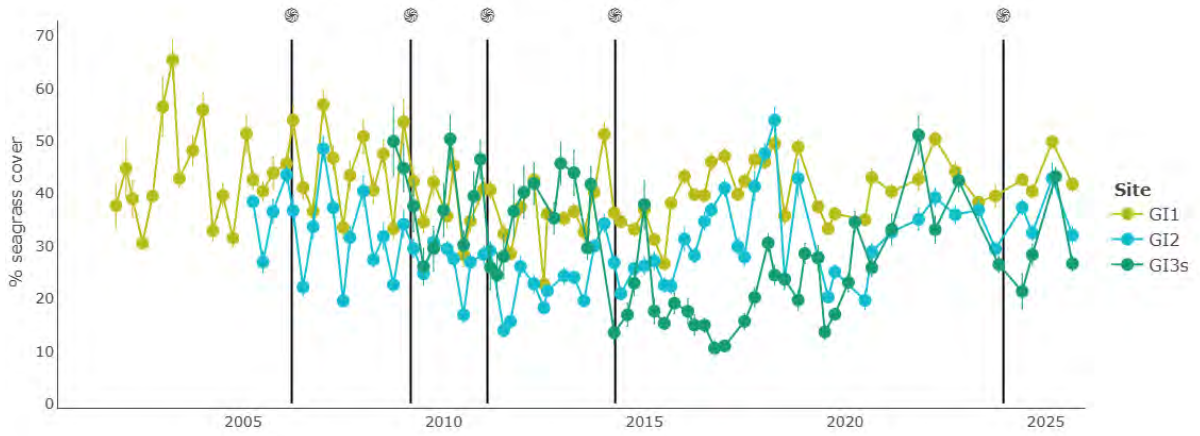


Figure 27: Reef Authority's Marine Monitoring Program long-term seagrass data showing seagrass percent cover at all three Green Island sites. Source: www.seagrasswatch.org/marine-monitoring-program. Vertical lines indicate tropical cyclones.

Data from Gunggandji-Mandingalbay Yidinji Peoples Prescribed Body Corporate

Data collected by GMYPPBC rangers in partnership with JCU TropWATER in the Ganyjira Beach area south of Yarrabah show there was a decline in intertidal seagrass post-TC Jasper. A targeted survey was conducted by the rangers in March 2024 to specifically understand the impacts TC Jasper had on their home monitoring meadow (Figure 28). There were fewer sites with seagrass present and a smaller overall footprint of seagrass in 2024. There was also evidence of burial of the seagrass meadow and significant erosion of the beachfront from TC Jasper. This data was adjacent to the reef area where drone surveys documented declines in coral cover related to significant freshwater runoff (Figure 38).

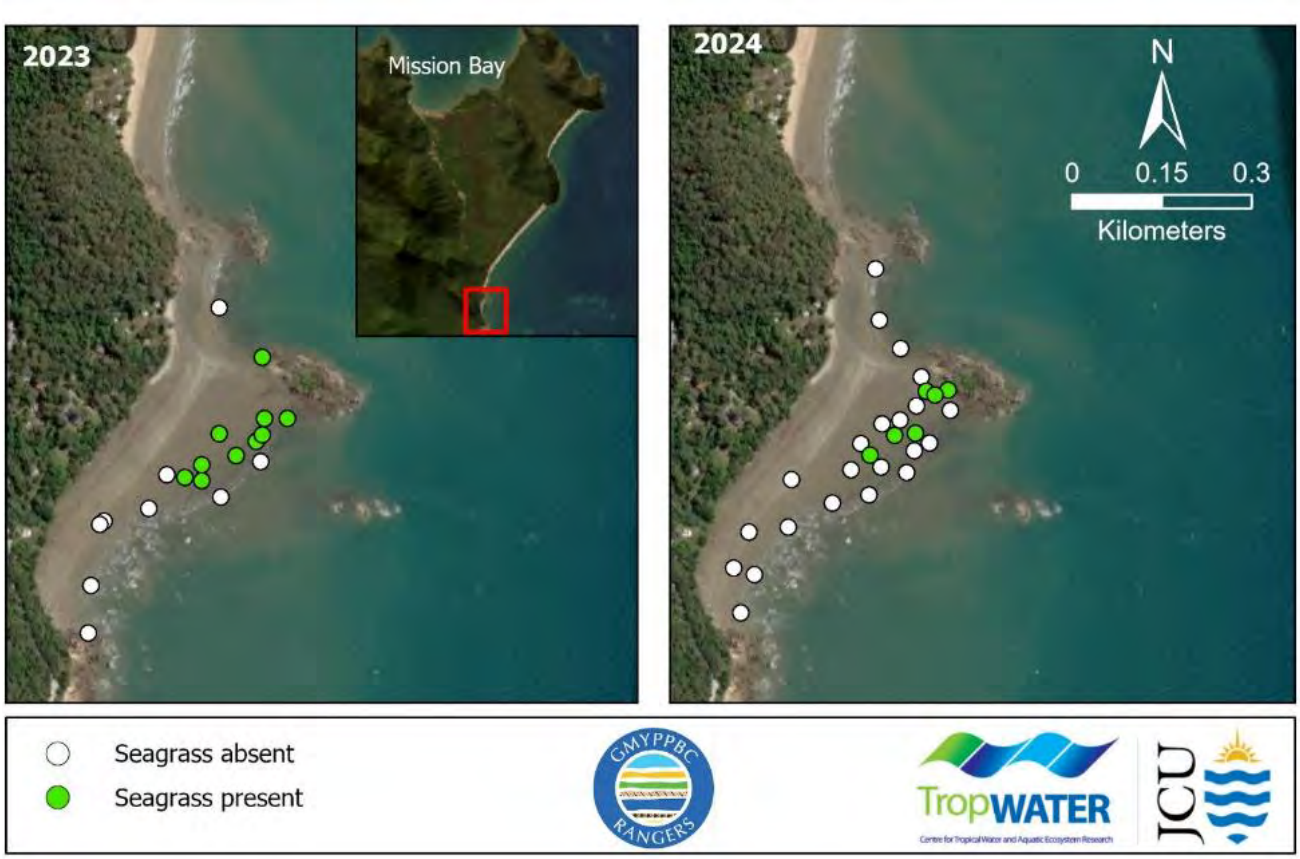


Figure 28: Seagrass data from Ganyjira Beach in 2023 and 2024. Data provided by Gunggandji-Mandingalbay Yidinji Peoples Prescribed Body Corporate (GMYPPBC).

Data from Mandubarra Aboriginal Land and Sea Incorporated

Data from Cowley and Kurrimine Beach collected by Mandubarra rangers in partnership with JCU TropWATER also recorded coastal seagrass declines related to TC Jasper impacts (Figure 29). In 2023, prior to TC Jasper, seagrass was present at 71 of 124 sites surveyed, whereas in 2024 after TC Jasper only 26 of 270 sites surveyed had seagrass present.

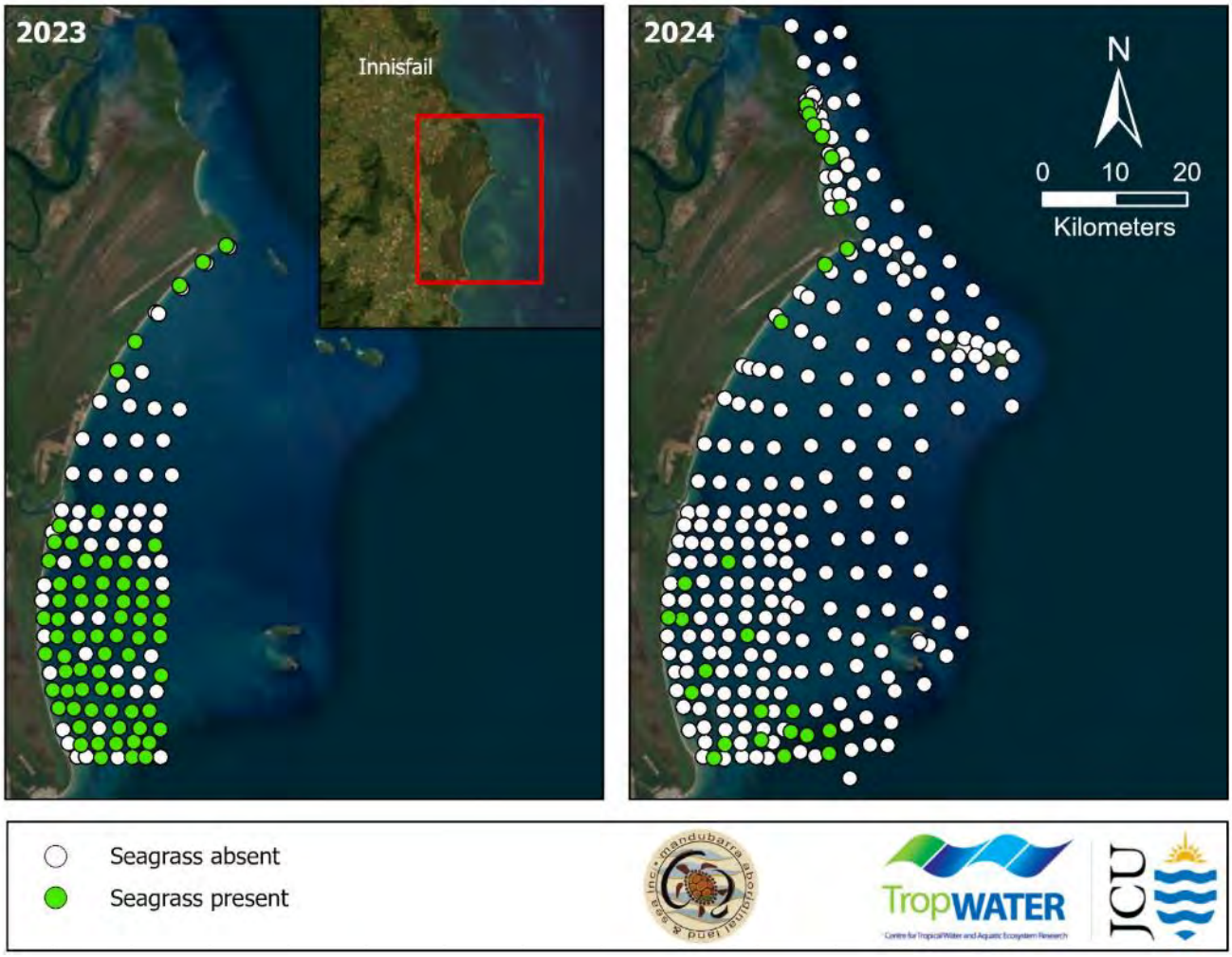


Figure 29: Seagrass data from Mandubarra sea country from 2023 and 2024. Data provided by Mandubarra Aboriginal Land & Sea Incorporated.

Summary of TC Jasper impacts on seagrasses in the region

This project substantially improved understanding of seagrass distribution and condition across a historically data-poor region through two years of coordinated post-TC Jasper surveys integrated with long-term and Traditional Owner-led monitoring programs.

The regional response of seagrass meadows was variable. Some meadows showed substantial declines in area, above-ground biomass, cover or species composition, while others showed relatively little change. Long-term monitoring programs and Traditional Owner-led monitoring demonstrated that impacts extended beyond the primary survey region.

The second year of surveys recorded greater seagrass area and increases in above-ground biomass and percent cover at many sites. Some of these differences are likely to reflect improved survey timing and access to reef-top meadows, while repeated surveys at several locations also recorded increases in seagrass condition between years.

Comparing with modelled and satellite data

As part of this project, satellite imagery and predictive habitat models were assessed as potential sources of information on pre-disturbance seagrass distribution in the region.

Satellite data

Satellite data from a range of sources was investigated as a potential historic data source to compare with the 2024 and 2025 post-impact surveys. Without good data to train a hindcast model, however, it is challenging to use this imagery. Figure 30 shows a comparison of satellite imagery and survey data highlighting the challenge in detecting seagrass from satellites, even with high resolution imagery.

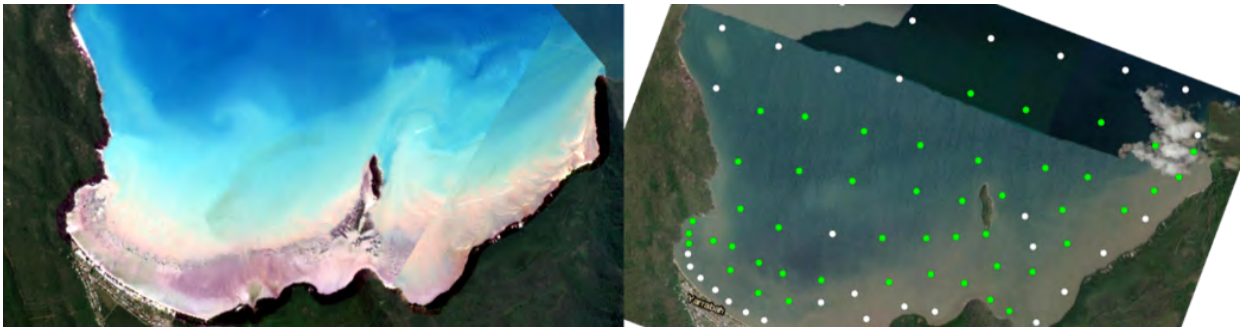


Figure 30: Queensland Globe imagery for Mission Bay (Yarrabah) in 2024 (left) compared to survey data with green and white dots showing seagrass presence and absence, respectively, from the 2024 survey (right).

Probability models

The seagrass probability model in Carter et al., (2021) identified potential seagrass habitat in the Great Barrier Reef and is shown for the survey region in Figure 31. This model predicts some of the coastal seagrass and identifies the deeper water hotspots observed during post-TC Jasper impact surveys. The added data can be used to better inform these types of models, improving model accuracy and our understanding of seagrass distribution in the more remote areas.

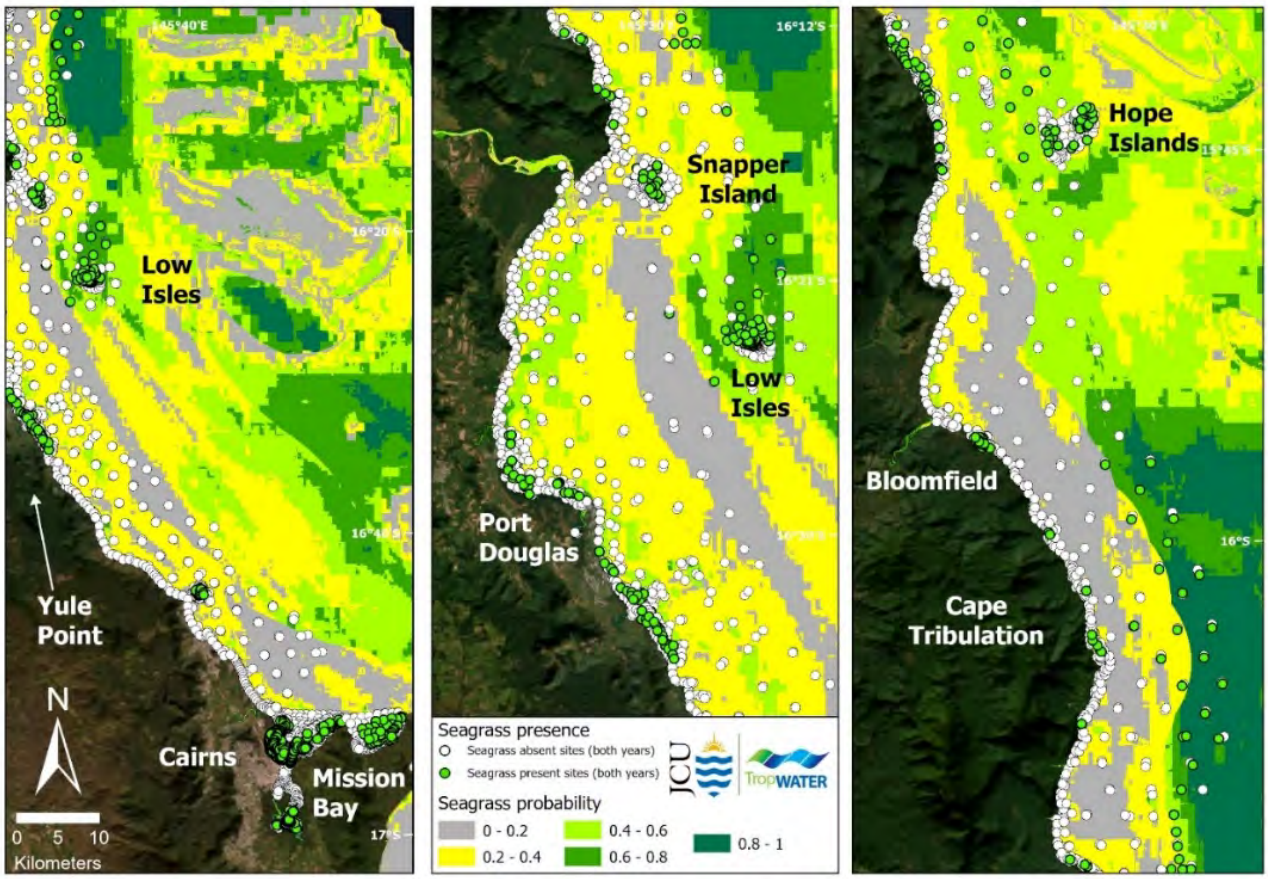


Figure 31: Seagrass survey data from 2024 and 2025 compared to predicted probability of seagrass presence across the GBRWHA (Carter et al., 2021).

Coral data

This section presents the coral habitat results of this project collected in 2024 and 2025, and drone imagery collected pre- and post-TC Jasper. This data is compared to long-term Marine Monitoring Program data to add to our understanding of the impact of TC Jasper on habitats in the region.

Regional scale coral data

Rapid assessment helicopter and boat-based surveys found few live corals on coastal fringing reefs in the survey region and numerous mud-smothered reefs impacted by floodwaters (Figure 32 and Figure 33). Of the 1,143 coastal intertidal and shallow subtidal sites surveyed, only 11 sites were recorded with live coral. In 2024, this was only one intertidal site off Struck Island and one subtidal site off Yule Point, both with ≤1% hard coral cover. In 2025, there were two intertidal coastal sites that had 1% cover north of Cape Tribulation. At Struck Island, there were seven shallow subtidal coastal sites in 2025 with coral between 4-7 m deep and with 1-15% cover.

On the islands surveyed—Double Island, Low Isles, Snapper Island and Hope Isles—some hard coral was still present in intertidal and subtidal areas (Figure 32). These are discussed in more detail below.

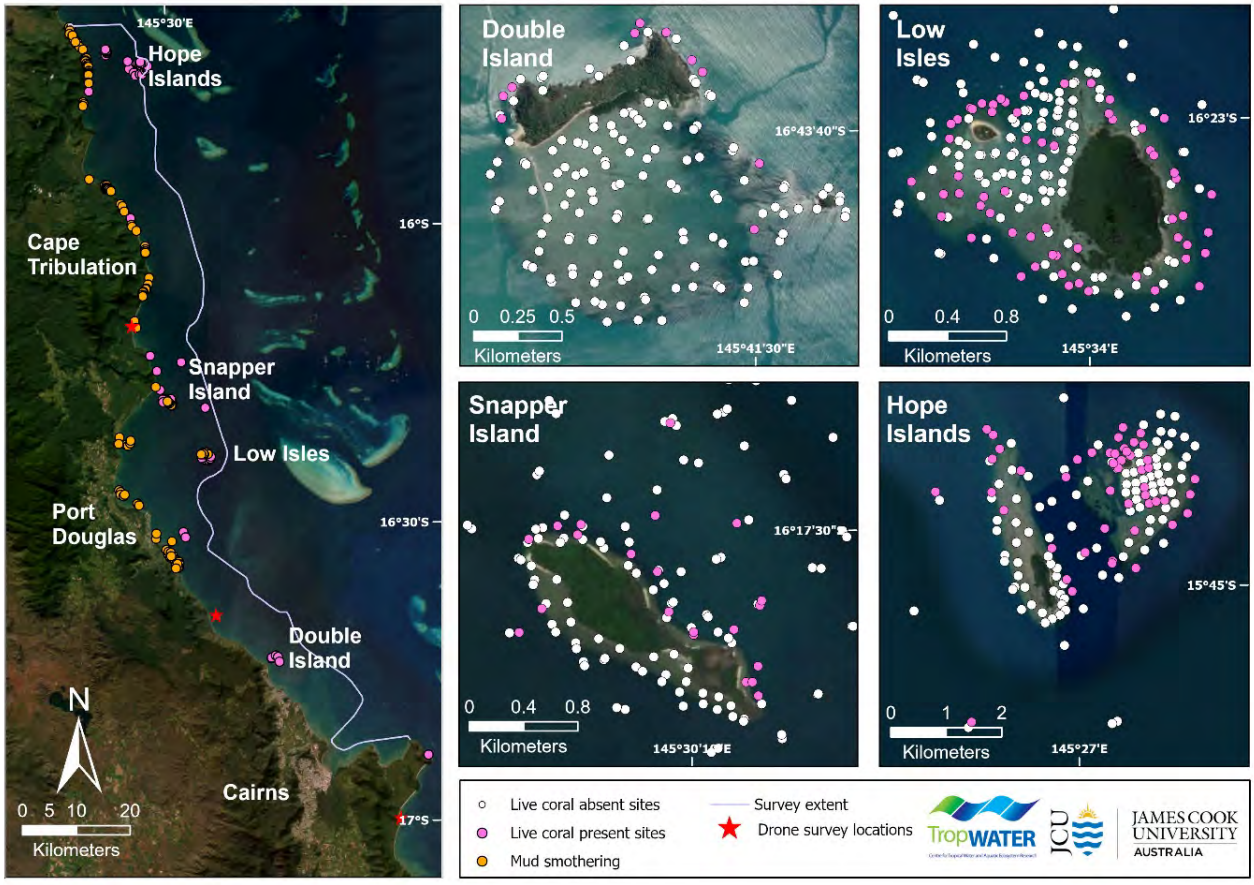


Figure 32: Habitat assessment sites with live coral and mud-smothered reefs throughout the survey region. Live coral presence/absence is also shown for the four Islands in the survey region.

Mud smothering was documented at reefs throughout the survey region (Figure 32 and Figure 33). Some of the mud smothering appeared to be sediment deposition after TC Jasper floodwaters, where coral wall structure was still clearly visible and reefs had died quite recently. However, sedimentation at some sites was on top of eroded reefs which had died prior to TC Jasper (Figure 33). In addition, coral mortality was more likely driven by sustained hyposaline conditions associated with TC Jasper floodwaters than by sediment deposition, with sediment subsequently settling on already-dead colonies. While limited data is available to identify living coral prior to TC Jasper in the region, pre-TC Jasper drone surveys found that live corals were present at two reefs (Struck Island and Unity Reef) in the survey area and one reef (Ganyjira) just to the south (see section 0). The impacts of flooding were observed from Yule Point to the northern extent of the survey region at Whalebone Beach (Figure 32).



Figure 33: Mud smothered reefs with historic death (left) and more recent death likely caused by TC Jasper flooding (right).

Hope Islands and Snapper Island

At Hope Islands, near the northern survey boundary, there were 145 sites surveyed, of which 47 sites had live hard coral and one site had only soft coral (Figure 34). Hard coral cover ranged from 1 - 70%, with 12.6% average hard coral cover, and bleaching observed at some sites. The coral community here was diverse with all coral morphotypes present.

Around Snapper Island, 142 sites were surveyed with live hard coral at 22 sites ranging from 1 - 50% cover and three sites with soft coral (Figure 34). Mean hard coral cover was 5.7% and all coral morphotypes were present except for vase/foliose coral. On the southern side of Snapper Island, only two of 47 surveyed sites had live coral present, both with only 1% coral cover.

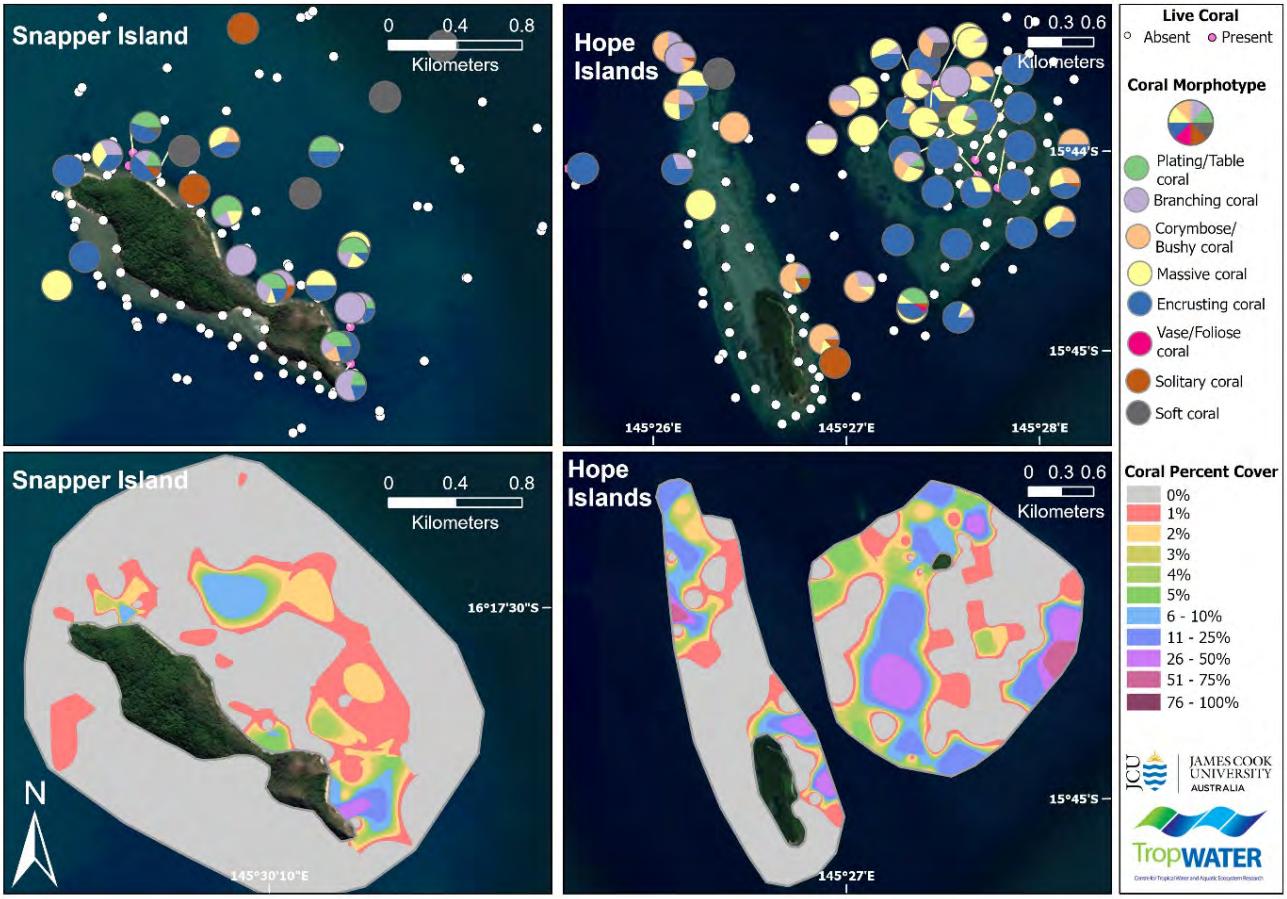


Figure 34: Live coral presence/absence, coral morphotypes and percent cover of live coral at Snapper Island and the Hope Islands.

Low Isles and Double Island

At Low Isles, 190 sites were surveyed for coral habitat. Sixty sites had live hard coral present with percent cover ranging from 1 - 40% (average of 7.1%) and five sites with only soft coral (Figure 35). Corals were dominated by massive and encrusting morphotypes, with all morphotypes present apart from vase/foliose.

There were 10 sites at Double Island with live hard coral out of 144 surveyed. The cover ranged from 1 - 70%, with an average cover of 14.5% and a range of morphotypes present. Cover was limited to the fringes and slopes of the northern and eastern reef perimeter. There were no vase/foliose, solitary or soft corals present at assessment sites.

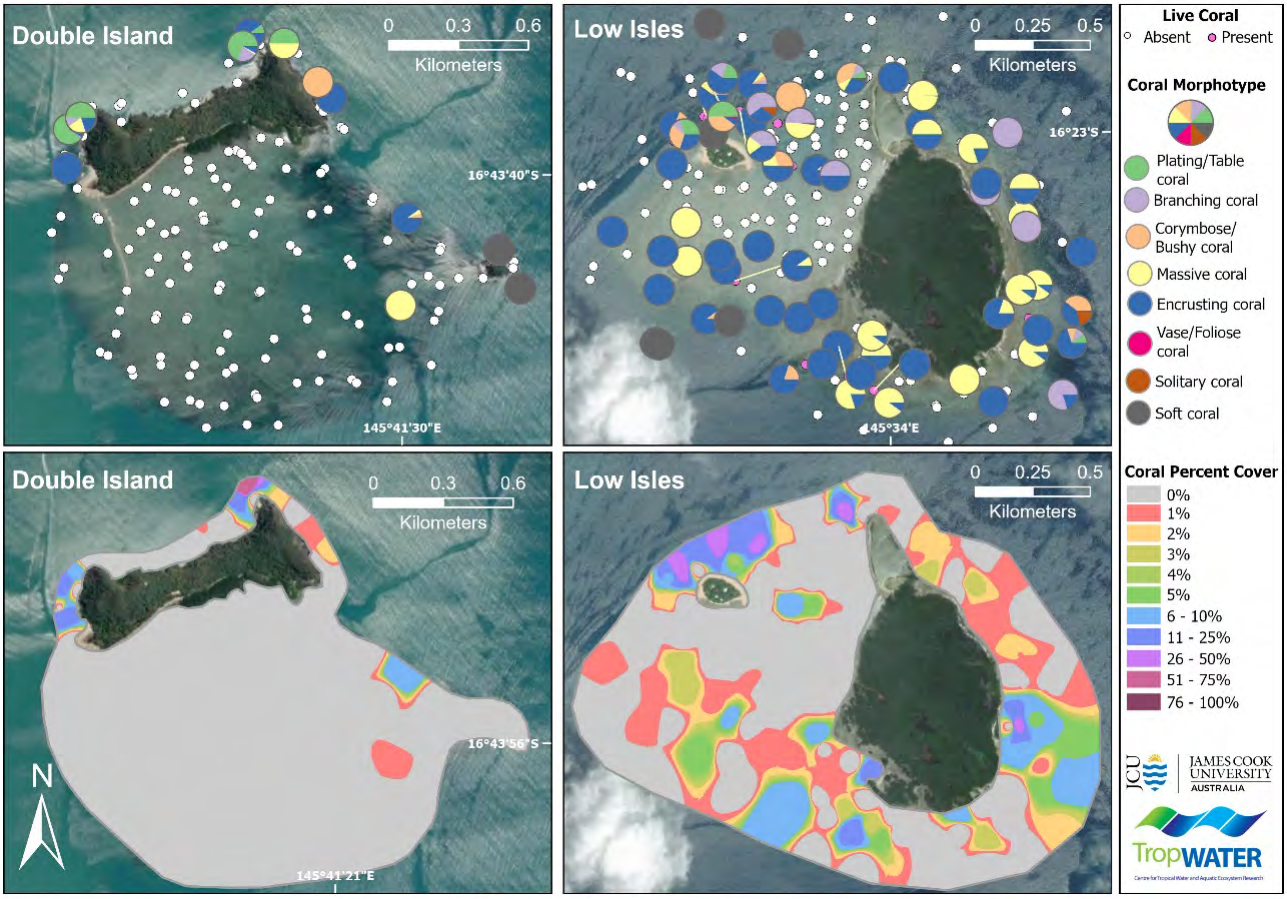


Figure 35: Live coral presence/absence, coral morphotypes and percent cover of live coral at Double Island and Low Isles.

Pre- and post-TC Jasper drone surveys

Drone imagery comparing coral cover pre- and post-TC Jasper was carried out at locations in Figure 5. This data is shown in Table 8 and - Figure 38. The imagery shows that all inshore reefs had high coral cover ranging from 74 - 87% prior to TC Jasper, with effectively no live corals visible during post-impact surveys. The drone imagery also shows high levels of sedimentation at Unity Reef after TC Jasper, which may be due to the presence of turfing algae trapping sediment (Figure 37, J. Gaskell *pers. obs.*).

Table 8: Percent cover at inshore reefs surveyed prior to TC Jasper.

	Coral morphotype	**Ganyjira (Yarrabah)**	**Unity Reef (Wangetti Beach)**	**Struck Island (Thornton Beach)**
Average Percent Cover	Branching Hard coral	1	8	16
	Corymbose Hard Coral	0	9	1
	Encrusting Hard Coral	17	6	11
	Foliose Hard Coral	23	25	36
	Plate Hard Coral	2	23	15
	Massive Hard Coral	5	0	1
	Solitary Hard Coral	0	1	0
	Soft Coral	25	2	7
	Macroalgae	9	16	3
	Other Benthos	16	10	10
Total Coral Cover %		**74**	**74**	**87**
Number of Images analysed		**33**	**41**	**21**



Figure 36: Drone surveys around Struck Island (Thornton Beach) before TC Jasper (November 2022) and after TC Jasper (January 2025).



Figure 37: Drone surveys at Unity Reef (Wangetti Beach) before TC Jasper (April 2022) and after TC Jasper (August 2024).

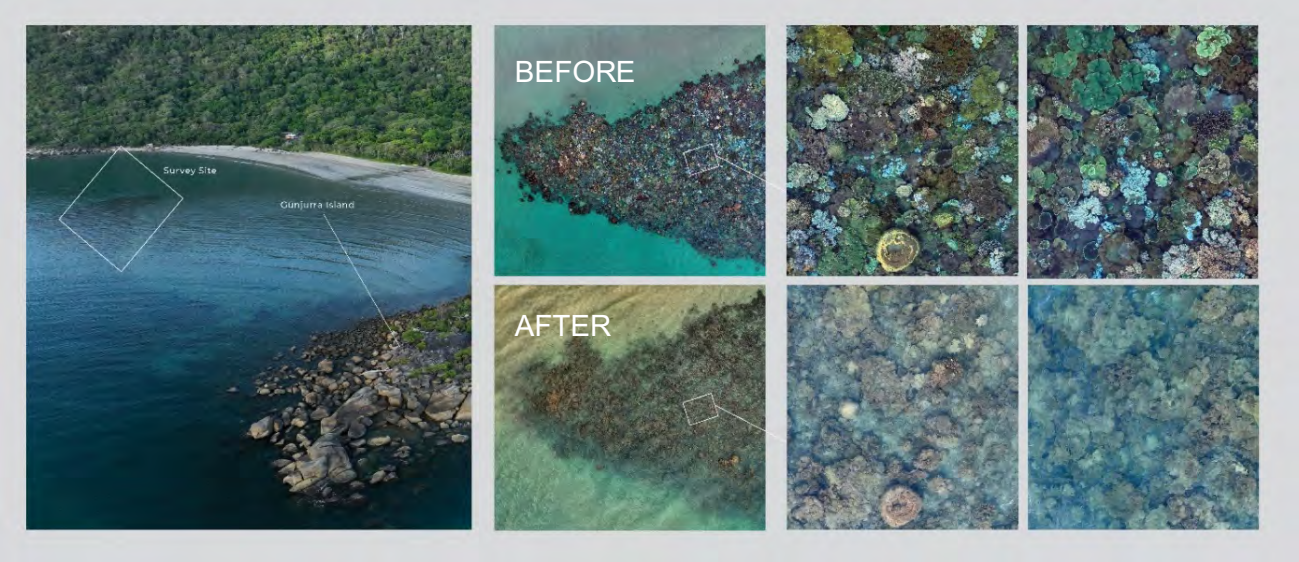


Figure 38: Drone surveys at Ganyjira Reef (Yarrabah) before TC Jasper (April 2022) and after TC Jasper (October 2024).

Long-term Marine Monitoring Program (MMP) coral data

The Reef Authority's long-term Marine Monitoring Program (MMP) at Snapper Island (see Thompson et al. 2026) found unprecedented declines in coral cover at their sites. At the South site, coral cover before TC Jasper was ~50%, with coral cover reduced to 0% in 2024 and 2025 surveys (Figure 39: Marine Monitoring Program data from Snapper Island north (left) and south (right) (AIMS, 2014). Source: https://apps.aims.gov.au/reef-monitoring.

). At the shallower North site, there were dramatic declines from 17% hard coral to 4% post-cyclone and 6% in 2025. In contrast, the deeper North site sustained no hard coral losses in 2024 and showed a positive trend in cover in 2025. The more severe impacts on the southern side of the island likely reflect direct exposure to Daintree River floodwaters, with the opposing faces partially sheltered by the island mass.

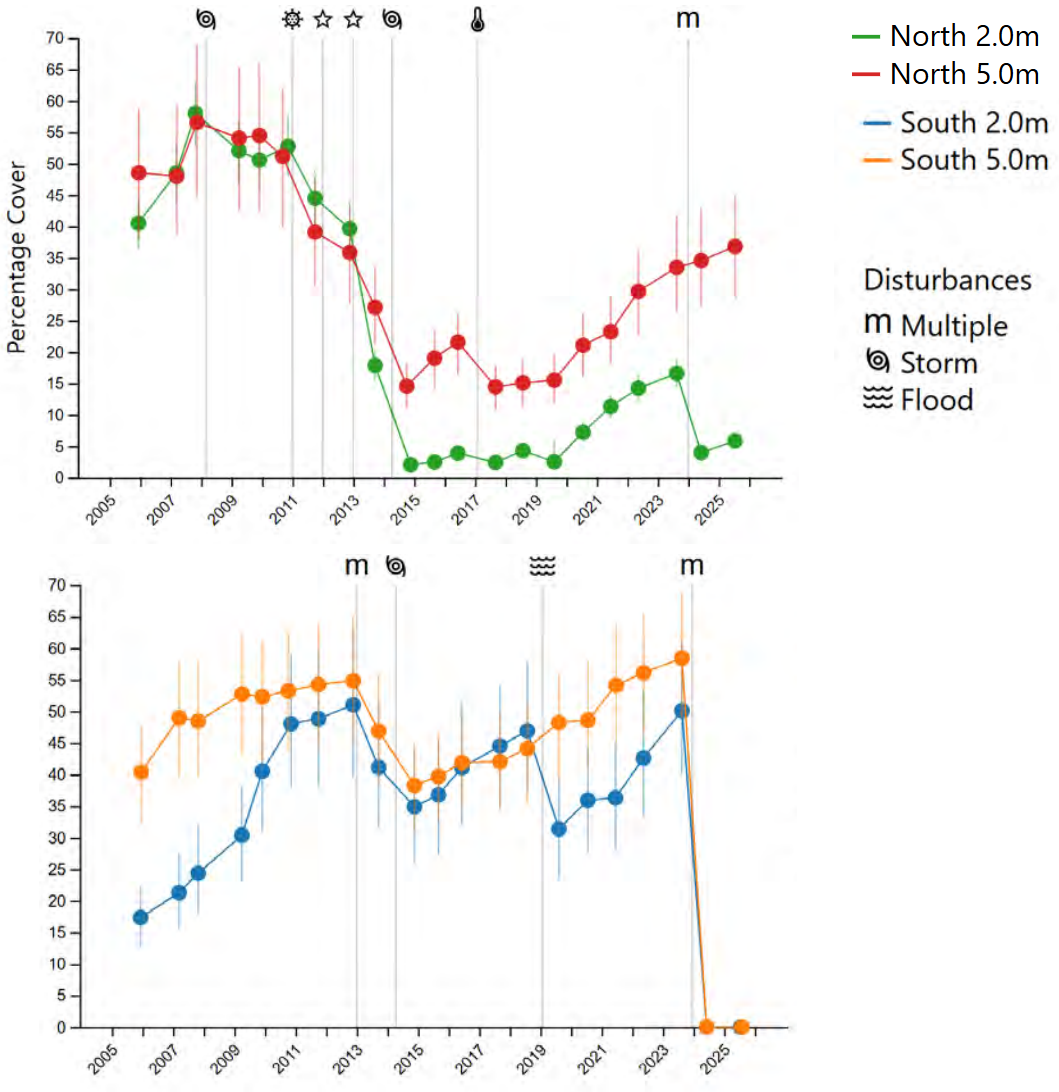


Figure 39: Marine Monitoring Program data from Snapper Island north (left) and south (right) (AIMS, 2014). Source: https://apps.aims.gov.au/reef-monitoring.

Manta tow surveys record reef-wide hard coral cover as a secondary measure of reef state. At Low Isles, this data showed a decline in coral cover from the highest level recorded of 51.1% before TC Jasper to 29.6% in 2025 and 29.4% in 2026 (Figure 40: Marine Monitoring Program manta tow survey data from Low Isles (AIMS, 2014). Source: https://apps.aims.gov.au/reef-monitoring.).

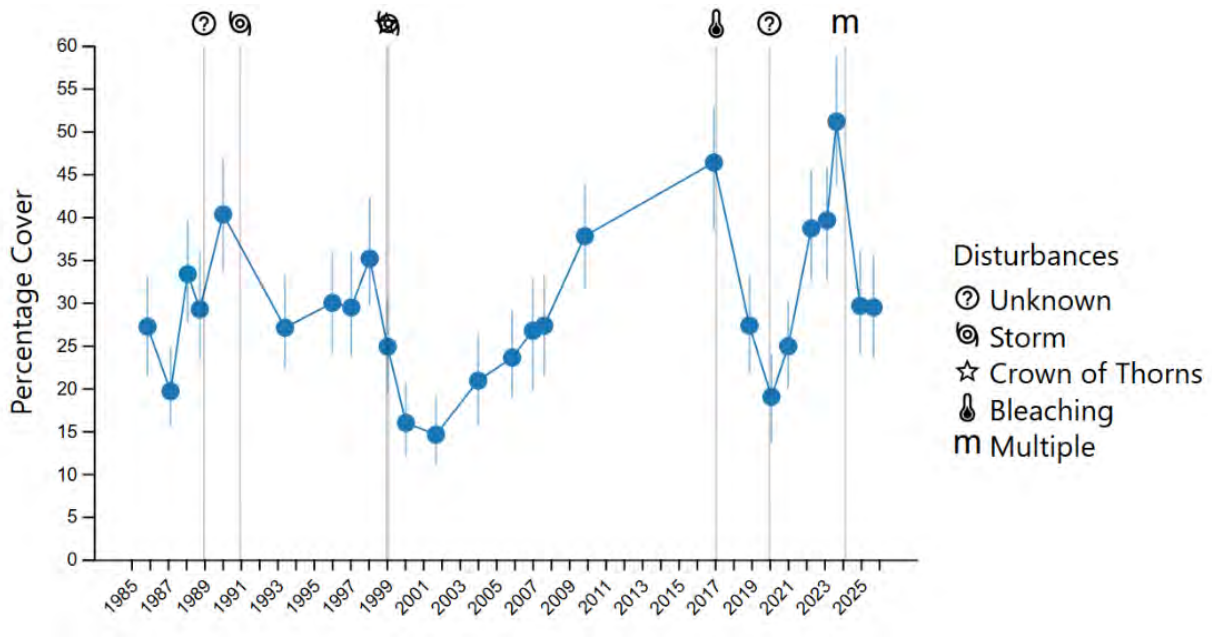


Figure 40: Marine Monitoring Program manta tow survey data from Low Isles (AIMS, 2014). Source: https://apps.aims.gov.au/reef-monitoring.

Summary of TC Jasper impacts on corals in the region

Field surveys recorded extensive coral mortality at many inshore reefs, with very little live coral observed at numerous locations during both survey years. Some of the reefs appeared to have died recently due to flooding associated with TC Jasper, whereas others appeared more eroded, indicating they had died prior to TC Jasper.

Drone data provided clear evidence of high coral cover at three inshore reefs in the region, all of these had almost no live corals seen after TC Jasper. Field observations showed recent damage to reefs around Cooya Beach; however, drone data shows that the damage to corals due to flooding and sedimentation impacted much of the survey region, beyond the Daintree catchment. MMP data from Snapper Island shows unprecedented losses of corals that were in the direct path of the flood plume.

4. Discussion

Overview: Scale and nature of Impact

TC Jasper made landfall as a Category 2 cyclone, but the scale of ecological impact was driven primarily by the hydrological aftermath rather than wind damage. Record-breaking rainfall, including the highest 24-hour total reliably measured in Australia, produced catastrophic flooding across steep, saturated catchments, delivering an unprecedented pulse of sediment and freshwater into inshore coastal and marine environments along a regional coastline from Cooktown to Kurrimine Beach. The result was simultaneous, severe impacts across mangrove, seagrass and inshore coral reef habitats at a scale not previously documented for a single disturbance event in this region of the Great Barrier Reef. This report presents the first coordinated regional assessment of those impacts and two years of post-impact and early recovery data, a critical reference point for understanding how these ecosystems respond to cumulative disturbance events that are likely to increase in frequency and intensity under projected climate trajectories.

The baseline problem: What we didn't know before TC Jasper

One of the most significant constraints on this assessment is the near-complete absence of pre-disturbance data for inshore coral reefs and seagrass across the Cooktown – Cairns coast.

For coral reefs, drone imagery from Struck Island (Thornton Beach), Unity Reef (Wangetti Beach) and Ganyjira Reef (Yarrabah) provides direct evidence that reefs with greater than 74% coral cover existed, where surveys now record effectively zero. But these three sites are exceptions; for most of the inshore reef system, pre-disturbance condition is unknown. This is further complicated by the observation that sediment smothering in some areas has buried reefs that had already died prior to TC Jasper, making it difficult to attribute all recorded losses to the cyclone event specifically.

The pre-existing seagrass record for the region is similarly limited. The regional synthesis layer (Carter et al., 2016) contained just 80 data points in the survey region, most from the 1980s, insufficient as a pre-disturbance baseline. Without knowing what was there before, the true scale of loss cannot be quantified, and recovery targets cannot easily be measured or set.

This contrasts with nearby areas that have long-term monitoring data. The Ports North Long-Term Seagrass Monitoring Program, Reef Authority's Marine Monitoring Programs (seagrass and coral), and the ranger-led seagrass programs of GMY and Mandubarra all provided meaningful pre/post context that project surveys conducted after the event could not. These programs demonstrate what sustained monitoring makes possible: the ability to detect change, define trajectory and identify where intervention may be warranted. Closing equivalent data gaps, although logistically challenging, across inshore reef and seagrass habitats before the next major event would help drive effective and appropriate investment in interventions and/or management decisions.

Mangroves: Damage mechanisms and potential recovery

TC Jasper caused extensive and, in some cases, unprecedented damage to mangroves across the Daintree and Bloomfield Rivers, representing the most significant recorded dieback event in this region. Two primary mechanisms drove mangrove losses across the survey region. In the Bloomfield system, direct physical destruction from floodwaters dominated, with flood damage, bank erosion and shoreline erosion recorded at or near maximum severity across extensive proportions of the surveyed coastline. In the Daintree, sediment burial was the defining stressor: deposited sediment in dead mangrove stands averaged nearly 11 cm depth compared to 6 cm in adjacent living stands, consistent with burial-driven mortality even in large, structurally mature trees. Of particular concern were large patches of standing dead mature mangrove trees, an indicator not previously observed in this region, likely resulting from sediment deposition that buried aerial roots and suffocated well-established stands, some estimated to be over 200 years old. Satellite-derived estimates indicate losses of approximately 576 ha from the Daintree and 89 ha from the Bloomfield by 2024, with negligible recovery in extent evident by 2025.

The death of mature trees from root burial presents a delayed risk of sediment remobilisation. As root systems degrade over the next 5-6 years, the potential for large-scale release of both recently deposited and foundation sediments increases, with implications for downstream water quality and the health of adjacent inshore habitats including seagrass meadows and coral reefs. Where extensive dead timber stands overlie accumulated sediment, decomposition and peat subsidence may also shift affected areas outside the elevation range suitable for pre-disturbance species, or in more extreme cases below the viable mangrove zone altogether.

There are early signs of recovery across both systems. Aerial survey stressor scores declined between 2024 and 2025, though they remain well above pre-cyclone levels. Seedling survival was high even within stands where the mature canopy was lost, suggesting active recruitment is underway. However, satellite imagery indicates recovery in canopy cover remains in early stages and does not represent a return to pre-cyclone forest conditions; recent regrowth will not yet have equivalent biomass, carbon storage, or ecological productivity as the former forests. Whether recovery continues will depend in part on the survival of recently established seedlings in future flood events, which may occur before adequate root establishment has been achieved. Full structural recovery will likely take decades.

For most affected areas, natural regeneration is the most appropriate initial management response. Mangroves are highly effective natural dispersers and colonisers, and in many instances, intervention may achieve greater impact by reducing barriers to propagule dispersal rather than direct planting. No restoration techniques exist at the scale required for environments of this complexity, and active planting carries a high risk of failure where site elevation, tidal regime, and species suitability have not been carefully assessed. Reviews of restoration projects in Southeast Asia have found average propagule survival rates of only 20%, with mudflat plantings as low as 1.4%, largely due to mismatched species and elevation (Wodehouse & Rayment, 2019).

Of the areas identified for potential rehabilitative interventions, sediment deposition was the dominant concern at 1,068 ha, predominantly across the Daintree estuary. Where extensive sediment deposition is impeding natural propagule establishment, experimental trials mobilising deposited sediment or testing planting methods on deposited clays would help identify the most effective approach before committing to large-scale intervention. Prior to any works, elevation

surveys at shortlisted sites are advisable, as peat subsidence beneath dead tree stands may have altered the inundation regime relative to pre-cyclone conditions, requiring adjusted species selection.

Areas affected by hydrological modifications such as drains and tidal bunds accounted for 155 ha, where altered tidal connectivity may be impeding recovery independently of cyclone impacts. Tidal barrier removal may appear straightforward in these cases but carries significant risks; accumulated sediments behind bund walls can be remobilised upon breach, potentially smothering downstream ecosystems and exposing acid sulphate soils. Sediment characteristics, volumes, and geochemistry should therefore be assessed prior to any intervention. A further 215 ha was highlighted for further on-ground investigation where impact type or recovery trajectory could not be confidently determined from available data alone. Continued monitoring of all shortlisted areas will remain important for tracking recovery trajectories before committing resources to active works.

Seagrass: patchy decline and early signs of resilience

This project has substantially improved understanding of seagrass distribution and condition across a historically data-poor region and provides the first coordinated regional assessment of seagrass following TC Jasper. Although baseline data were limited prior to the cyclone, the two years of post-event surveys provide an early picture of areas that potentially had seagrass present before the event and early signs of recovery. When interpreted alongside long-term monitoring programs and Traditional Owner-led monitoring, these surveys provide valuable context for understanding changes in seagrass condition at key locations. Importantly, the Gunggandji-Mandingalbay Yidinji and Mandubarra monitoring programs demonstrate that the impacts of the TC Jasper flood event extended beyond the primary survey region, highlighting the value of community-led monitoring for understanding disturbance at regional scales.

Nine seagrass species were recorded across the two survey years, and substantial meadow areas were mapped; 3,532 ha in 2024–25 and 21,033 ha in 2025. The large increase in extent between years is primarily due to the expansion of the deep-water *H. tricostata* meadows, which are known to germinate annually from seed and are only present for a few months each year. Despite relatively strong species diversity, overall densities and patchiness of shallow subtidal and intertidal seagrass were consistent with a community in early recovery from remnant rhizomes and shoots rather than an established meadow.

The long-term Cairns Harbour data provides relevant context. Following TC Yasi and sustained La Niña conditions from 2010–2014, Cairns coastal meadows declined sharply but recovered substantially over subsequent years, most likely from remnant patches (Scott et al., 2026). In contrast, the more isolated Mourilyan Harbour system, south of Cairns, where very little seagrass remained after the same period of disturbance, did not recover (Shepherd et al., 2026). These examples illustrate that the amount and connectivity of remnant patches, rhizomes and shoots, and a potential existing seed bank after a disturbance event strongly influences whether and how quickly recovery occurs. The current status of seagrass in the northern survey area - low density, limited species diversity, reduced connectivity - places it in a vulnerable position which could make recovery challenging.

Seagrass monitoring data contributed by GMY and Mandubarra rangers at Ganyjira, Cowley and Kurrimine Beach confirmed that TC Jasper's effects extended well beyond the most visibly impacted northern sector, providing the only pre/post comparison available at those locations.

The sediment-laden floodwaters associated with TC Jasper exposed seagrass meadows to multiple stressors, including reduced salinity and prolonged periods of poor underwater light availability. The primary acute driver of seagrass decline was likely the loss of light caused by sediment-laden floodwaters (Collier et al., 2012). Additional contributing factors include sustained low salinities, elevated nutrient levels, and sediment burial. These combined stressors are likely responsible for the lower-than-expected seagrass distribution observed during the surveys, relative to predicted seagrass coverage for the region (Carter et al., 2021, McKenna et al., 2015).

The regional response of seagrass meadows was variable rather than uniform. Some meadows showed substantial declines in biomass, cover or species composition, while others appeared relatively unaffected or retained sufficient remnant patches of seagrass to support early recovery. This spatial variability likely reflects differences in flood exposure, local environmental conditions and the availability of remnant plants and seed banks to facilitate recovery once conditions improved.

The second year of surveys recorded increases in seagrass area, above-ground biomass and, at many locations, percent cover. These improvements likely reflect a combination of ecological recovery and differences in survey timing, with the 2025 surveys generally undertaken closer to the peak growing season and under conditions that provided better access to reef-top meadows at Hope Islands. Nevertheless, increases in biomass and cover at several repeatedly surveyed locations provide encouraging early signs of recovery following TC Jasper.

No seagrass restoration techniques have been demonstrated at scale for tropical species under these conditions. Studies which focus on establishing restoration methods for tropical species across a range of habitats should be prioritised to provide methods to help meadows recover after disturbances. Reducing sediment and nutrient input at catchment scale remains the most effective available lever for supporting recovery, though this operates largely outside the scope of direct habitat management.

Coral: Freshwater die-back and mud-smothered reefs

The coral results are the most severe documented in this report. Of 1,143 inshore coastal intertidal/shallow subtidal sites surveyed across two years, only 11 recorded any live coral. Sediment smothering was documented continuously from Yule Point to the northern survey region at Whalebone Beach, and drone imagery at the three sites with pre-disturbance data confirms coastal reefs that previously exceeded 74% coral cover are now at effectively zero. Long-term MMP monitoring at Snapper Island showed that hard coral declined from greater than 50% to 0% at sites on the southern side of the Island between 2-5m that were directly exposed to Daintree River floodwaters (Thompson et al., 2026). This represents one of the most clearly documented cases of flood-driven coral loss on the Great Barrier Reef and one of the most severe impacts of any acute event during the 20-year history of the MMP (Thompson et al., 2026).

Flood-related coral mortality events have been recorded in other parts of the Great Barrier Reef (Pratchett et al., 2026; Jones and Berkelmans 2014). TC Jasper caused reductions in salinity below 25ppt for six days during and after TC Jasper at Dawson Reef, resulting in freshwater bleaching and coral death on inshore to mid-shelf reefs (Howley at al 2024). Salinity was also reduced below 25ppt for over three days at Forrester Reef, located 44km from the Annan River mouth, resulting in freshwater bleaching and coral mortality (Howley et al 2024). Although our data does not determine the cause of mortality on inshore reefs, it is likely to be freshwater stress causing mortality followed by sediments preventing recovery.

Two categories of reef death were identifiable in the survey data: recent post-TC Jasper mortality where coral skeletal structure remained visible after flood damage and beneath sediment smothering, and pre-existing reef degradation (no coral skeletal structure) now additionally buried. This distinction matters both for impact attribution and for recovery expectations, as not all smothered reef represents flood-damaged habitat with realistic potential to return to coral-dominated condition.

The islands - Low Isles, Double Island and the Hope Islands - were less directly exposed to flood plumes and retain meaningful coral communities, albeit reduced. These sites represent a potential source of larval supply for natural recolonisation of coastal inshore reefs if and when conditions allow, although little is known on connectivity amongst inshore coral communities in the region.

Recovery is constrained by a fundamental requirement that sediment must clear from reef surfaces before coral recruitment can occur. This is a passive process with no demonstrated means of acceleration at this scale. No coral restoration methods are feasible under current smothering conditions, and techniques such as coral gardening are not suited to highly turbid coastal inshore environments as turfing algae and sediment can impact successful outplant self-attachment (Scott et al., 2024). Even without further disturbance, fine sediment redistribution in estuarine-influenced systems can persist over multiple years, and the recovery trajectory for these reefs remains uncertain.

Experience from comparable disturbance events elsewhere on the GBR supports a cautious outlook for recovery. Severe Tropical Cyclone Debbie caused coral cover losses exceeding 50% across Whitsunday reefs in 2017, with no significant recovery recorded five to six years later, and a shift toward macroalgal and turf-dominated substrates likely inhibiting coral re-establishment (Srinivasan et al., 2026). Post-cyclonic flooding on Keppel Island fringing reefs caused 40–100% coral mortality correlated with distance from the flood plume, with recovery estimated at 10–15 years – a trajectory subsequently interrupted by further cyclone and bleaching events (Jones and Berkelmans, 2014; Thompson et al., 2026). Even where larval supply has supported some recolonisation, predicted disturbance recurrence intervals are insufficient for recovery of slower-growing species (Torda et al., 2018). The compounding effect of repeated disturbance before recovery is complete is a consistent pattern across inshore GBR reef systems and is particularly relevant to the inshore reefs assessed here.

The value of the baseline now established

While the absence of pre-disturbance data for seagrass and coral is a central limitation of this study, the surveys conducted across 2024–25 have produced the most spatially comprehensive baseline of inshore coastal habitat condition in this region on record. The seagrass mapping in particular fills longstanding data gaps across the Cooktown – Cairns coast, and the combined coral, mangrove and seagrass datasets now provide a reference point from which future change, whether from cyclones, bleaching, or cumulative stress, can be meaningfully assessed.

The contribution of Traditional Owner ranger programs to this baseline is substantial. GMYPPBC and Mandubarra monitoring data provided spatial and temporal coverage that project-funded science alone could not replicate, and their integration into this assessment reflects the broader value of sustained, co-designed ranger monitoring as part of regional reef health reporting. Maintaining and resourcing these programs is as important as any recommendation arising from this project.

The future disturbance landscape: What TC Jasper tells us about the new normal

TC Jasper's impact was not a function of cyclone intensity. A Category 2 system produced region-wide habitat losses because of prolonged, extreme rainfall across steep, saturated catchments. This type of disturbance mechanism is not something a standard cyclone categorisation captures. The freshwater and sediment pulse that followed would have caused severe marine habitat damage regardless of wind speed.

Under projected climate trajectories for the northern GBR, the conditions that drove TC Jasper's impact are expected to become more frequent: more intense rainfall events associated with tropical systems, shorter recovery intervals between major disturbances, and continued catchment pressures that increase sediment delivery during extreme events (Wolff et al., 2018; Fabricius et al., 2022). These will act on inshore reef systems already weakened by repeated bleaching events and chronic water quality stress, with compounding effects that may limit recovery capacity over time.

These impacted inshore habitats (mangroves, coral and seagrass) documented in 2024 and 2025 may increasingly represent a recurring post-disturbance state rather than a temporary condition before recovery to a stable baseline. Where disturbance intervals are shorter than recovery timescales, the practical management goal may need to shift from restoring pre-disturbance condition to maintaining ecological function, connectivity and resilience across a system that will be periodically and substantially reset by extreme events (Harris et al., 2006; Kopf et al., 2015; Emslie et al., 2024).

Recommendations

Continue monitoring to track recovery

Annual or biennial repeat surveys at priority sites; MMP sites, drone survey reefs, Cairns Harbour meadows, and ranger-monitored locations are needed to detect whether habitats are recovering, stabilising or declining further. Formal integration of Traditional Owner ranger data into regional habitat reporting, with sustained resourcing of those programs is a priority.

No active coral restoration is recommended under current conditions

Sediment clearance is a prerequisite for coral recruitment and cannot be accelerated at this scale. If smothering conditions improve at specific subtidal reef sites, targeted surveillance of natural recruitment using ROV or drone technology would be an appropriate next step.

Allow natural regeneration of mangroves and seagrass to proceed

Early recruitment signals in both habitats are encouraging and no established restoration technique exists at the scale required here. Where mangrove rehabilitation trials are being considered across the 1,776 ha of shortlisted area, elevation surveys and sediment assessment should precede any intervention. Seed bank condition and seedling recruitment in the Daintree and Bloomfield estuaries are the most useful early indicators of regeneration trajectory and warrant targeted monitoring. Research should be prioritised to understand the most effective seagrass restoration techniques in all of the tropical species across a range of habitats, to provide the tools to assist recovery following disturbance events.

Invest in catchment-scale sediment management

Reducing ongoing sediment input, including stabilisation of active landslide areas, is the most impactful available lever for supporting long-term seagrass and coral recovery and operates upstream of the estuarine and marine system itself.

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Appendix A

Selected photos comparing mangrove condition from similar viewpoints from oblique aerial surveys conducted in 2017 and 2024.

IMAGE 1. The Daintree River estuary had large amounts of flood sediments (mud and sand) deposited in mangroves throughout lower-mid reaches resulting in mature trees dying in abnormally large patches.



Before TC Jasper May 2017



After TC Jasper October 2024

IMAGE 2. Sediments (sand and mud) deposited amongst estuarine shore-edges killed mature lower tidal zone mangroves in the Daintree River estuary. In the image centre, dead trees of the central light gap in the image centre predated the cyclone.



Before TC Jasper Nov 2023



After TC Jasper October 2024

IMAGE 3. Significant densely-forested bank edges of the lower Daintree estuary were severely eroded, resulting slumping and loss of large sections of mangroves. Notice also behind the inner trees killed by deposited sediments of mud and sand (Image 1).



Before TC Jasper May 2017



After TC Jasper October 2024

IMAGE 4. The Daintree River estuary suffered severe bank erosion and loss of shoreline edges in many places, especially in areas with little or no buffering mangrove and riparian vegetation.



Before TC Jasper May 2017



After TC Jasper October 2024

IMAGE 5. The Daintree River estuary had small sections of bank restoration prior to Jasper. Fortunately these mitigation works survived the severe flooding, but young mangrove seedlings and saplings were swept away or died.



Before TC Jasper May 2017



After TC Jasper October 2024

IMAGE 6. The mangrove-lined Bloomfield estuary was noticeably scoured by severe floodwaters that followed TC Jasper, eroding and removing large areas of dense mangrove stands.



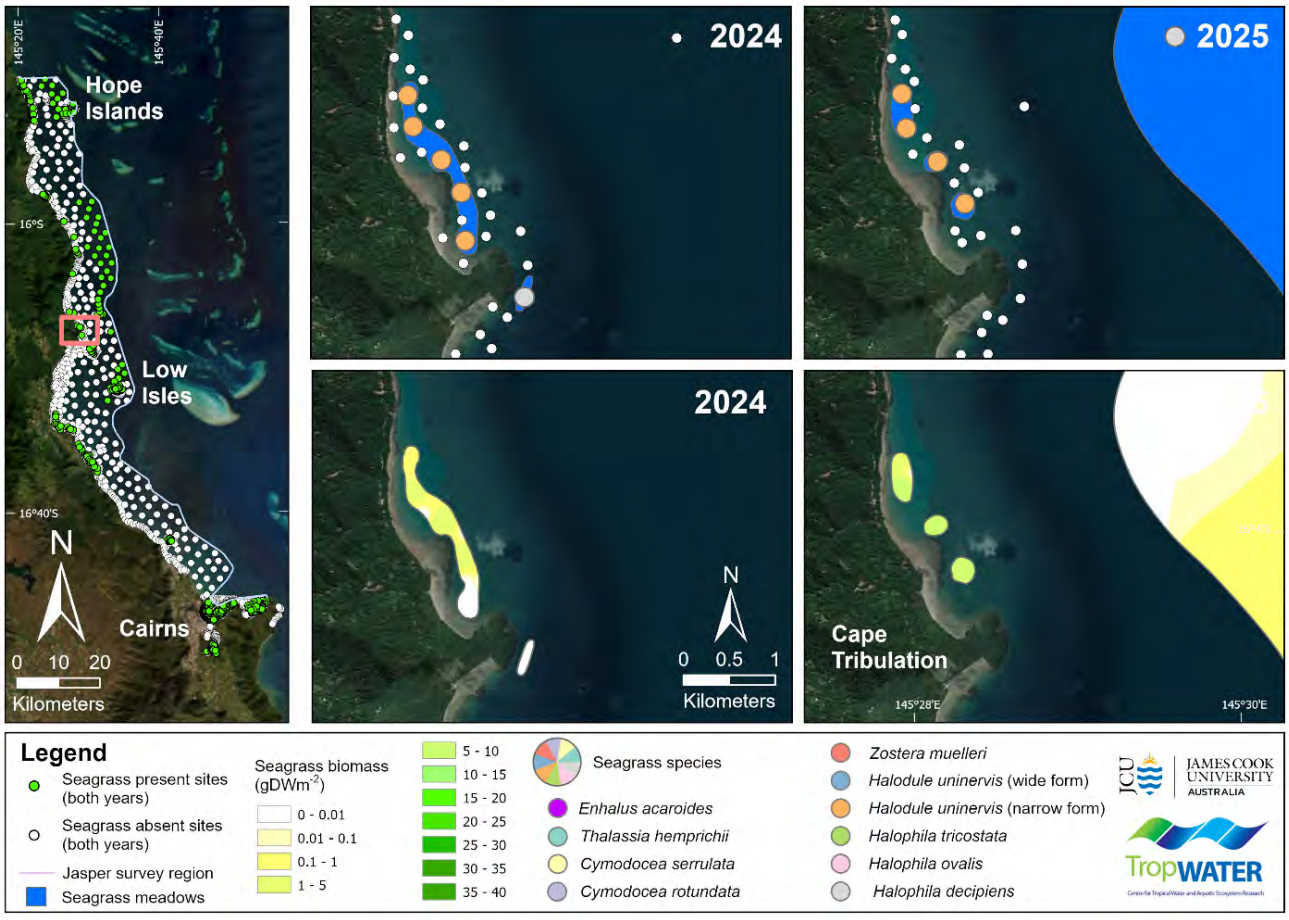
Before TC Jasper May 2017



After TC Jasper October 2024

Appendix B

Seagrass presence/absence, above-ground biomass and species composition and mapped meadows at Cape Tribulation.





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