Benthic habitats of Marra Sea Country - Gulf of Carpentaria

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The report may be cited as
Collier C.J., Carter A., Shepherd L., van de Wetering C., Coles R., Evans S., Barrett D., Willan R.C., Groom R. (2022) *Benthic habitats of Marra Sea Country - Gulf of Carpentaria*. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Report Number 23/13, James Cook University, Cairns, 75 pp.

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Rhoda Hammer – Artist biography and description of artwork

Language: Marra

Rhoda was born at Numbulwar which is a community on the coast of the Gulf of Carpentaria. She went to a boarding school in Darwin in the 1970's, but she has lived in Borroloola for most of her life. Rhoda has been employed doing office work at various places in the community and started at the art centre in 2010.

Rhoda is a prolific jewellery and craft maker, always experimenting with new bush materials, and is keen to use traditional materials in both traditional and contemporary ways. Daughter of the prominent Marra artist Violet Hammer, Rhoda has also turned her passion to carrying on the legacy in recent years.

She often paints bush tucker, especially freshwater and saltwater foods, as fishing and collection of bush foods is a particular passion. Rhoda's knowledge of traditional bush foods and bush craft is extensive, and she continues to pass on this important knowledge to her children and grandchildren living in the Borroloola region. Rhoda works as a studio assistant at Waralungku Arts, is qualified in arts conservation and is actively involved with the peak body organisation, Arnhem, Northern and Kimberley Artists (ANKA) Aboriginal Corporation.

Acknowledgements

This project was undertaken as a collaboration between researchers from TropWATER (James Cook University), Charles Darwin University/Australian Institute of Marine Science, li-Anthawirriyarra Sea Rangers, and Marra Traditional Owners and Custodians. We acknowledge the Marra Traditional Owners of the sea country on which the research took place, and pay our respects to Elders past, present and future. We honour their continuing culture, knowledge, beliefs and spiritual relationship and connection to country. Specifically, we thank them for their time, and the valuable guidance and feedback given in conversations and meetings that helped shape this project and the interpretation of survey findings.
We also recognise Aboriginal and Torres Strait Islander peoples as the Traditional Owners of the land and sea, and as Australia's first knowledge holders.

This project was jointly funded by the Australian Government through Our Marine Parks Grants Round 2, Mabunji Aboriginal Resource Indigenous Corporation, Northern Territory Parks and Wildlife Commission, Charles Darwin University and James Cook University.

Thanks to the following people and organisations for their huge support and input into the planning, logistics and people power required to undertake the field campaign: Fiona Keighran (Mabunji Aboriginal Resource Indigenous Corporation); li-Anthawirriyarra Sea Ranger Cedric John; Marra people and custodians and support from the Barrett family at Limmen fishing camp; *Kerra Lyn* crew Wade Alleyn, Joe Berwick and Cameron Lambie; North Australian Helicopters Tom Speed and pilots Henry Menzies and David Cashman; Department of Environment, Parks and Water Security Northern Territory Government's Roz Kerr, Tom Lewsley, Jonathan Vea and Glenn Durie; Steve and Patsy Barrett at the Limmen Fishing Camp; Reece Verdoorn at the Nathan River Ranger Station; and McArthur River Mine staff Johnny Waerea, Warren Addison, Shane Jolly and Daniel Smith at Bing Bong port.

Thanks also to Sam Frederick for capturing the project on film, and to the Museum and Art Gallery of the Northern Territory for their support with the invertebrate analysis

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Executive summary

Marra land and sea country includes coastal waters in the southern Gulf of Carpentaria in the Northern Territory (NT). The Limmen Marine Park (Commonwealth Government) and the Limmen Bight Marine Park (NT Government) are in Marra country. The co-management aspirations identified within the two Marine Park Plans of Management and the Marra Healthy Country Plan include a need to improve information on habitats and key species because they have not been previously mapped.

Benthic habitats were assessed for 2072 sites during October 2021, with a primary focus on seagrass. Intertidal habitats were surveyed using a helicopter to assess the large, exposed banks, islands and reef tops. For subtidal waters a combination of drop and towed cameras, van Veen grabs and benthic sleds were used for surveys. At each site, a visual estimate of seagrass, as well as benthic macroinvertebrates, algae and open substrate were made.

Seagrass was found at 21% of the sites surveyed. The majority were within the coastal strip of the Limmen Bight Marine Park adjacent to the Limmen Marine Park. Seagrass in this region formed a meadow 65 km long to 9.7 m depth below mean sea level (dbMSL), extending 7–8 km from shore and including areas of very high seagrass biomass. Seagrass also occurred around the Roper River mouth, at sites around Maria Island, and to depths of 21.1 m dbMSL within the Limmen Marine Park. Seven seagrass species were documented in the area.

Eighty species of mobile (non-habitat forming) and sessile (habitat-forming) invertebrate species were identified. Soft corals, hard corals and sponges formed habitat through much of the Limmen Marine Park and Limmen Bight Marine Park, though all became sparser as distance from the coast increased. Coral reefs fringed the eastern and southern sides of Maria Island. Ascidians, crinoids, and hydroids were also present and so dense at some sites that they dominated the benthic communities. Diverse fish assemblages, as well as dolphins, dugongs, sea snakes and turtles were also observed on the survey.

This is the first comprehensive survey of the benthic habitats of Marra sea country and the southern Gulf of Carpentaria marine parks. This information is essential for natural resource planning and to establish a monitoring program that incorporates Traditional Owner and Custodian knowledge and values, and western scientific knowledge. Ongoing monitoring is required to understand variability in the habitats such as seasonal and inter-annual changes in abundance and composition, the environmental pressures influencing habitats and the effect of these changes on species that depend on them including dugong and turtles. Marra sea country is part of the highly connected southern Gulf of Carpentaria meaning local actions to protect habitats need to be embedded within regional strategies to protect the resilience of the cultural-ecological system.

Introduction

Marra sea country and the Limmen marine parks

Marra country in the Northern Territory's (NT) southern Gulf of Carpentaria is rich in biological diversity and supports iconic and culturally significant wildlife such as dugong, dolphins, turtles, whales, waterbirds, crocodiles, sea snakes and diverse fish communities (Griffiths et al., 2020; Groom et al., 2017; Hamann et al., 2006; Parks and Wildlife Commission, 2019). Seagrass, corals, mangroves, macroalgae and saltmarsh provide the benthic habitat that support these iconic species (Long et al., 1995; Phillips et al., 1999).

The land and sea country of the Marra people includes a coastal strip of land in the Gulf of Carpentaria roughly bounded by the Roper River and Rosie Creek (Figure 1). Marra people strongly identify with the coast and see themselves as 'saltwater people' and their identity is intricately linked with the sea (Bradley, 2018). Major Dreamings, songs and ceremony are imbued within the sea. The Dreamings give Marra people rights, responsibilities, obligations, and a sense of belonging to their clan and country, including the sea.

In recognition of these natural values and their importance to the Marra people and all Australians including future generations the Limmen Bight Marine Park (NT Government) and the Limmen Marine Park (Australian Government) were designated in 2012 and 2013, respectively. The Northern Territory Coastal and Marine Management Strategy (2019–2029) outlines the vision for managing the NT's coasts and seas. The Strategy aims to integrate informed co-operation among government agencies together with Traditional Owners, industry, and the community. The Limmen Bight Marine Park Plan of Management (Parks and Wildlife Commission, 2019) is a key deliverable in this Strategy to demonstrate integrated, cooperative management.

The Limmen Bight Marine Park covers an area of 884 km^2 including the coastal waters extending from the mean low water mark to 3 nautical miles (5.5 km) offshore. It also includes the coastal areas within 3 nautical miles of Maria Island which lies further offshore (Figure 1). It is a multiple use marine park established to protect the environment, cultural and heritage values, develop employment opportunities for Aboriginal people, support sustainable fisheries development, and deliver sustainable tourism and recreation opportunities (Parks and Wildlife Commission, 2019). It is governed primarily by the *Territory Parks and Wildlife Conservation Act 1976* and the *NT Fisheries Act 1988*.

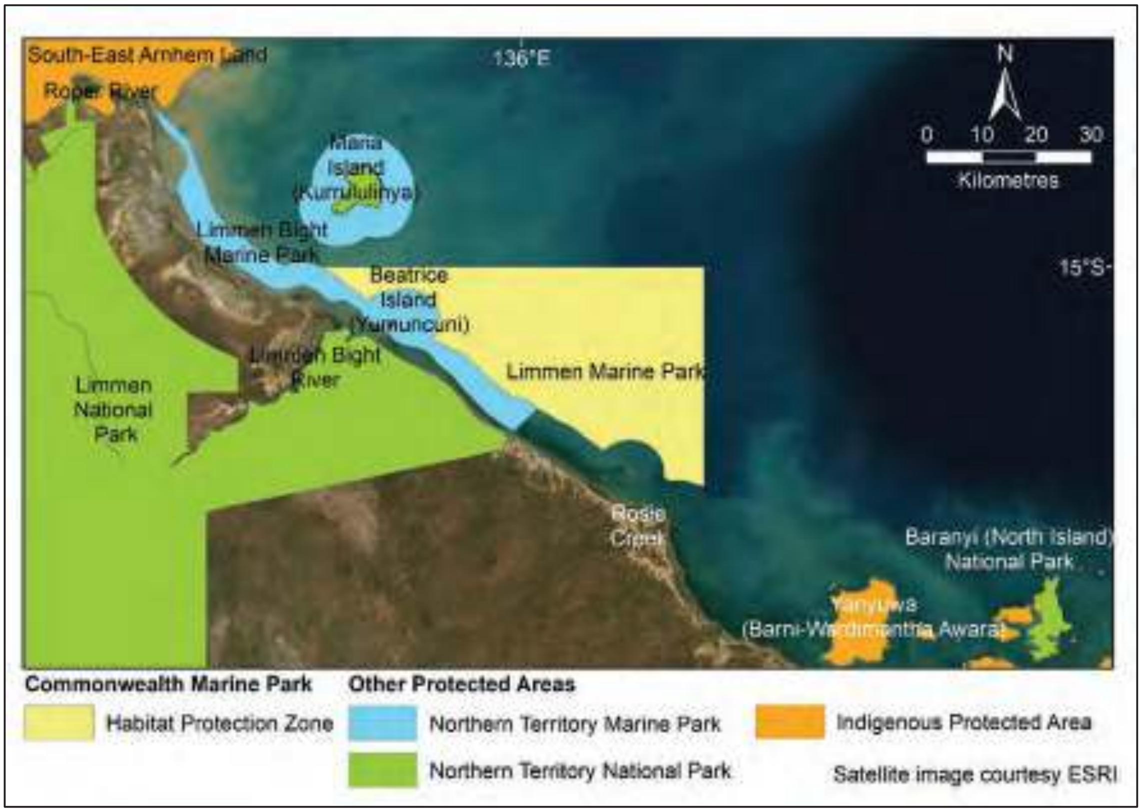

Figure 1. Protected areas in the southern Gulf of Carpentaria including South-east Arnhem Land Indigenous Protection Area, the Limmen Bight Marine Park, the Limmen Marine Park, terrestrial Limmen National Park and the Yanyuwa Indigenous Protection Area.

The Limmen Marine Park lies in the deeper waters adjacent to the Limmen Bight Marine Park and covers an area of 1,399 km^2 (Figure 1). It is one of eight Marine Parks in the North Marine Parks Network (Figure 2). It is protected under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and managed through the *North Marine Parks Network Management Plan 2018*. Eight key features in the North Marine Network have been identified of which the Gulf of Carpentaria Coastal Zone is one. It supports high productivity, aggregations of marine life, biodiversity and endemism (Australian Government, 2012). The Limmen Marine Park captures part of this coastal zone. Limmen Marine Park is zoned as a Habitat Protection Zone (IUCN Category IV), which aims to protect particular species or habitats. Category IV areas frequently play a role in 'plugging the gaps' as they usually protect a part of the system, leading to a greater emphasis on overall ecosystem management approaches and compatible management in other parts of the seascape.

The Commonwealth's Marine Parks follow several principles to support Indigenous people to engage in management of Australian Marine Parks, these include:

"Principle 1: *It is recognised that Indigenous people have been sustainably using and managing their sea country, including areas now included within Australian Marine Parks, for thousands of years in some cases since before rising sea levels created these marine environments.*

Principle 2: *Management of Australian Marine Parks should be undertaken on the basis that native title exists in sea country within Commonwealth waters.*

Principle 3: *Indigenous people should be engaged in planning and managing Australian Marine Parks on the basis of their nationally and internationally recognised rights and cultural interests, not as a 'stakeholder' group.*

Principle 4: *Maximise opportunities for Indigenous people to enjoy the management and use of their sea country.*

Principle 5: *Maximise opportunities for the development of Indigenous livelihoods, consistent with national 'closing the gap' commitments.*

Principle 6: *Governance and management activities within Australian Marine Parks should respect and complement local Indigenous governance arrangements, plans, capacities, and activities.*

Principle 7: *Indigenous engagement in managing Australian Marine Parks should be undertaken through good faith negotiations, seeking to build on the common ground that exists between Indigenous people and the Australian Government to protect and sustainably use Australia's sea country environments and resources.*

Principle 8: *Third party investment in management activities in Australian Marine Parks (e.g. through environmental offset investments) should include support for Indigenous people's interests, capacity-building and development of livelihoods, consistent with all other principles outlined above; such third party investments must not impact on native title compensation negotiations or on the right to compensation."* (www.parksaustralia.gov.au).

Other IUCN Protected Areas objectives for category IV include:

- To protect vegetation patterns or other biological features through traditional management approaches.
- To protect fragments of habitats as components of landscape or seascape-scale conservation strategies.
- To develop public education and appreciation of the species and/or habitats concerned.
- To provide a means by which the urban residents may obtain regular contact with nature.

The priorities outlined in the management plans for both marine parks identify the need to improve information on habitats for key species in the region including dugong and turtles (Parks and Wildlife Commission, 2019).

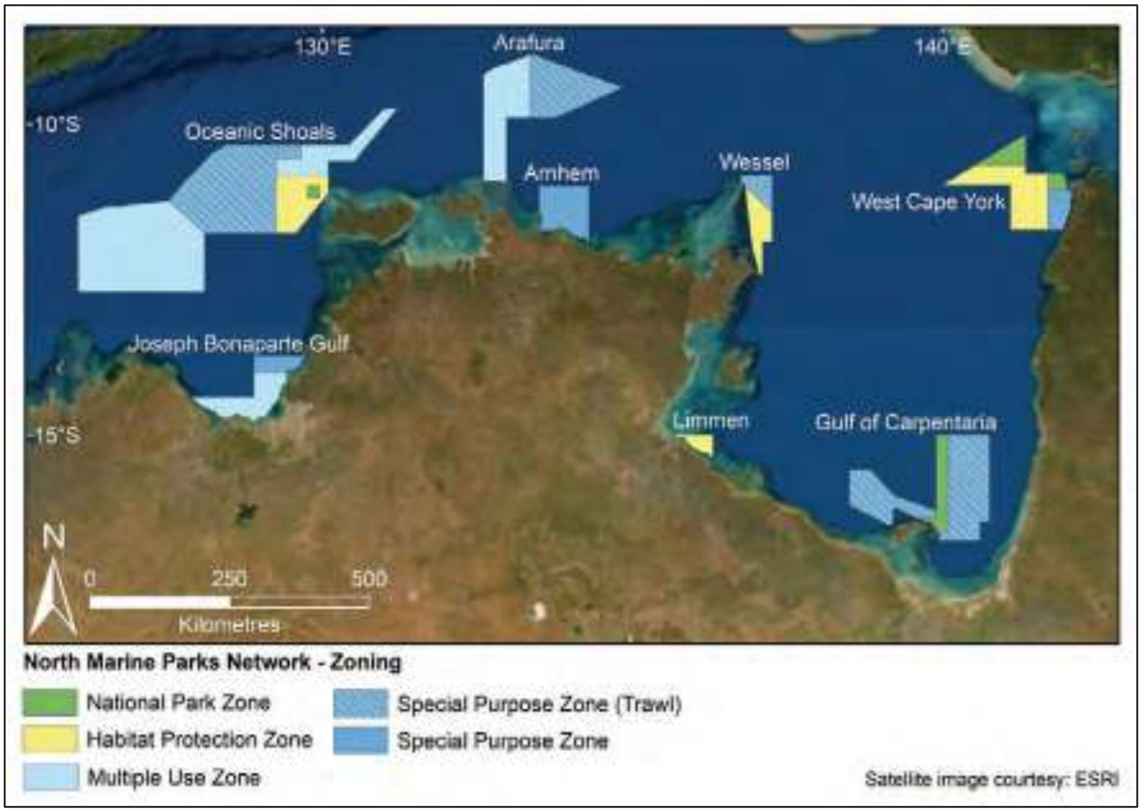

Figure 2. North Marine Parks Network of Australia including park zoning. Spatial layer courtesy of Parks Australia.

The Marra people are in the final stages of a Healthy Country Plan which outlines the values of Marra people regarding their country. The Plan also includes management strategies and priorities for the Limmen Bight Marine Park and Limmen National Park. This plan is the result of extensive consultation with Marra people, and it establishes a vision and pathway for future management on Marra country. Building on this, the Marra community and relevant stakeholders aspire to develop a Marra Aboriginal Corporation to further empower local decision-making and facilitate on-country management.

Biodiversity values

Animals

Marra sea country in the Gulf of Carpentaria is known to have critically important biodiversity values. Dugong are culturally important to Marra, which is reflected in the language and the numerous terms for dugong at various stages of life, and according to gender. The southern Gulf of Carpentaria has consistently — over decades — been identified as having a high density of dugong groups and calves and has been identified by the IUCN World Commission on Protected Areas (WCPA) as an Important Marine Mammal Area (IMMA) and a priority for conservation (IUCN-MMPATF, 2019).

Both the dugong (Marsh & Sobtzick, 2019) and the Australian snubfin dolphin (Parra et al., 2017) are listed by the IUCN as Vulnerable. The southern Gulf of Carpentaria IMMA supports the highest density of dugongs in the Northern Territory (Groom, 2020; Marsh, Grech, et al., 2008) with more than 1% of the global population. The most recent data on dugongs in the Gulf of Carpentaria in the NT suggest that the population is stable and that there is a population of approximately 5000 dugongs (Griffiths et al., 2020). The entire IMMA spanning NT and Queensland supports >3% of the estimated global dugong population. Dugongs are the only strictly herbivorous marine mammal and are dependent on seagrass for subsistence so are restricted to the coastal habitats which support seagrass meadows (Marsh et al., 2011; Sheppard et al., 2007; Sheppard et al., 2010). Blue Mud Bay (South-east Arnhem Land) and Limmen Bight are consistent hotspots for snubfin dolphins (Bayliss & Freeland, 1989; Groom et al., 2017). The highest densities along the NT coast were recorded at these locations with 0.34 and 0.21 snubfin km^{-2}, respectively. The focal areas mentioned above for both dugongs and Australian snubfin dolphins have been consistent for more than 30 years, suggesting that the populations are resident.

Maria Island has been surveyed several times for nesting marine turtles, with the region rated as highly significant for flatback turtles (Chatto & Baker, 2008). Eggs are laid during the dry season months and nests here are not affected by introduced animals such as feral dogs and pigs that are found on the mainland. The prevalence of intertidal mudflats and saline wetlands on the mainland coast also make it mostly unsuitable for nesting, although low numbers of flatback turtles are known to nest at the few small beaches found north of the Limmen Bight River. Flatback and green turtles feed on seagrass and the seagrass meadows in Limmen Bight. Satellite telemetry data from green turtles tagged in northeast Arnhem Land (NT), Groote Eylandt (NT) and Raine Island (QLD) indicate the seagrass habitat that extends from Limmen Bight to the Sir Edward Pellew Islands (NT) and the Wellesley Islands (QLD) is significant, with most of the tagged turtles feeding in the southern Gulf of Carpentaria.

The fish diversity of Limmen Bight Marine Park is not well known. The Museum and Art Gallery of the Northern Territory (MAGNT) briefly surveyed the coastal and estuarine fish of the Roper River and neighbouring waterways (including Nayarnpi Creek and the Towns River) in 1994, as part of a comparison with the fish fauna of Bing Bong Creek, west of the McArthur River (Larson 1996). Any other scientific knowledge of the fish fauna in the areas is based largely on prawn bycatch, demersal fish trawl catch and very limited ad hoc collecting. Despite this limited sampling, over 100 species of fish are known from the area (Larson, 1996), including three species of pipefish (*Hippichthys cyanospilus, H. parvicarinatus and H. penicillus*) that are restricted to seagrass habitats. These pipefish are in the Family Syngnathidae (seahorses and pipefish), which are listed marine species under the EPBC Act. Threatened sharks (Freshwater Sawfish) have been recorded in inshore waters and the adjacent estuaries, plus species of recreational/commercial importance such as barramundi, golden snapper, blue salmon and northern whiting. Gobies had the most species in the Larson survey, partly due to the number of mangrove-associated species and the sampling techniques used. The fish fauna of the Roper River is similar to that of the East Alligator River, the southern Gulf of Carpentaria and the Gulf of Papua. This is not surprising as these are all highly turbid areas with largely muddy substrates and fluctuating salinity (Larson 1996). Further detailed sampling would add considerably to the species list and our understanding of ecological assets in the area. The total number of known species would likely increase markedly and include seagrass-dependent pipefish and seahorses (Syngnathids), threatened sharks (eg. speartoothed shark), and species important for amateur fishers such as Black Jewfish, Mangrove Jack, Mackerel species, and Giant Trevally.

Habitat

Extensive seagrass habitat is found throughout the Gulf of Carpentaria and Torres Strait, with 1,467,031 ha of seagrass mapped since the early 1980s (Figure 3) (Carter, A. et al., 2022). The first Gulf-wide survey of intertidal and near-shore shallow subtidal seagrass occurred in 1982–1984, with extensive areas of shallow water seagrass habitats in the southern Gulf of Carpentaria mapped (Poiner et al 1987). In 2004, intertidal areas of the entire mainland coastline of the Gulf of Carpentaria and some islands were also surveyed (Roelofs et al., 2005). Dedicated annual seagrass monitoring programs are established in the eastern Gulf (Queensland) at the ports of Karumba and Weipa (e.g. Scott & Rasheed, 2021; Smith et al., 2020) and throughout Torres Strait (e.g. Carter, A.B. et al., 2021). Ongoing monitoring in the NT is restricted to Bing Bong (by the McArthur River Mine) but does not occur anywhere else in the western Gulf of Carpentaria where the majority of seagrass habitat occurs. Large areas remain unmapped especially in subtidal locations. The extent of deep-water seagrass is unknown except in Torres Strait where surveys of the Dugong Sanctuary have extended into the north-east Gulf (Carter, A. et al., 2022; Coles et al., 2018; Roelofs et al., 2005). Seagrass mapping is also lacking in the complex areas of tidal inlets and creeks and around the islands. In these areas existing maps are relatively coarse and inadequate for development of management plans for the relatively new protection areas.

The coastal areas of the Gulf of Carpentaria support diverse fish communities and species of importance to fisheries. Some of these depend on seagrass meadows which provide important nursery habitat for commercial species including juvenile tiger (*Penaeus esculentus* and *P. semisulcatus*) and endeavour (*Metapenaeus endeavouri*) prawns and fish (Coles & Lee Long, 1985; Coles et al., 1993; Staples et al., 1985; Vance et al., 1985). These prawn species form a major component of the Northern Prawn Fishery, one of Australia's most valuable Commonwealth fisheries with an estimated value of $120m in 2018–19 (https://www.csiro.au/en/research/animals/fisheries/northern-prawn-fishery). Following Tropical Cyclone Sandy in 1985 there was loss of ~186 km^2 of seagrass between the Sir Edward Pellew Islands (Yanyuwa sea country) and the Roper River (Marra sea country). This had a significant effect on the Gulf of Carpentaria prawn fishery, with reduction in juvenile prawns and commercial catch (Poiner et al., 1993). Mangroves adjacent to intertidal seagrass meadows provide important habitat for commercially fished barramundi (*Lates calcarifer*) and mud crabs (*Scylla serrata*) (Robins et al., 2005). Ecological information is sparse and unavailable for some habitats (such as habitat-forming benthic invertebrates) in the region.

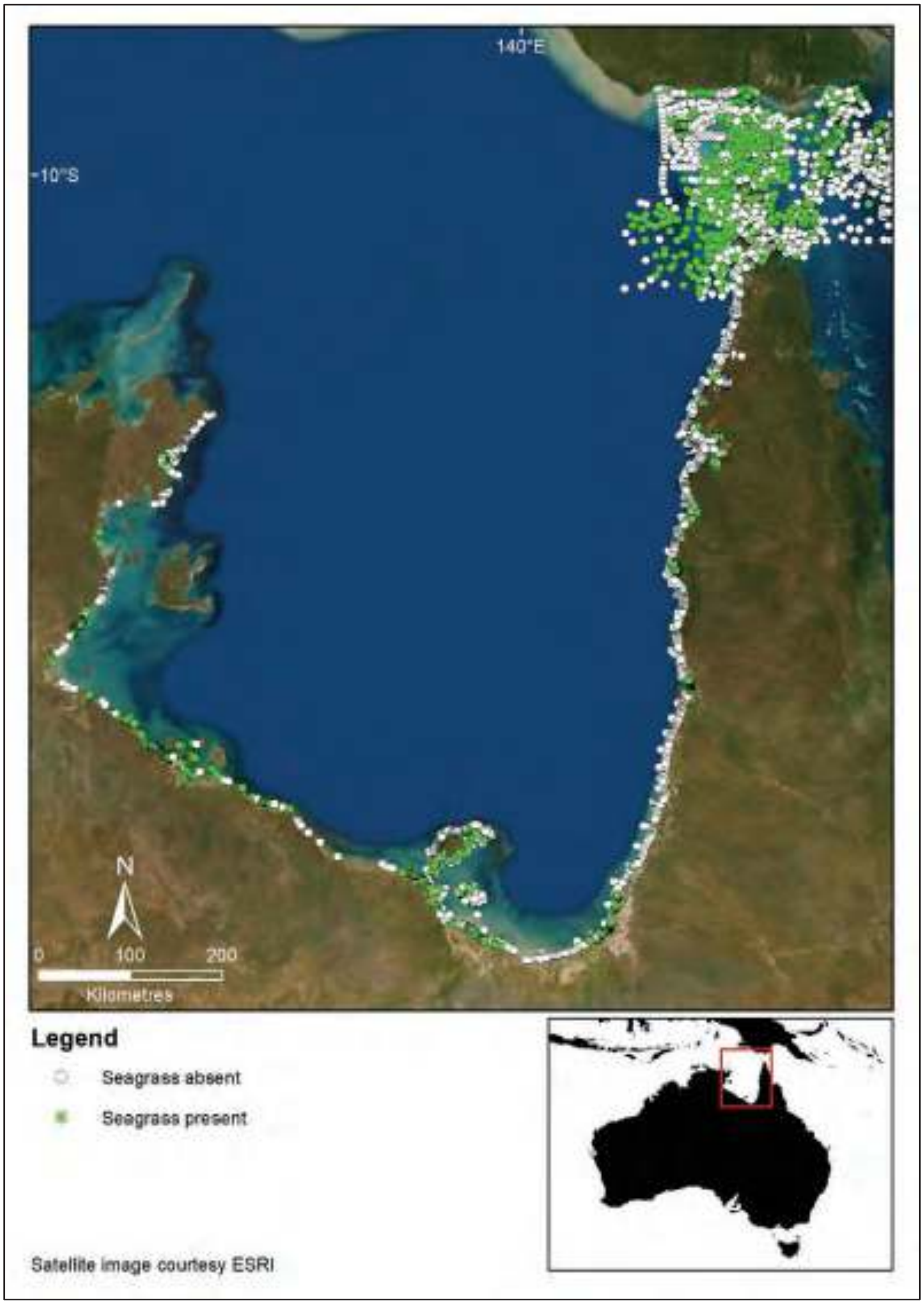

Figure 3. Seagrass presence and absence at individual sampling sites across Torres Strait and the Gulf of Carpentaria, 1983–2022, excluding this study.

Threats to biodiversity

The region's human population is relatively low and growth is not anticipated to be very high in Marra country (Kyne et al., 2018), despite large-scale development activities planned for the north in general (NAILSMA, 2018). Historically, the region is identified on a global scale as an area with very low anthropogenic impact (Halpern et al., 2008) and compared with other areas in Northern Australia current threats are also relatively low.

Productivity in the shallow coastal areas of the Gulf of Carpentaria is fuelled by nutrients from the rivers that flow into it (Burford et al., 2009) and nitrogen fixation within sediments and on the surfaces of habitats (Moriarty et al., 1990). Changes in river flows, due to water resource development will impact many coastal species in the Gulf. There has been a growing interest in the mining of the Limmen Bight Region's catchment and developing agriculture which will increase demand for surface and groundwater extraction (Plagányi et al., 2022). There are likely bigger impacts if freshwater is removed from more than one river catchment, and if water is removed from low-level flows in drier years. Species that are most at risk from water extraction include largetooth sawfish, banana prawns, barramundi, and mud crabs (Plagányi et al., 2022).

The Gulf of Carpentaria may be vulnerable to regional changes in climate. Climate extremes led to seagrass loss in Weipa caused by elevated temperature and UV exposure, and in Karumba caused by desiccation, and elevated temperature and rainfall (Rasheed & Unsworth, 2011; Unsworth et al., 2012). Large-scale dieback of mangroves in the western Gulf of Carpentaria in 2015–2016 further demonstrates the vulnerability of the region's habitats to climate extremes (Duke et al., 2017).

Limmen Bight Marine Park and the Limmen Marine Park have been used by commercial and recreational fishers targeting prawns, barramundi, mud crabs and other species. There is limited data available on commercial fishing in the Limmen Bight Region (except for prawn fishery catches and interactions with threatened species). The data that does exist is old and has limited regional coverage. Although the NT-wide number of licences are known for the Barramundi (14 licences), Mud Crab (49 licences), Offshore Net and Line (17 licences) and Northern Prawn (52 licensed boats that fish out to the edge of Australia's Exclusive Economic Zone) fisheries, it is unclear just how many licensed commercial fishers operate regularly within the Limmen Bight Region and Limmen Bight Marine Park. Information from fisheries with less than five active operators cannot be released without consent and so is not publicly available. It is difficult to evaluate the impact of fisheries to the Limmen region, however, benthic trawling is no longer permitted in the Limmen Marine Park. Predicted increases in boating and fishing activities (commercial and recreational) in the region suggest moderately high threat levels in the future (Kyne et al., 2018). The threats to biodiversity from commercial fisheries as well as incidental boat strike and entrapment in ghost nets are well recognised by saltwater people across the north (NAILSMA 2018).

Aims

To address benthic habitat information gaps, a collaboration was undertaken among the Mabunji Aboriginal Resource Indigenous Corporation, li-Anthawirriyarra Sea Rangers, Charles Darwin University, James Cook University, Parks Australia, Northern Territory Parks and Wildlife Commission, and the Museum and Art Gallery Northern Territory to survey this important region. This report includes survey information for both marine parks in recognition of their connectivity.

The aims of this project were to:

1. Map the benthic habitats of the Limmen marine parks and adjacent inshore coastal areas.
2. Assess the biomass and diversity of seagrass in the Limmen marine parks.

3. Increase technical capacity of li-Anthawirriyarra rangers to map and monitor benthic habitats.
4. Engage with the Marra community in two-way knowledge sharing of information about sea country.
5. Provide recommendations to all with responsibility for managing the area including Marra people, Parks Australia and the Northern Territory Government.

A film and artwork were also developed as a component of this study. The artwork is included throughout this report. The film is publicly available at: https://www.youtube.com/watch?v=Xd9m9fsA6uw.

Methods

Study region

The study region included the Limmen Marine Park, the Limmen Bight Marine Park, and the subtidal and intertidal areas adjacent to the Marra Aboriginal Land Trust (Figure 4).

The main features of the coast in this shallow shelf region of the south-western Gulf of Carpentaria include (Poiner et al., 1987; Short, 2020):

- shallow bathymetry
- two distinct seasons with marked variation in rainfall, temperature, salinity and wind. The dry season (May–October) is characterised by south-easterly winds, and the wet monsoon season (December–February) is characterised by high rainfall and north-westerly winds
- variable sediment across the Gulf of Carpentaria, but in Limmen Marine Park and Limmen Bight Marine Park sediments are generally sandy (<25% mud) (Somers & Long, 1994)
- low to moderate wave energy
- micro-meso tide regime with tidal ranges of approximately 2–3 m
- low gradient nearshore and intertidal zone (i.e. expansive intertidal areas)
- circulation and seasonal changes in water level
- rich biotic diversity
- creeks and rivers draining into the Gulf of Carpentaria delivering freshwater, nutrients and sediments; and
- relatively smaller drainage basins and fewer rivers compared to the eastern Gulf of Carpentaria.

The survey area included some sites that are sacred and were inappropriate to survey or required special permission to access. These were generally small areas. There are other areas that could be surveyed, but images cannot be shown. These decisions were guided by the Marra people, in particular David Barrett and Shaun Evans, who collaborated in surveys and survey design. We recognise that no single person (or two people) can speak for Marra people, and we sought to engage the community more broadly, including closely linked Yanyuwa people, through community forums, artwork and films.

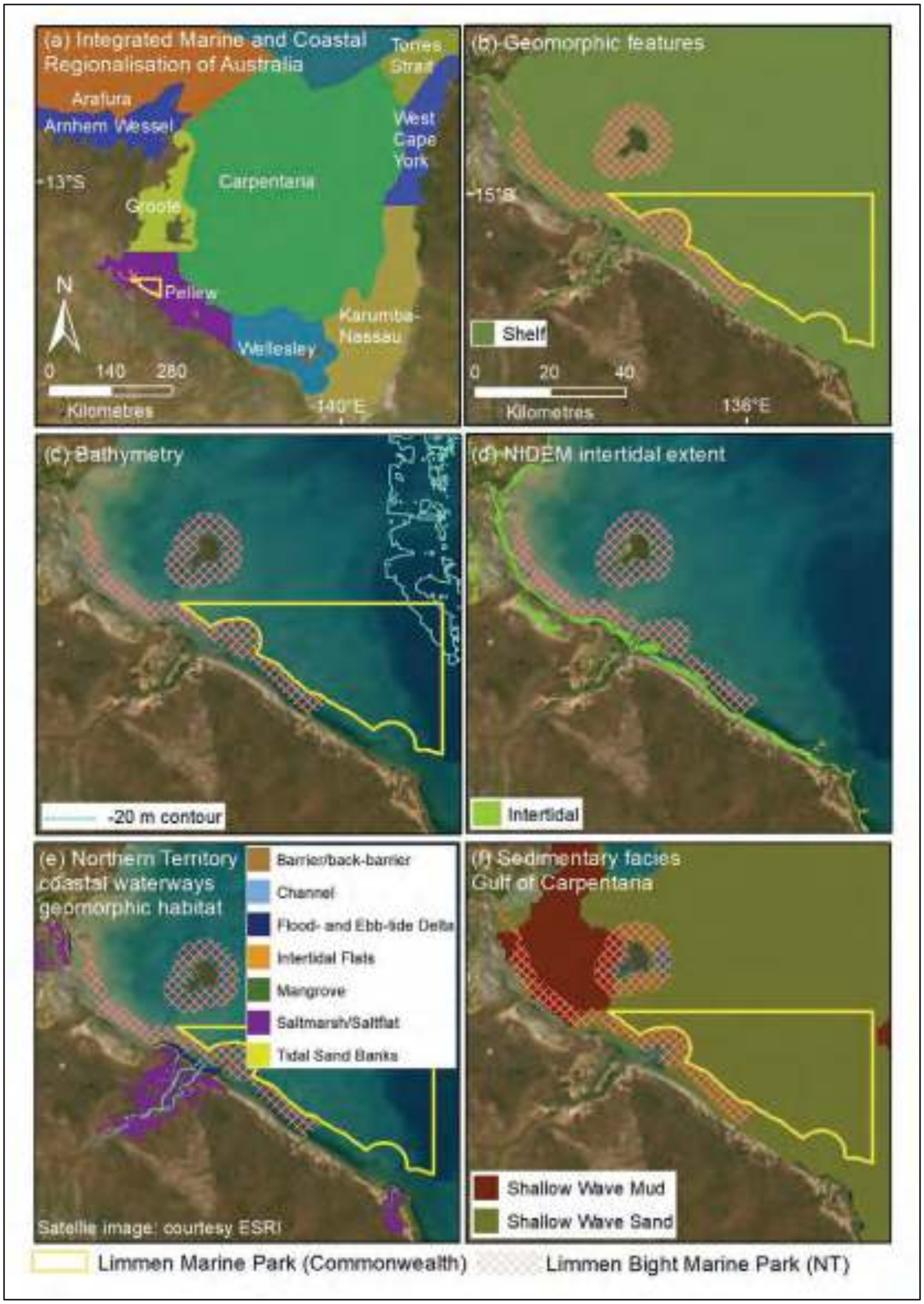

Figure 4. Features of the Gulf of Carpentaria and Limmen Bight region. (a) Interim Marine and Coastal Regionalisation of Australia ; (Thackway, 1998)(b) geomorphic features (Heap et al., 2010), (c) bathymetry (http://dx.doi.org/10.4225/25/53D99B6581B9A), (d) intertidal extent (Bishop-Taylor et al 2019), (e) geomorphic habitat (http://www.ozestuaries.org (Dyall et al.)), and (f) sedimentary facies (Hinde et al., 2004).

Climate and environment

Long-term climate data were summarised to identify how conditions in 2021 compared to average conditions for the region. There are no weather gauging stations within or adjacent to the survey area or in Marra country. Daily 9 am and 3 pm wind, rainfall and air temperature data were obtained for each day in 2021 from the Bureau of Meteorology for Centre Island (station 012703) in Yanyuwa country (Yanyuwa Indigenous Protected Area; Figure 1). Monthly mean values were calculated for 9 am and 3 pm data in each month in 2021. Long-term monthly averages were downloaded as monthly averages for the period 1974–2010 for rainfall and wind, and for 1968–2021 for rainfall (default periods).

River discharge from the Roper River was obtained from the Northern Territory Water Data Web Portal for the Red Rock (G9030250) gauge (https://water.nt.gov.au/Data/DataSet/Summary/Location/G9030250/DataSet/Discharge%20Volume/Total%20Volume/Interval/Latest). This gauge was selected because it is the only gauge on the river to include long-term data and the entirety of 2021 in the records; however, it is more than 100 km upstream in the South-East Arnhem Land Indigenous Protected Area. Daily discharge for the period 15 January 1967–31 December 2021 were summarised as monthly totals for each month in 2021 and a long-term monthly mean total for the period 1967–2021.

Data Collection

Benthic habitat assessments were conducted at 2072 sites in October 2021. This included 1776 intertidal sites surveyed by helicopter on the 11–13th October, and 296 subtidal sites surveyed by boat on the 16–21st October. Of these, 196 sites were surveyed within the Limmen Marine Park. Sites were haphazardly assigned prior to the surveys, and when seagrass was observed additional sites were added so that the meadow edge could be identified. Survey dates were selected to coincide with the peak seagrass growing period that occurs in spring and early summer in northern Australia. This ensures data are comparable among years and with other survey locations in northern Australia.

The subtidal surveys used three vessels: the live-aboard MV *Kerra Lyn*, with support from the li-Anthawirriyarra ranger vessel MV *A-Walamakamaka* and NT Parks vessel MV *Barranyi*. Survey site coordinates and survey dates are included in the GIS shapefiles produced for this project and available at www.eatlas.org.au and shown on Figure 5.

Benthic habitats were assessed following TropWATER's methods used in previous benthic surveys of Torres Strait (Carter, A. et al., 2021; Carter & Rasheed, 2016). At each site, latitude and longitude were recorded by GPS. Sediment was described using broad categories (e.g., mud, sand, rubble) and assessed by a combination of video footage, van Veen grab samples, or sled net samples. Where more than one sediment category was used, the sediment is listed from the most dominant to the least dominant type. Depth in metres (m) was recorded for each subtidal site from the vessel sounder and converted to depth below mean sea level (dbMSL).

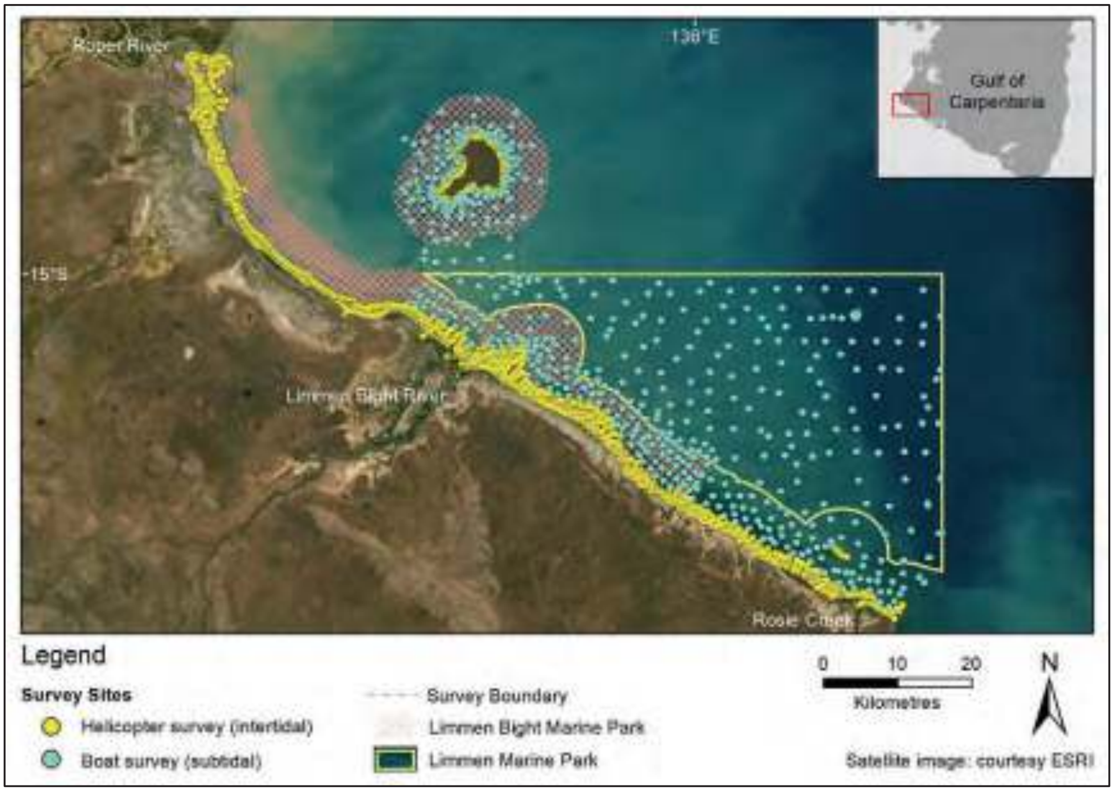

Figure 5. Intertidal and subtidal survey sites in the Limmen Marine Park and Limmen Bight Marine Park, October 2021.

Benthic habitat observations

Helicopter

Entire exposed intertidal banks including reef-tops and islands were surveyed by helicopter, which allows for rapid surveys across large areas (Figure 6). Intertidal sites were sampled while the helicopter maintained a low hover. At each site a visual estimate was made of percent cover of seagrass, benthic macro-invertebrates (BMI), algae, and open substrate within a 10 m^2 circular area. At each site seagrass biomass and species composition was estimated in three replicate 0.25 m^2 quadrats.

Figure 6. Intertidal sites were surveyed by helicopter, with seagrass ranked in three replicate quadrats.

Drop video

This method was used from MV *Barranyi* and MV *A-Walamakamaka* (242 sites), and is designed for rapid assessments from small boats with limited space and no winch/davit (Figure 7a). At each site an underwater CCTV camera (SpotX) with a frame that incorporated the area of a 0.25 m^2 quadrat was lowered by hand from the tender to the sea floor (Figure 7b-c). Benthic habitat was observed on a monitor and habitat assessments conducted in real time. Video was also recorded by the SpotX or a GoPro attached to the side of the frame at a number of sites for communications purposes.

Figure 7. Camera drop video and grab method for benthic surveys: (a) ranger vessel MV *A-Walamakamaka*, (b) camera on drop frame, (c) camera filming sea floor, and (d) van Veen grab.

Towed video

This method was used on MV *Kerra Lyn* (54 sites) and is designed for detailed assessments using larger vessels with towing capability. At each site, an underwater CCTV camera (SpotX) was winched from the vessel to the sea floor. A GoPro was also attached to the camera sled frame as a back-up camera system. For each transect, the camera was towed at drift speed (< 1 knot) for approximately 100 m. At sites where there was a large amount of benthic structure, such as corals, or very high densities of crinoids, transects were reduced to 50 m to reduce the number of individuals sampled or the sled becoming entangled. Benthic habitat was observed on a monitor and digitally recorded (Figure 8a-c). Video footage was analysed using the point count method after the survey with *CoralNet* software.

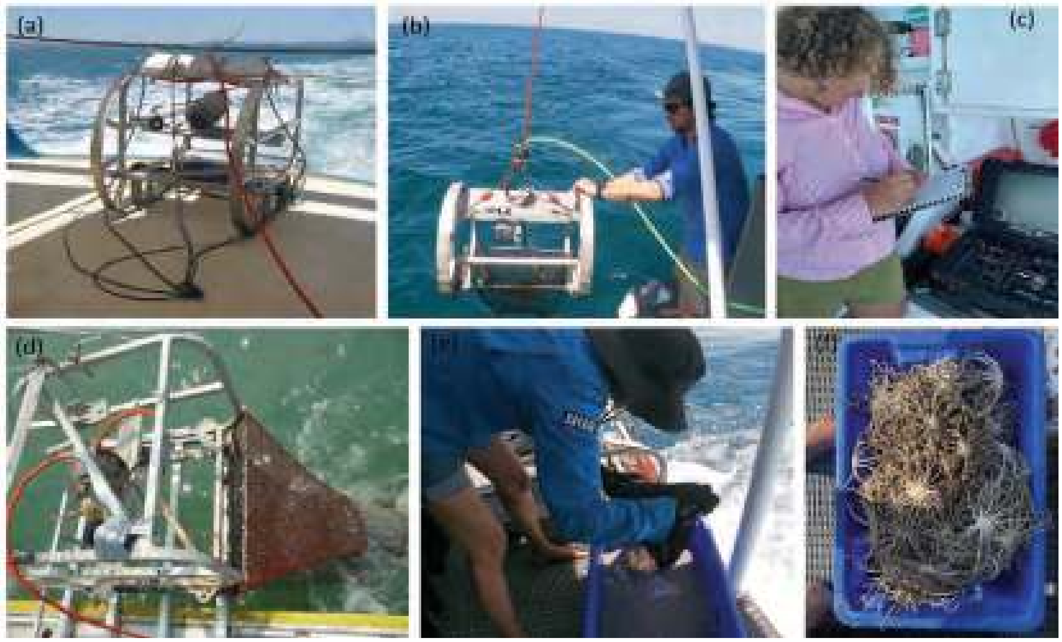

Figure 8. Towed video and sled net method for benthic surveys: (a) sled with camera attached, (b) deploying sled from MV *Kerra Lyn*, (c) camera monitor, (d) rinsing sled net, (e) emptying samples from net to sorting tray, and (f) sorted sled net contents, in this case crinoids.

Benthic sampling

No biological samples were retained on this survey. All specimens collected by the van Veen grab and sled net were recorded on data sheets and immediately returned to the sea. A sample of each seagrass species was collected as an herbarium record to verify species identification.

Van Veen grab

When habitat could not be easily identified by video camera on MV *Barranyi* or MV *A-Walamakamaka*, a van Veen grab (grab area 0.0625 m^2) was used to collect a small sample to confirm sediment type and seagrass species identification at shallow water sites (Figure 7d).

Sled net

For the sites sampled from MV *Kerra Lyn*, a small net was attached to the back of the sled to collect a benthic sample at each site and confirm sediment type (Figure 8b, d–e). Sled net contents were photographed for species identification purposes, including mobile and sessile invertebrates, before returning them to the sea.

Data analysis

Benthic habitats

Benthic habitat data were recorded in real time for sites surveyed by drop video, while more detailed assessments were conducted for the 54 sites surveyed using recorded towed video footage.

For sites surveyed by drop video, a trained observer estimated the percent cover of the main benthic categories as the camera hovered and drifted over a transect of approximately 10 m in length. These categories included seagrass (all species combined), algae (with the percent contribution of macroalgae, calcareous, encrusting, filamentous and turf mat also recorded), benthic macroinvertebrates (including percent contribution of hard corals, soft corals, sponges, crinoids, other), and open substrate.

For sites surveyed by towed video, benthic communities were analysed using *CoralNet* software (https://coralnet.ucsd.edu). For each recorded video transect 10 still images were extracted for analysis using a random time point generator. If a still image was not appropriate for analysis (such as when the sled had "bounced" and the seafloor was not visible, or the sled had stopped moving and the same image was selected twice), then the video was played until an appropriate still could be extracted. Fifteen annotations (3 rows x 5 columns) were applied to each still image, with a 15% offset from the top of the image and 5% offsets from the bottom, left and right of the image, to account for camera angle and field of view (Figure 9). Annotations were size 8 crosshair style.

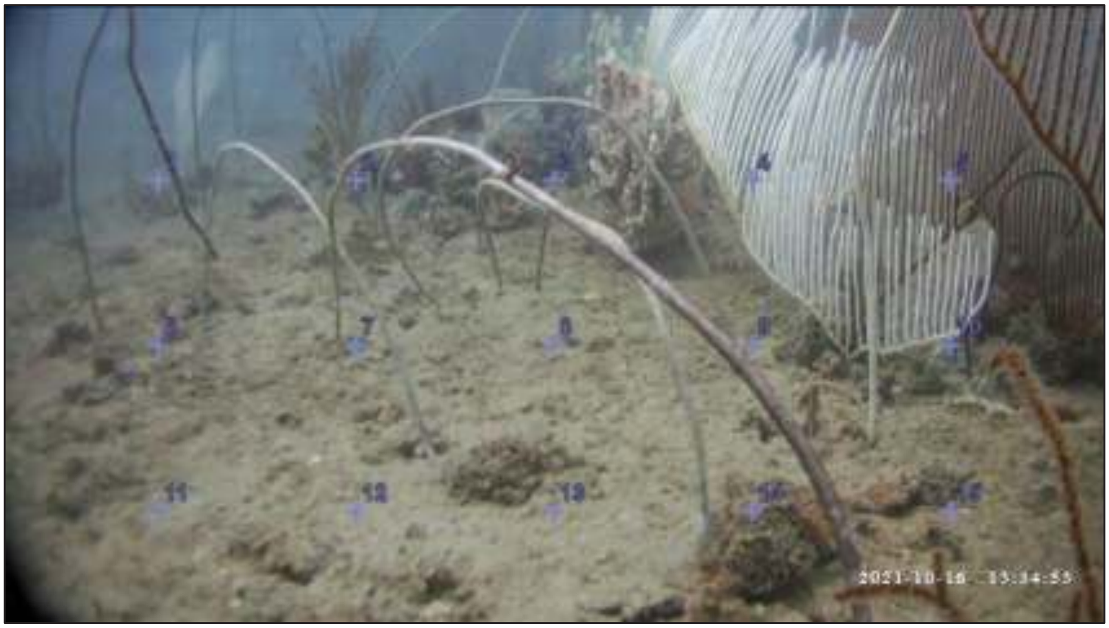

Figure 9. Screen capture of *CoralNet* annotations.

Annotations in each image were analysed and labelled using a pre-determined label list and set of rules:

- Benthic habitat categories – seagrass (all species combined), algae (macroalgae, calcareous, encrusting, filamentous, turf), hard corals, soft corals (with gorgonians and sea whips separated from general soft coral), sponges, crinoids, other benthic macroinvertebrates (with sea pens, sponges, ascidians, and hydroids separated), and open substrate. Benthic habitat for each site was calculated as the average cover of each of these categories for the 10 replicate photos.
- The following labels were used to label annotations but were excluded from calculations of percent benthic cover: null (use for annotations that fell on fish, shadows, and obstructions), water (used for annotations that fell on infinite water or poor water quality made annotation impossible), blur (used to described motion blur or an out of focus image).

Algae communities

The percent cover of algae was divided into five functional groups:

- Erect macrophyte – macrophytic algae with an erect growth form and high level of cellular differentiation, e.g. *Sargassum*, *Caulerpa* and *Galaxaura* species (Figure 10a).
- Filamentous – thin, thread-like algae with little cellular differentiation (Figure 10b).
- Encrusting – algae that grows in a sheet-like form attached to the substrate or benthos, e.g. coralline algae (Figure 10c).

- Turf mat – algae that forms a dense mat on the substrate (Figure 10d).
- Erect calcareous – algae with erect growth form and high level of cellular differentiation containing calcified segments, e.g. *Halimeda* species (Figure 10e).

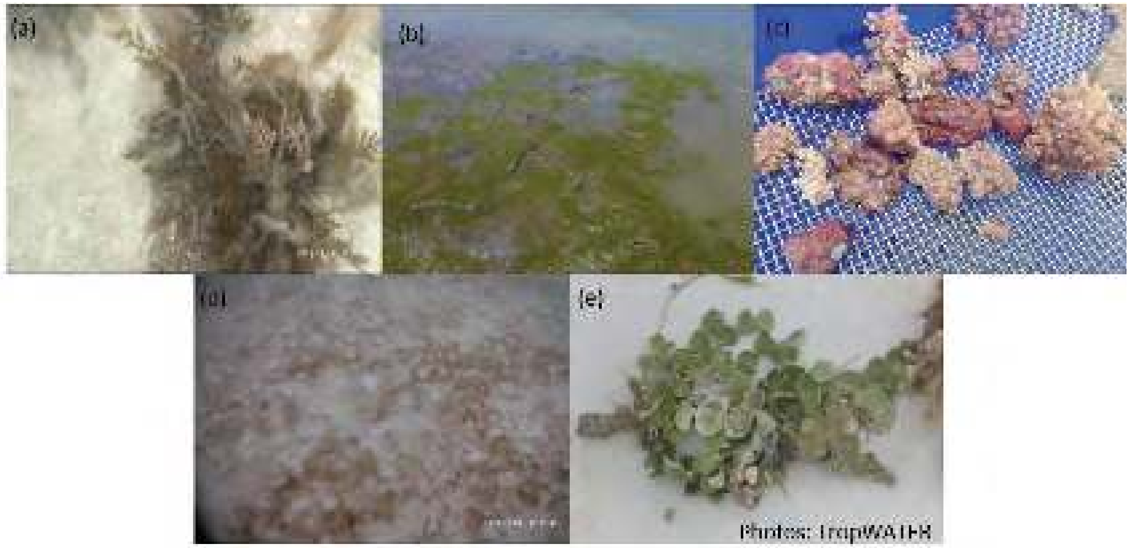

Figure 10. Examples of algae functional groups (a) erect macrophyte, (b) filamentous, (c) encrusting, (d) turf mat and (e) erect calcareous.

Invertebrate communities

The percent cover of habitat-forming benthic macroinvertebrates (BMI) were divided into broad taxonomic groups:

- hard coral which were all scleractinian corals including massive, branching, tabular, digitate and mushroom
- soft coral including all alcyonarian corals, i.e. corals lacking a hard calcareous skeleton
- sponge
- crinoid
- other BMI – any other BMI identified, e.g. hydroids, ascidians, barnacles, oysters, and habitat-forming molluscs such as clams, and listed in the “comments” column of the GIS site layer.

Identification to the lowest taxonomic level of sessile and mobile invertebrates from photos taken of sled net contents was conducted at MAGNT, Darwin in February 2022.

Seagrass biomass

Seagrass above-ground biomass was estimated at three 0.25 m^2 replicate quadrats within each helicopter and camera drop site, and for the 10 replicate random still images used in the benthic habitat assessment using a 0.25 m^2 quadrat superimposed onto the monitor. Seagrass biomass was determined for each quadrat using the “visual estimates of biomass” technique (Mellors, 1991). This involves ranking seagrass biomass while referring to a series of quadrat photographs of similar seagrass habitats for which the above-ground biomass has been previously measured. Three separate biomass scales were used for this survey: low biomass, high biomass, *Enhalus* biomass. The percent contribution of each seagrass species to total above-ground biomass within each quadrat was also estimated. At the completion of the field trip or video analysis, each observer ranked a series of calibration quadrats. A linear regression was then calculated for the relationship between observer ranks and the harvested values and used to calibrate above-ground biomass estimates for all ranks made by that observer during the survey. Biomass ranks were then converted to above-ground biomass in grams dry weight per square metre (gDW m^{-2}) and averaged among replicates to provide mean total seagrass above-ground biomass, and contribution to total above-ground biomass for each species, for each site.

Geographic Information System (GIS)

All survey data were entered into a Geographic Information System (GIS) using ArcGIS 10.8© (Redlands, CA: Environmental Systems Research Institute, ESRI). Three GIS layers were created to describe spatial features of the region: a habitat site layer, seagrass meadow layer and seagrass biomass interpolation layer. All spatial layers are publicly available at eAtlas (www.eatlas.org.au).

Habitat site layer

The habitat layer contains point data collected at each survey site. The data includes:

- temporal details – survey date and time
- spatial details – location, tidal zone, latitude/longitude, depth (dbMSL), depth model.
- Sediment type
- habitat information – percent cover of each benthic category (see *data analysis – benthic habitats* section for categories)
- seagrass-specific information – seagrass presence/absence, mean total above-ground biomass ± standard error (s.e.), and mean biomass for each species
- sampling method
- presence of turtles, dugongs (or dugong feeding trails) or dolphin at the site
- meadow identification (ID) code
- vessel name and
- comments.

Seagrass meadow layer

Seagrass presence/absence site data and meadow edges recorded by GPS during the survey were used to construct the meadow (polygon) layer. Rectified colour satellite imagery of the survey region were sourced from ESRI or Allen Coral Atlas (The Satellite Coral Reef Mosaic is © 2022 Planet Labs and licensed CC BY-SA-NC 4.0) (https://creativecommons.org/licenses/by-nc-sa/4.0/) and field notes and photographs taken during the survey were used to identify geographical features, such as reef tops, channels and deep-water drop-offs, to assist in determining seagrass meadow boundaries. The meadow layer provides summary information for all sites within each seagrass meadow, including:

- temporal details – survey date
- seagrass meadow information – meadow identification (id) code, seagrass species present, meadow community type, meadow density, mean meadow above-ground biomass ± standard error (s.e.), meadow area ± reliability estimate (r), persistence, dominant species, and number of total and biomass sites within the meadow
- marine park name
- tidal zone
- habitat sampling method
- dugong feeding trail presence in meadow (intertidal meadows only)
- vessel name
- comments.

Intertidal seagrass meadow (polygon) layers were constructed using seagrass presence/absence site data and meadow boundaries mapped using GPS points recorded while flying along the intertidal meadow edge. Subtidal meadow mapping precision estimates were based on the distance between sites with and without seagrass or distance to hard boundaries such as land (Table 1). The mapping precision estimate was used to calculate an error buffer around each meadow. The area of this buffer is expressed as a meadow reliability estimate (R) in hectares.

Table 1. Mapping precision and methods for subtidal seagrass meadows.

Mapping precision	Mapping method
1–20 m	Meadow boundaries mapped in detail by GPS from helicopter. Intertidal meadows completely exposed or visible at low tide. Relatively high density of mapping and survey sites. Recent aerial photography and satellite imagery aided in mapping.
20–50 m	Parts of meadow boundary mapped in detail by GPS from helicopter. Parts of meadow boundary determined from presence/absence site data and satellite imagery. Relatively high density of mapping and survey sites.
50–100 m	Seagrass meadow boundary determined from distance between sites. Distinct topographic features from satellite imagery aided in mapping (reefs, islands). Medium density of survey sites.
>100–500 m	Seagrass meadow boundary determined from distance between sites. No distinct topographic features from satellite imagery aided in mapping. Low density of survey sites.

Seagrass biomass interpolation layer

An inverse distance weighted (IDW) interpolation was applied to total seagrass above-ground biomass point data (using the habitat site layer) to describe spatial variation in biomass across seagrass meadows. The interpolation was conducted in ArcMap 10.8©.

Results

Climate and environment

In 2021, the air temperature at Centre Island was above average in most months, including October when the benthic habitat surveys were conducted (Figure 11). The average 9 am temperature was 2.6°C above the long-term average. Wind speed was above average at 9 am and around average at 3 pm in most months in 2021. The exception was October when wind speed at 9 am was below average and half the average speed in September or November.

Rain often falls in large events in this region, but on average is the highest in January to March, with very little falling in October (Figure 11). In 2021, there was considerable rain from 17–23 February at Centre Island, but otherwise rainfall was below average. Discharge from the Roper River was well below average in 2021 (Figure 11).

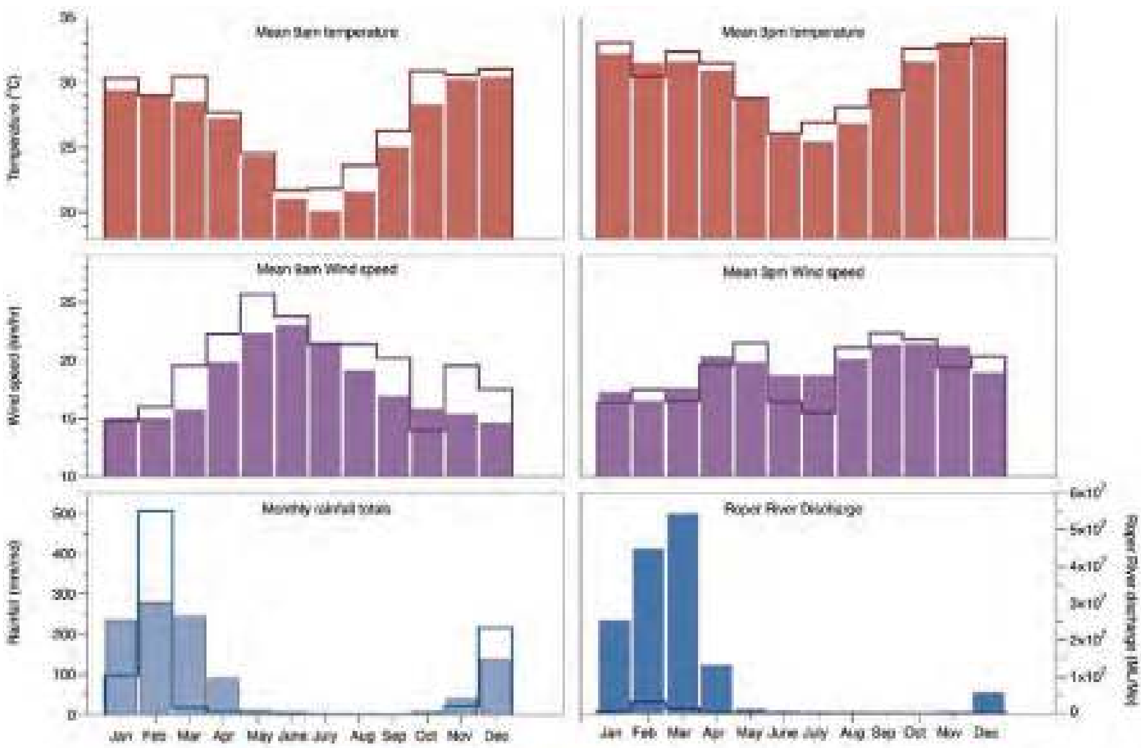

Figure 11. Temperature, wind speed (9am and 3pm) and rainfall at Centre Island and discharge from the Roper River showing long-term average (1974–2010 for temperature and wind, and 1974–2021 for rainfall, bars) and 2021 values (lines). Data from BoM, and the NT Water data WebPortal.

Seagrass

Seagrass was present at 21% of the 2072 sites surveyed (Figure 12). Seagrass was most frequently found in the Limmen Bight Marine Park (Figure 12). Of the 411 sites surveyed within that park, 127 sites had seagrass. Seagrass presence was also high inshore from the Limmen Bight Marine Park near Beatrice Island, and along the coast south-east of the Limmen Bight Marine Park in the coastal area adjacent to the southern section of the Limmen Marine Park near Rosie Creek. Within Limmen Marine Park, seagrass was present at 18 of the 196 sites surveyed (9%); sites with seagrass were mainly in the deeper offshore waters near the north-east boundary of the park, and inshore along the edges of the extensive shallow subtidal meadow in the Limmen Bight Marine Park (Figure 12). Seagrass frequently occurred at sites close to the Roper River mouth and was patchy around Maria

Island. The maximum depth recorded during the survey was 24 m dbMSL, and seagrass was found growing to a depth of 21 m dbMSL (Table 2), both within the Limmen Marine Park.

Seven seagrass species from two families were identified during the survey (Figure 13). These were *Halodule uninervis*, *Syringodium isoetifolium*, *Halophila spinulosa*, *Cymodocea serrulata*, *Halophila ovalis*, *Enhalus acoroides* and *Halophila decipiens*.

Seagrass species diversity was greatest in the large shallow coastal meadow between Limmen Bight River and Rosie Creek (Figure 14). All seven species were recorded in the Limmen Bight Marine Park. Six of the seven species in the survey area were present in this meadow (*H. decipiens* not recorded). *Halodule uninervis* was the dominant species in the intertidal and shallowest areas. The most common species in terms of frequency and contribution to total biomass for most of the meadow was *S. isoetifolium*. Other species present throughout the meadow were *H. spinulosa*, *H. ovalis*, *C. serrulata* and *H. uninervis*. Patchy, small seagrass meadows were present inshore of Beatrice Island; these were dominated by *H. uninervis* and *H. ovalis*. Seagrass near the mouth of the Roper River was all *H. uninervis.* At the majority of sites at Maria Island the only species was *H. decipiens*.

Four species were recorded in the Limmen Marine Park. The only species in the deepwater below 10 m dbMSL was *H. decipiens* near the north-east park boundary. Seagrass along the inshore edge of the Limmen Marine Park were more diverse with *H. ovalis*, *C. serrulata* and *H. uninervis* all recorded.

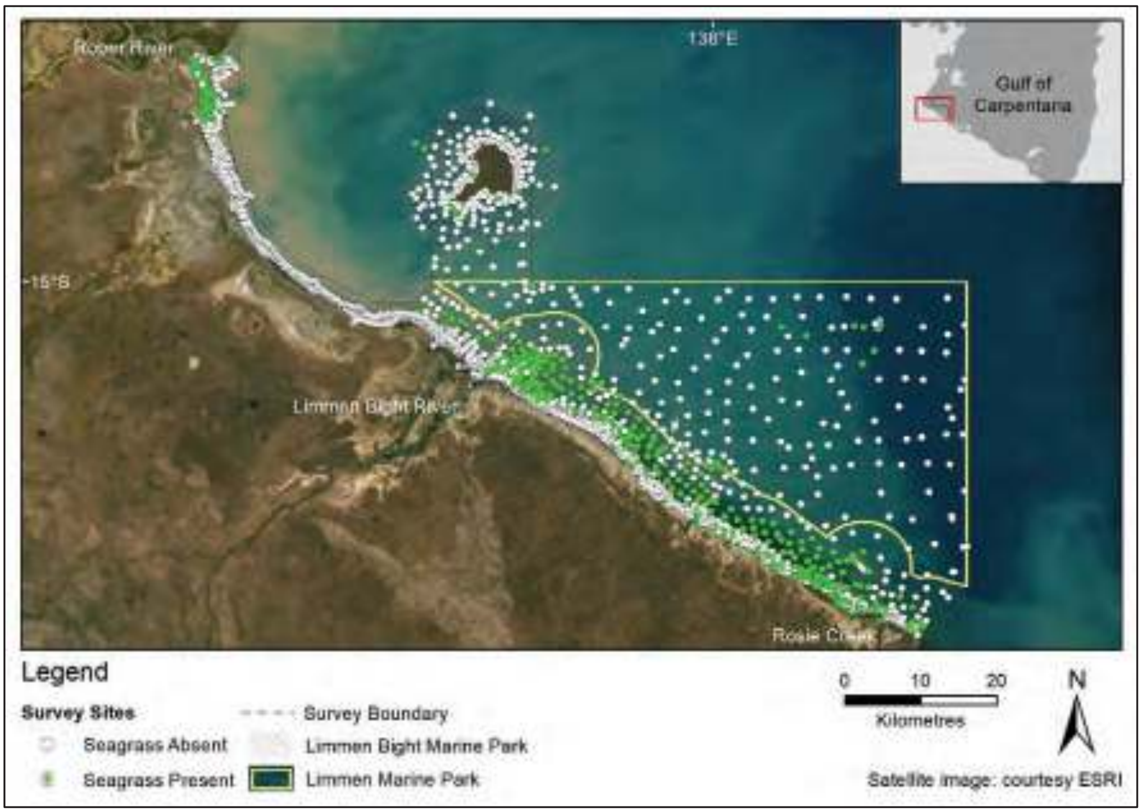

Figure 12. Seagrass presence and absence at survey sites.

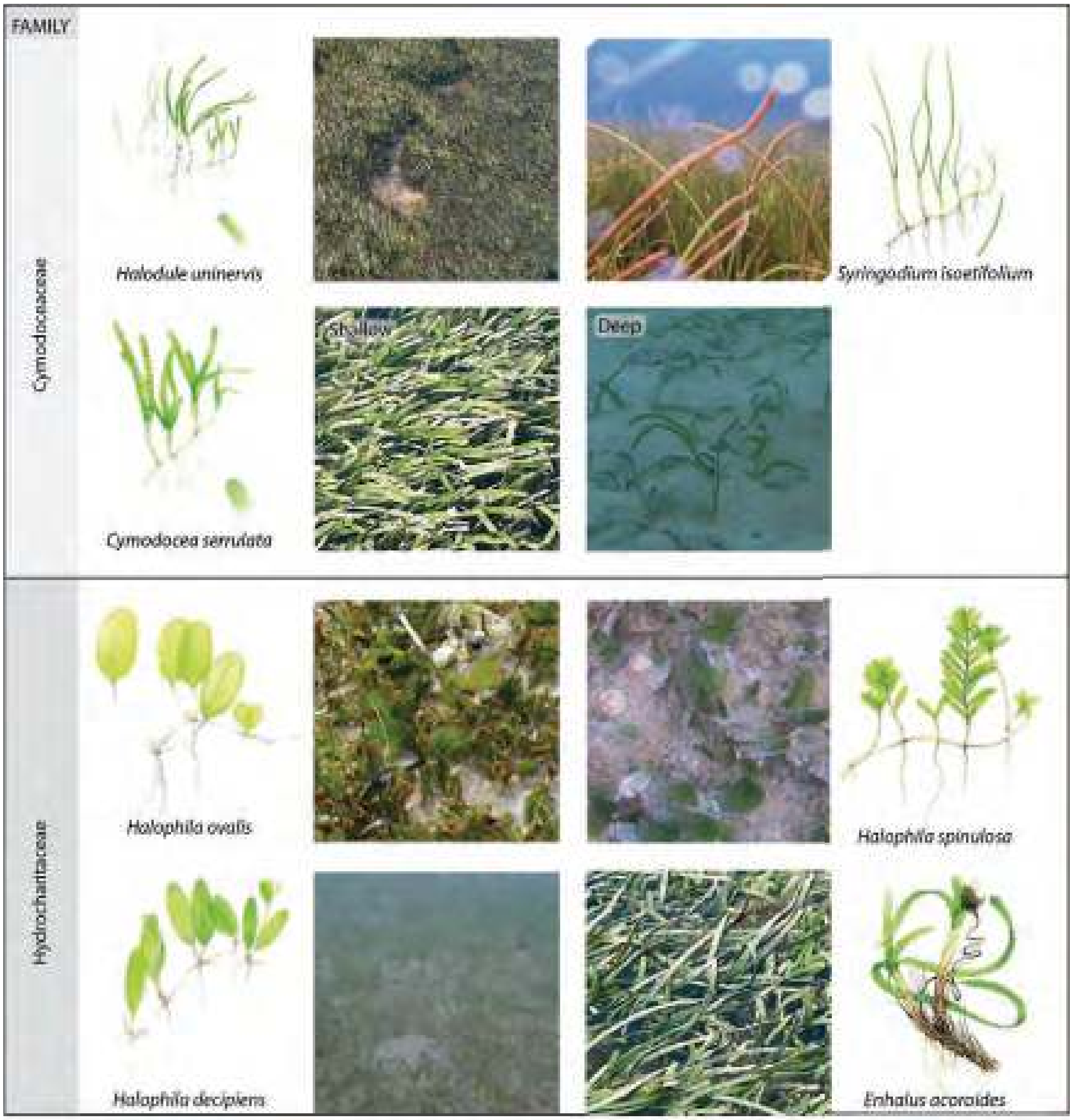

Figure 13. Seagrass species present in and photos of them taken during the survey in October 2021.

Table 2. Minimum and maximum depth (metres below mean sea level) for each species in Limmen Bight Marine Park, Limmen Marine Park and adjacent waters. Values in brackets indicate minimum depth in the subtidal data base.

Species	Minimum depth (m)	Maximum depth (m)
C. serrulata	0 (3.3)	9.7
H. uninervis (wide)	0 (4.2)	6.2
H. uninervis (narrow)	0 (1.3)	9.7
S. isoetifolium	0 (3.3)	7.5
H. spinulosa	0 (1.3)	6.8
H. ovalis	0 (3.0)	9.6
H. decipiens	4.6	21.2
E. acoroides	0	0

A total of 32,352 ± 1651 ha of seagrass was mapped (Figure 14). Most of the seagrass area was within the large meadow between Limmen Bight River and Rosie Creek which, at 24,341 ± 840 ha, accounted for 75% of the seagrass mapped in the survey area. A large portion of this meadow spanned the eastern section of the Limmen Bight Marine Park. The meadow extended 65 km along the coast but is likely to be much longer as the eastern boundary at Rosie Creek represents the survey limit rather than seagrass extent. Helicopter flights traversing between the survey area and Bing Bong (adjacent to the Yanyuwa Indigenous Protected Area) indicated seagrass continues eastward to the Yanyuwa IPA, but this was not ground-truthed. The meadow also extended up to 8.5 km from shore meaning small areas extended into the Limmen Marine Park. Six of the mapped meadows were only subtidal; four of these were within the Limmen Marine Park between 6 and 27 km offshore, and the other two were in the Limmen Bight Marine Park near Maria Island. The two deepwater *H. decipiens* meadows in the Limmen Marine Park covered an estimated area of 1091 ± 155 ha and 3442 ± 235 ha, though seagrass was patchy and sparse so the boundaries are estimates. Nine meadows spanned the intertidal and subtidal zone, including the largest meadow, and smaller meadows near Beatrice and Maria Islands. The remaining 54 meadows were intertidal; these meadows were generally small patches of seagrass that were mapped along the intertidal area closest to the shoreline, and the larger meadows near the Roper River (Figure 14).

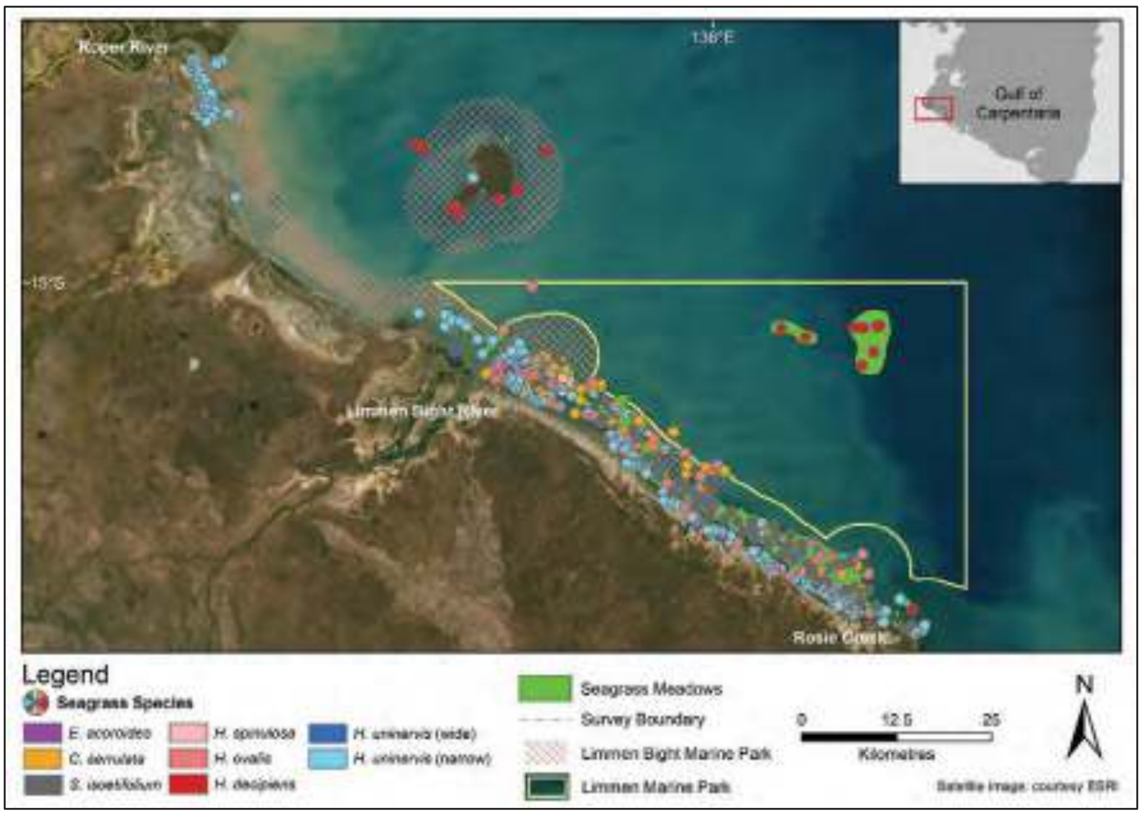

Figure 14. Seagrass species composition at survey sites and meadows in the survey area.

Seagrass biomass hotspots were more prevalent in the large coastal meadow between Limmen Bight River and Rosie Creek where biomass reached 96 gDW m^{-2} (Figure 15). Mean meadow biomass was 11.12 ± 0.04 gDW m^{-2}. Other high biomass sites also were in this meadow, particularly around Beatrice Island, and some of the inshore seagrass patches adjacent to this meadow. Biomass hotspots in the largest meadow at the Roper River mouth reached 21 gDW m^{-2}. Biomass in the Limmen Marine Park did not exceed 11 gDW m^{-2} at any site. In the Limmen Marine Park, mean biomass of the two *H. decipiens* offshore meadows in the north-east section were <1 gDW m^{-2}, while higher biomass occurred in the smaller *H. ovalis* (~6 gDW m^{-2}) and *C. serrulata* (~3 gDW m^{-2}) meadows closer to shore but there is high uncertainty in these values because there were few sampling sites.

Figure 15. Variation in seagrass biomass across meadows.

Algal communities

Algae cover in the survey area was extensive (Figure 16). Algae was present at 21% of the survey sites and accounted for up to 99% of benthic cover at an individual site. All five algae functional groups were recorded, with many sites featuring a mix of groups. Erect macrophyte algae (e.g. *Caulerpa taxifolia*) was the most common algal type throughout the survey area (present at 16% of sites), followed by filamentous algae (7% of sites). Filamentous algae were more common in shallow regions, especially near the mouths of rivers (Figure 17). Erect calcareous algae (e.g. *Halimeda minima*) were most frequently recorded in the large meadow between Beatrice Island and Rosie Creek (Figure 16). Encrusting algae (e.g. Corallinaceae sp.) and turf algae were largely restricted to deep-water regions and around Maria Island (Figure 16).

Figure 16. Algae cover and composition at survey sites.

Invertebrate communities

From the benthic sled, 80 different species of mobile (non-habitat forming; Figure 17) and sessile (habitat-forming; Figure 18) invertebrates were identified from a diverse range of taxa, including:

- Porifera (sponges)
- Urochordata (ascidians)
- Mollusca (gastropods, cephalopods, bivalves)
- Echinodermata (echinoideans, holothuroideans, ophiuroideans, crinoideans, asteroideans).
- Crustacea (penaeids, amphipods, brachyurans, anomurans)
- Cnidaria (scyphozoans, scleratinians, hydrozoans, alcyonarians, actinarians)
- Bryozoa
- Annelida (segmented worms) and
- ‘minor’ phyla (pycnogonids).

A complete list of invertebrates identified from the sled is given in Appendix 5.

Diverse habitat-forming invertebrate communities were recorded in the Limmen Marine Park, in subtidal waters between the Limmen Bight River mouth and Rosie Creek, and around Maria Island (Figure 19). Soft corals (including gorgonians and sea whips), hard corals and sponges were recorded throughout the survey area. A sponge, that may have been the rare *Cliona patera*, was observed from the video at one camera tow site in the Limmen Marine Park; however, samples were not collected as part of these surveys for species identification. Bleaching was analysed for the 54 camera tow sites and observed in soft corals, whips and gorgonians at a total 15 sites across the survey area (Figure 18). Distribution of “other” invertebrates, primarily ascidians, hydroids, and crinoids, was patchier, with low densities at sites (generally <10%) recorded in the Limmen Marine Park and extending north of Beatrice Island to Maria Island.

In the Limmen Marine Park, the dominant taxa based on point analysis were:

Larger taxa are likely to be recorded more often using the annotated point analysis.

Diversity in the taxa were observed was high at sites throughout the Limmen Marine Park as indicated by a higher number of pie chart segments in Figure 19. Numerous sites in the north west and the south east of the Limmen Marine Park had a diverse range of taxa. Species diversity was not recorded in this survey.

Figure 17. Examples of mobile invertebrates sampled using the sled net.

Figure 18. Examples of common sessile invertebrates sampled using the sled net and towed video.

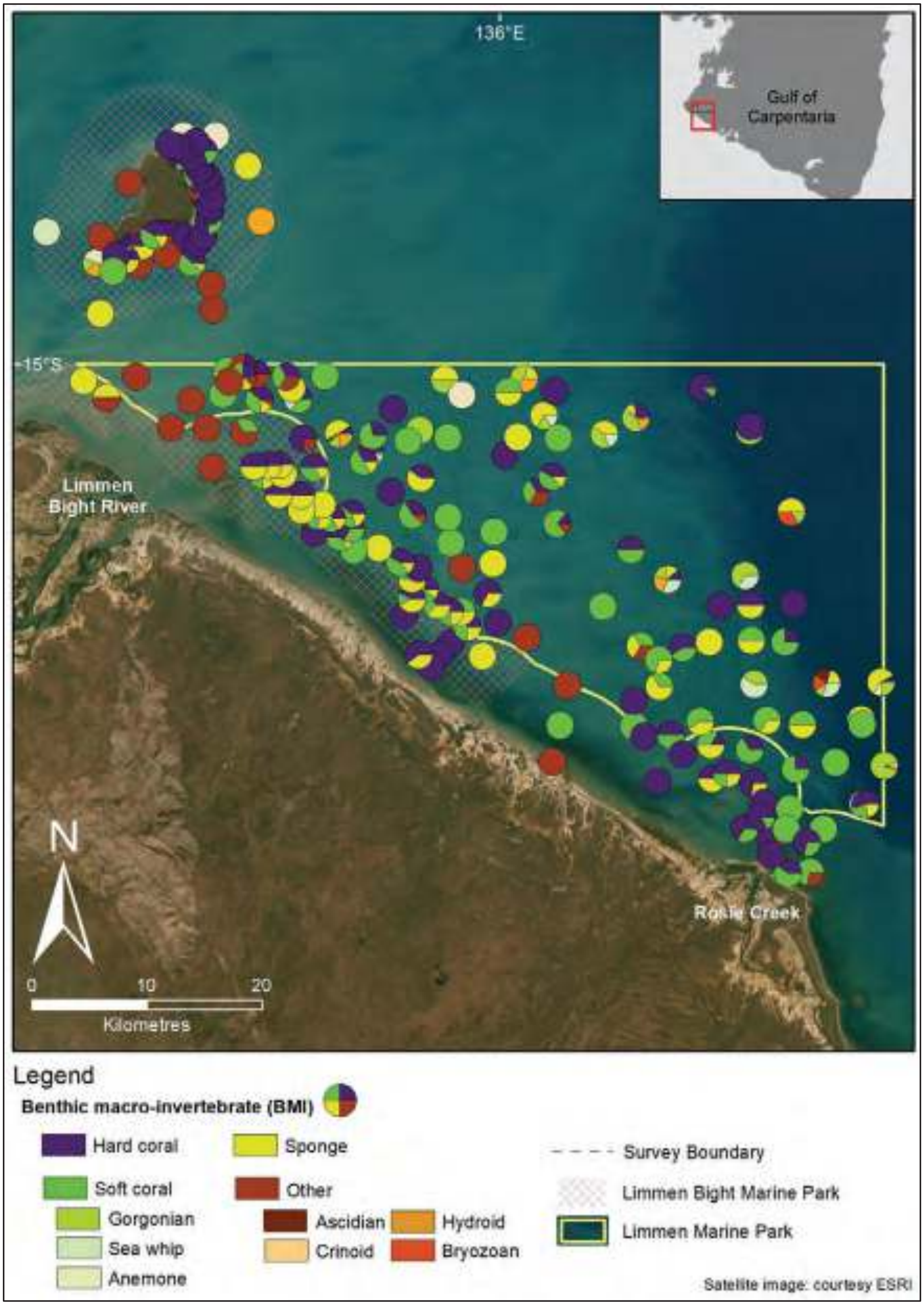

Figure 19. Benthic macroinvertebrate presence and composition at survey sites.

The invertebrate communities around Maria Island were largely confined to the eastern side of the island, with hard corals dominating the rocky north-east coast (up to 80% hard coral cover) and more diverse communities that included crinoids, ascidians and soft corals along the south-east coast. Crinoid "fields" were recorded at two sites north of Maria Island, where densely packed crinoids were resting on the sea floor and comprising 39% and 68% of benthic cover. Crinoids were included as a benthic "habitat" in our analysis despite their ability to move, due to their propensity to cover the seafloor. Sponges were recorded at 25% of subtidal sites but no intertidal sites; coverage at a site was relatively low (<10% cover). Away from the Maria Island coast, hard corals were more likely to be solitary individuals growing on soft-bottom sediment (Figure 20).

Intertidal survey sites had few instances of habitat-forming benthic macro-invertebrates except for Maria Island, where soft and hard corals, oysters and clams were recorded along the rocky coastline (Figure 19). No benthic invertebrates were recorded on intertidal banks between the Roper River mouth and the Limmen Bight River mouth (Appendix 4).

Figure 20. Examples of solitary hard corals and large sponges on soft bottom sediment. The coral in the upper photo is *Turbinaria* sp. and the large sponges in both photos are *Ianthella* sp.

Other species observed

Large marine vertebrates observed during the survey include green turtles (*Chelonia mydas*), bottlenose dolphins (*Tursiops aduncus*), saltwater crocodiles (*Crocodylus porosus*), dugongs (*Dugong dugon*), and olive sea snakes (*Aipysurus laevis*). Mud crabs were frequently observed by helicopter on intertidal banks.

Fish surveys were out of the scope for this survey; however, the following species were observed serendipitously in the field and on video footage:

- *Cybiosarda elegans* (leaping bonito)
- *Plectropomus maculatus* (barcheek coral trout)
- *Plectropmus leoparus* (common coral trout)
- *Choerodon schoenleinii* (blackspot tusk fish)
- *Chaetodontoplus duboulayi* (scribbled angelfish)
- *Pterocaesio chrysozona* (fusilier)
- *Lutjanus malabaricus* (largemouth nannygai/ saddletail snapper)
- *Plectorhinchus unicolor* (sombre sweetlip)
- *Diagramma pictum labiosum* (painted sweetlip)
- *Plectorhinchus multivittatus* (manyline sweetlip)
- *Lutjanus carponotatus* (stripey snapper)
- *Chelmon marginalis* (margined coralfish)
- *Scomberomorus commerson* (spanish mackerel)
- *Stegostoma tigrinum* (zebra shark)
- *Nebrius ferrugineus* (tawny shark)

It should be emphasised that this list is in no way comprehensive or representative of the diversity of fish species in the survey area.

Discussion

We found vast and dense seagrass habitats, complex invertebrate communities including soft bottom and reef-building corals and associated pelagic fauna in the Limmen Bight Marine Park, Limmen Marine Park, and adjacent coastal waters (Figure 21). This information complements Marra people's Indigenous Knowledge on the biological diversity of Marra sea country (Bradley, 2018). Both knowledge systems are critical in making decisions for marine park management and for Healthy Country planning. This partnership identifies key species and habitats and their distribution, priority sites and threatening processes. Baseline information such as this is a necessary first step for designing and establishing a habitat monitoring program.

Important ecological features of the marine parks in Marra sea country are:

- an extensive coastal seagrass meadow from Rosie Creek to Limmen Bight River (~65km in length)
- deepwater seagrass not previously recorded in the south-western Gulf of Carpentaria.
- coral reefs at Maria Island, and
- diverse soft coral and invertebrate habitat throughout most of the Limmen Marine Park and.

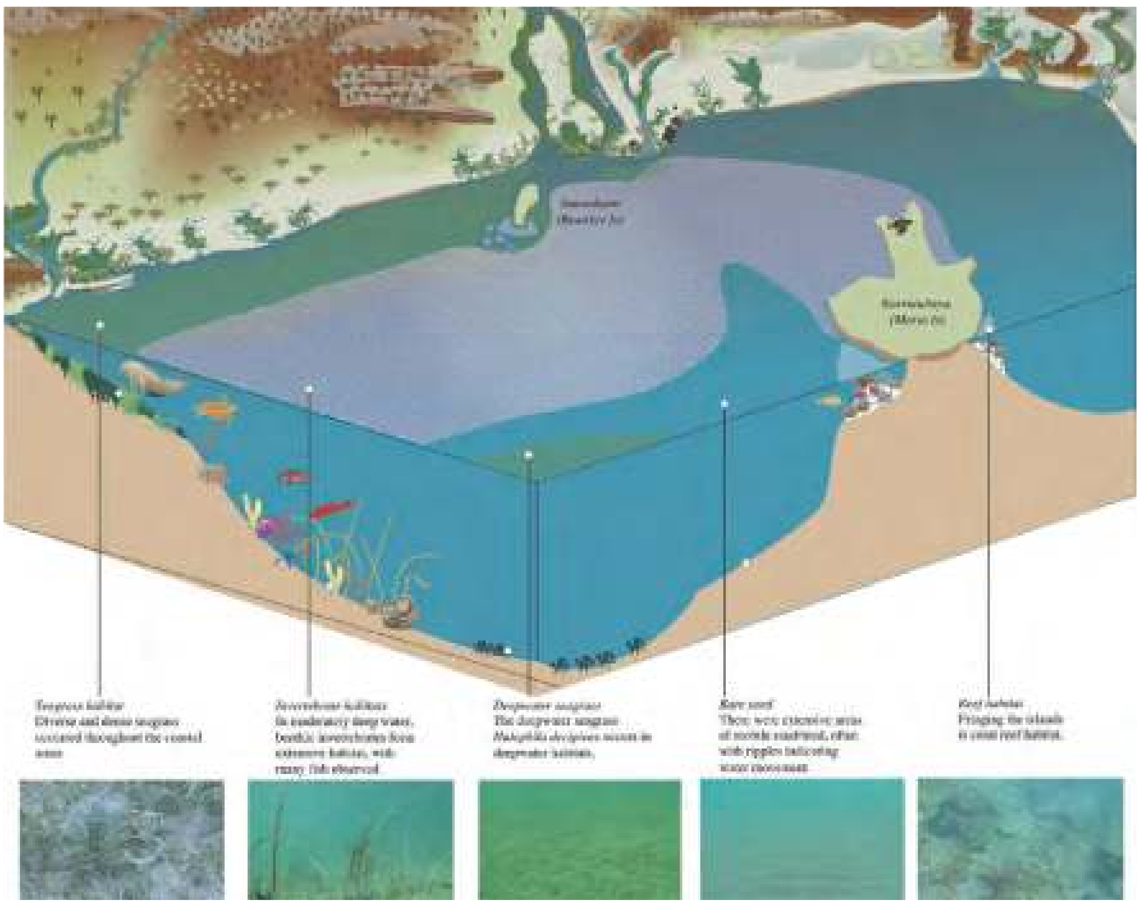

Figure 21. Conceptual map of the Limmen Bight region showing the main ecological features observed in Marra sea country.

Shallow coastal seagrass

There was a 65 km long meadow that began adjacent to mangroves in intertidal areas with high tidal exposure and extended to 8.5 km offshore and depths to 9.7 m dbMSL. Shallow coastal seagrass habitat extended in area and depth well beyond the previously mapped meadows in the survey area (Figure 22). The low-energy, relatively shallow environment of the southern Gulf of Carpentaria enables these coastal habitats to thrive (Poiner et al., 1987; Wightman et al., 2004). These coastal habitats are referred to as 'maja' by Marra people and are distinguished from 'julangal' for seagrass commonly found growing on reefs.

Tropical seagrasses are diverse and both Limmen Marine Parks are a seagrass diversity hotspot within the Indo-Pacific (Waycott et al., 2004). We identified six seagrass species in the large coastal meadow with the dominant species changing with tidal exposure and depth due to differences in the optimal growing conditions for each of them. The species found in this meadow and transition between species matched previous observations of western Gulf of Carpentaria seagrass meadows in open coastlines, where intertidal regions are dominated by *H. uninervis* and *H. ovalis*, and *C. serrulata* and *S. isoetifolium* dominate shallow subtidal waters (Poiner et al. 1987).

Figure 22. Previously mapped *Halophila ovalis* dominated intertidal seagrass meadows (Roelofs et al., 2005).

Understanding why and where seagrass species grow provides insight into what environmental conditions and pressures can be addressed for protection and restoration of coastal habitats. The narrow form of *H. uninervis* and to a lesser extent *H. ovalis* were dominant in the intertidal habitats, except for slightly deeper drainage channels where other species also grew. Towards the Roper River, only *H. uninervis* was observed. The intertidal zone where these two species dominated is an environment of extremes, and the dominance of these species in high exposure intertidal meadows is typical of other locations in the southern Gulf of Carpentaria (Rasheed & Unsworth, 2011). Low tide exposure occurs over brief windows of around six days once or twice a month during spring tides bringing a risk of desiccation and heat stress. In these intertidal habitats, photosynthesis can occur at or around low tide when there is sufficient light (Petrou et al., 2013). When there are no spring tides and the seagrass is not exposed, the high turbidity regime of the inshore (Rothlisberg & Burford, 2016; Thompson & McDonald, 2020) might prevent light reaching seagrass habitats. During summer, spring tides do not usually occur during the day so there is likely to be extended periods of very low light reaching seagrass throughout summer.

The narrow-leaved form of *H. uninervis* has small flexible leaves that lie on the surface of the mud at low tide, thus staying moist and avoiding desiccation (Figure 23). Despite its small stature (especially in the narrow form), *H. uninervis* has around 84% of its plant mass below ground in rhizomes (Collier et al., 2021) and it has a very high ratio of energy reserves (sugars and starch) compared to the plant size (Collier et al., 2012). Energy reserves build up when there is sufficient light and can sustain growth during periods of low light. Combined with morphological and physiological plasticity, this might enable *H. uninervis* to tolerate the highly turbid conditions and extended periods of low light near the Roper River (Collier et al., 2016; Collier et al., 2012). It also grows and spreads relatively quickly and the *H. uninervis* near the Roper River grew in patches that indicate recent growth and expansion. The coloniser species *H. ovalis* is less tolerant to periods of low light (Collier et al., 2016; Longstaff & Dennison, 1999), but maintains overall resilience by recovering quickly from sub-optimal conditions, including by regrowing from seeds (Kilminster et al., 2015; Rasheed et al., 2014).

Figure 23. Typical shallow seagrass communities including (a) *H. uninervis* (narrow) laying over wet mud, (b) extensive dense seagrass meadows east of Limmen Bight River, (c) dense seagrass in shallow channels, (d) sparse *C. serrulata* with rhizomes extending at the deep edge of a meadow.

The large coastal meadow transitioned to a mixed community dominated by *S. isoetifolium*, *C. serrulata*, and *H. spinulosa* in the shallow subtidal areas. These species also occurred at some intertidal sites but are less suited to intertidal habitats because they are larger and sensitive to desiccation stress and dominated shallow subtidal waters adjacent to the intertidal zone (Figure 23). The species *C. serrulata* and *H. uninervis* (narrow) extended the deepest in this meadow, followed closely by *H. ovalis*, suggesting relatively higher tolerance to low light conditions.

The maximum biomass observed in this meadow was high (96 gDW m^{-2}). This is comparable to the highest values observed in meadows with similar environmental conditions and species composition in coastal subtidal communities elsewhere in Queensland (Carter, A. B. et al., 2022; Carter, Alex B. et al., 2021). The average biomass in this coastal meadow (11 gDW m^{-2}) was also similar to the 'desired state' these coastal subtidal communities exhibit on Queensland's east coast (Carter et al 2022b). Seagrass biomass and extent vary seasonally and inter-annually according to climatic conditions and anthropogenic pressures in the Gulf and Torres Strait (Carter et al., 2014; Unsworth et al., 2012) and along the Great Barrier Reef coast (Carter, A. B. et al., 2022; Collier et al., 2020; Lambert et al., 2021). Several years of monitoring are required to measure changes in meadow extent and the ranges in biomass for the meadow to investigate how representative these biomass values are for the meadow.

Deepwater seagrass

In deeper waters there were two *H. decipiens* meadows at 21 m dbMSL in the Limmen Marine Park, but mostly an extensive zone where no seagrass was found. There are a number of reasons for the lack of seagrass in this region, including mobile sand with ripples that are too unstable to support seagrass (Figure 24), areas of hard or rubble substrate (reef) unsuitable for seagrass growth, and an unsuitable light environment. High inshore turbidity due to tidal movement and wind-driven resuspension, combined with increasing depth, most likely make this zone unsuitable as habitat for plants that require light for photosynthesis.

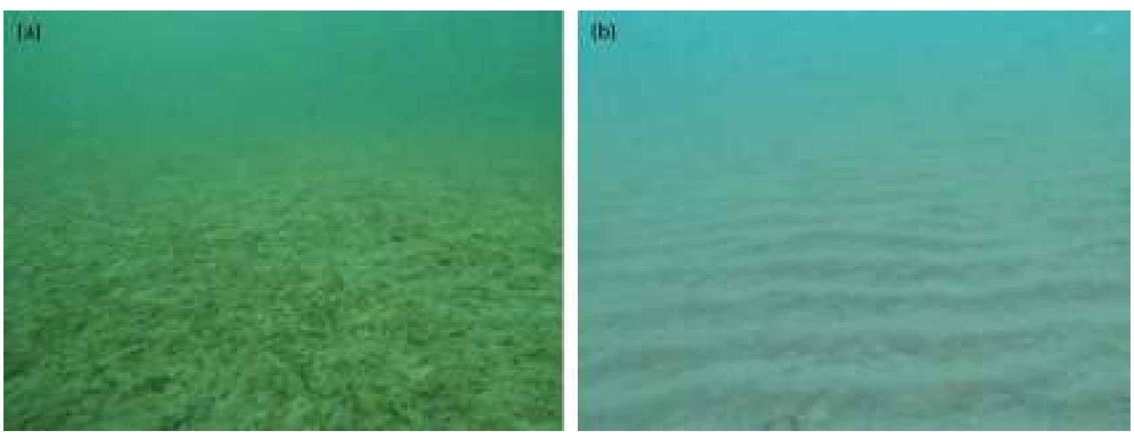

Figure 24 (a) A typical deep-water *H. decipiens* seagrass habitat in Limmen Marine Park and (b) mobile sand with ripples.

Offshore waters are typically less turbid because they are further away from the processes in the shallow coastal areas that elevate turbidity (such as riverine input and resuspension). Light levels of only around 4% of surface irradiance are required by *H. decipiens* (Chartrand et al., 2018). Only brief periods below these light requirements will cause seagrass loss (Chartrand et al., 2018; York et al., 2015) because they do not have substantial rhizomes capable of storing energy reserves (Collier et al., 2021). These surveys were conducted in the dry season in October at a time when benthic light levels, extent and biomass are expected to be highest.

This is the first time that deep-water seagrass (i.e. deeper than 10 m), has been recorded in Marra sea country. This is because previous surveys have focussed on the shallow coastal margin where seagrass can be seen from small planes or helicopters, or where access by small vessels are restricted to nearshore surveys (Carter, A. et al., 2022). The presence of deep-water seagrass in this area and at similar depths in the north-eastern Gulf in West Cape York (Carter et al. unpublished data) and Torres Strait Dugong Sanctuary (Taylor & Rasheed, 2010), warrants further investigation of deep-water seagrass habitats in the entire Gulf of Carpentaria.

The effect of previous trawling (prior to 2018) on the Limmen Marine Park deepwater seagrass communities is unknown. The colonising *H. decipiens* seeds and fragments are predicted to be dispersed for 10s to 100s of kilometers with currents (Grech et al., 2016). However the time taken for dispersal within the Gulf of Carpentaria is not known, and propagule production may be limited by low density and patchy seagrass. This species can grow rapidly when conditions are favourable (York et al., 2015); however, whether they were suitable for deepwater seagrass growth from 2018 to 2021 is not known. Comparative studies inside and outside of the Limmen Marine Park could provide insight into the effect of prohibiting trawling in the Limmen Marine Park on deepwater seagrass recovery and distribution.

Invertebrate communities

Most benthic species found in tropical northern Australia also occur in the waters of at least one other country (particularly within the 'Coral Triangle' to the north and northwest of northern Australia), but their occurrence and the communities they form are largely unique to Australia (Figure 25). The few previous quantitative surveys that give information on soft sediment benthic invertebrate communities in the Gulf of Carpentaria (such as that by Post et al. (2006)) were based on trawls, so their species assemblages and conclusions are very different to ours that were based on non-destructive methods. Post et al. (2006) recorded 569 species with the six taxa having the highest abundance being polychaetes (marine bristle worms), ophiuroidea (brittle stars), a bryozoan (moss animal), a hydroid, crinoidea (feather stars), and an echinoid (heart urchin). Therefore, the only concordance between their survey and ours is that of the significance of crinoids.

Figure 25 Reef-associated invertebrate communities around Maria Island.

Pressures and threats

Evaluating risks to benthic habitats from environmental threats is necessary to support the development of a management framework for the south-west Gulf of Carpentaria. Biodiversity in the Gulf of Carpentaria is threatened by climate change (including sea level rise, warming water temperature and cyclones), pollution (light, noise, chemical), habitat modification, water quality, marine debris, fisheries (prawn trawling, gill-netting) and boat strike (Parks and Wildlife Commission, 2019).

Global and regional-scale assessment of risks identified that the fauna of Limmen Marine Park was at relatively low risk (Kyne et al., 2018). However, data and models on key natural values such as benthic habitats are needed to understand threats at local and species-relevant scales (Kyne et al., 2018). This study aimed to address that gap by collecting detailed habitat information on spatial scales relevant to management.

There is little information on the pressures on habitats in shallow inshore areas in the NT Gulf of Carpentaria, except for risk modelling studies (Kyne et al., 2018; Plagányi et al., 2022). Interactive and cumulative impacts are poorly understood in general within Australia, and there is nothing known on cumulative impacts in the Gulf of Carpentaria, for example how elevated temperature affects stress caused by turbidity and vice versa. There is also no information on the local adaptation and acclimation of species to environmental conditions and pressures.

Water quality

Habitats in Marra sea country are in shallow coastal inshore areas that are highly turbid. Turbidity is influenced by sediment and nutrient loads from creeks and rivers, and resuspension of sediment and particulates during windy periods.

Seagrass and algae are primary producers and must produce their own energy through photosynthesis. Water quality can affect photosynthesis by influencing:

- turbidity and low benthic light that slows photosynthetic rates
- pollutants in the water, such as metals that damage photosynthetic pathways
- nutrient availability which can affect the growth of epiphytic algae and macroalgae.

In areas that have intermittent or seasonally variable water quality, seagrass extent and biomass might also vary seasonally. Seagrass growth in tropical Australia is generally highest in the late dry season (around October and November) and declines during the wet season caused by a combination of clouds, rainfall and runoff reducing light availability, and elevated water temperature. *Halophila ovalis* is the most sensitive of the shallow and intertidal seagrass species and will decline after two weeks and completely die after approximately one month's exposure to turbid, low light conditions (Collier et al., 2016; Longstaff & Dennison, 1999). Other species will decline after about a month of exposure to low light but can survive for two to three months by drawing on energy reserves (Collier et al., 2016; Longstaff & Dennison, 1999). The degree of seasonal change in biomass and extent is influenced by the level of turbidity and the duration of exposure to elevated turbidity.

Near the Roper River, filamentous and epiphytic algae grew over seagrass and there were also isolated patches of seagrass (Figure 26), both indicative of seagrass habitats under pressure and with low resilience (Unsworth et al., 2015). The deeper edge of the seagrass meadow is also generally limited by the amount of light reaching the benthic habitats (Abal & Dennison, 1996). During large rain events, turbidity is likely to increase, and the deep edge may retreat to shallower waters.

Turbidity by itself can strongly affect the biodiversity and composition of marine invertebrate communities. At this point, we have insufficient baseline data to assess the response(s) by the benthic invertebrate communities to the impacts of turbidity and/or other threatening processes in this region.

Figure 26. Threats to the condition of benthic habitats observed during the surveys including (a) filamentous algae growing over *H. uninervis* near the Roper River, (b) fragmented habitat near the Roper River, (c) desiccated seagrass leaves exposed to air at the tips at low tide and sitting in a pool of shallow water, (d) a crab pot in an area important for dugong feeding based on their trails.

Climate change

Climate change threatens the ecosystems of the Gulf of Carpentaria through thermal stress, sea level rise and extreme weather events such as cyclones and floods (Parks and Wildlife Commission, 2019). From October to February, the shallow waters in the Gulf of Carpentaria heat up quickly (Wijffels et al., 2018). Warm (>30 °C) water originating in the Gulf of Carpentaria can also influence the Torres Strait and Great Barrier Reef (Wolanski et al., 2017).

A mass mangrove dieback event in the Gulf of Carpentaria in 2015 and 2016 revealed the risk to inshore habitats caused by climate variability (Duke et al., 2017). The losses were attributed to a combination of falling sea level (associated with the El Niño event) and thermal stress (Duke et al., 2021). This event demonstrates the risk of extreme climate events to the Limmen Bight Marine Park and Limmen Marine Park. The impacts of climatic extremes on benthic habitats have been documented from other localities in northern Australia. Drought and elevated temperature were associated with seagrass decline in Karumba in Queensland in 2002–2003 (Rasheed & Unsworth, 2011), and catastrophic loss of seagrass habitat and associated ecosystems occurred when thermal stress was sustained over months in Shark Bay in Western Australia (Strydom et al., 2020).

Habitats in shallow pools in the intertidal areas and creeks and inlets of the Limmen Bight Marine Park and adjacent areas are also at risk of thermal extremes at low tide when water temperature can heat to well above ambient air or sea temperature (Pedersen et al., 2016). As temperatures rise above 33–35°C respiratory rates increase, net productivity declines and plants lose energy (Collier et al., 2017). Prolonged exposure to temperatures above 40°C for 4 hours leads to photosynthetic impairment and leaf damage (Campbell et al., 2006; Pedersen et al., 2016) and mortality occurs after multiple days of exposure to this regime (Collier & Waycott, 2014).

Seagrass desiccation (drying/burning) was observed during the surveys in the shallow dense intertidal meadows in the Limmen Bight Marine Park (Figure 26). This is common in healthy shallow or intertidal habitats at low tide, but it can exacerbate heat stress on the plant (Rasheed & Unsworth, 2011). Increased drought conditions are also associated with high salinity in shallow inshore habitats and inlets which can add to plant stress (Rasheed & Unsworth, 2011).

The effect on coral communities of the 2015–2016 period of thermal stress in the southern Gulf, however, is undocumented. The incidence of bleaching, particularly of soft corals, at 15 sites in subtidal waters of the Limmen Marine Park during the 2021 survey highlights the potential vulnerability of habitats in this region to thermal stress.

Resilience and dependant species

Ecological resilience underpins ecosystem longevity and provision of cultural values. It is therefore essential to understand what influences resilience in the benthic habitats of Marra sea country. For example, the health of dugongs and turtles are known by Marra people to be linked to seagrass health, recognising that grazing by these animals is also important for the health of the seagrass itself (John Bradley and Yanyuwa families, 2007; NAILSMA, 2018).

The dugong population of NT Gulf of Carpentaria has been stable for decades (Groom et al., 2017). Dugongs likely move throughout the region, and movement is most likely when they are searching for new seagrass patches (Marsh, Hodgson, et al., 2008) (Figure 27). How dugongs use the habitats in Marra country has not been studied; however, recent studies in Yanyuwa country bordering Marra country showed nine tagged dugongs had relatively short ranges (< 200 linear km). The data recorded from these dugongs also showed that the use of deeper habitats (> 5 m bathymetry) by dugongs was infrequent (less than 1% of detections from four dugongs) (Udyawer et al., 2019).

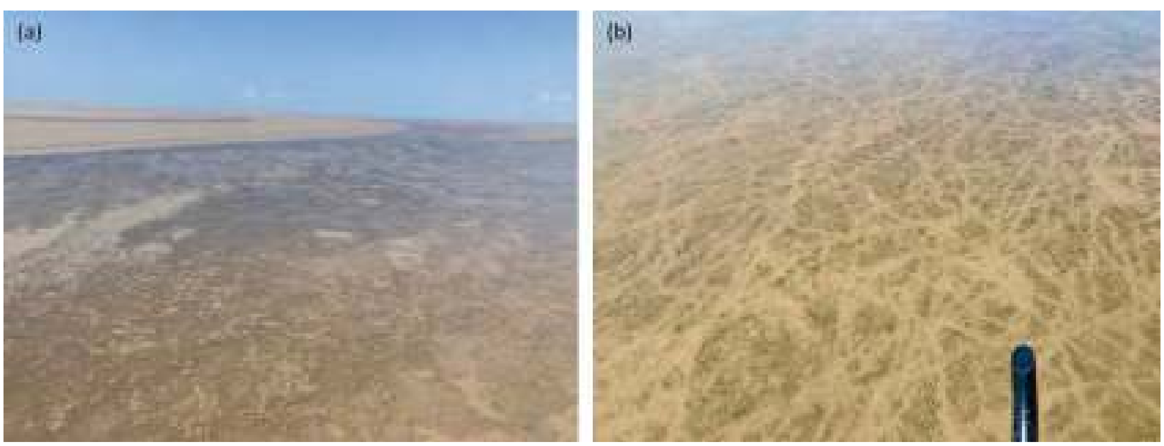

Figure 27. Dugong feeding trails in Marra sea country and the Limmen Bight Marine Park.

Seagrass habitats are connected through the transport of seagrass propagules in currents (Grech et al., 2016; Schlaefer et al., 2022) and may also be spread by grazing animals (Tol et al., 2017). The production and spread of propagules including seeds is essential for resilience because it increases genetic and species diversity and enhances rates of recovery (Unsworth et al., 2015). Therefore, the habitats of Marra are influenced by the condition of and actions in adjacent areas. The resilience of the Gulf of Carpentaria is also dependant on linkages between habitats such as mangroves, seagrass and reef habitats for shoreline stabilisation, blue carbon storage and fisheries (Huxham et al., 2018; Unsworth et al., 2015).

Next steps and future priorities

Partnerships

A partnership approach is required to implement the North Marine Parks Network Management Plan 2018, and it should be led by Marra Traditional Owners and custodians so that research is guided by local decision-making structures and methods are culturally appropriate. Participatory mapping is a foundation to guide discussions and establish an understanding of what knowledge exists, what knowledge is needed, where it is needed, and how those needs can be addressed.

Indigenous cultural knowledge, including tangible and intangible cultural heritage and values, are central to marine park management. The principles outlined in Watkin Lui et al.'s (2016; p.1271) "setting the table" needs to be followed to support respectful relationships and exchange of knowledge. The design process will include the co-development of protocols and a research agreement for managing culturally sensitive data and identification of values for future monitoring and management. This will be co-developed with Marra knowledge authorities to establish the protocols for managing layers of access for public, private, and privileged data.

Management actions in Marra sea country need to be nested within a wider management framework that address the space and time scales that influence resilience (O'Brien et al., 2018). Local-scale actions can be taken to increase resilience, but regional and national actions and policy are also needed to address climate change and land-sea connectivity (Duke et al., 2021; Serrano et al., 2021).

The following near-term priorities were identified by Marra Traditional Owners and custodians and the research team. They are the result of discussions with Marra people, li-Anthawirriyarra rangers and researchers that regarded ways to improve local and regional management of sea country:

- Identify opportunities for families and kids be part of future projects and cultural learning on Marra country
- Survey connected (adjacent) areas including the South-east Arnhem Indigenous Protected Area (IPA) and Yanyuwa IPA and subtidal waters and the creeks and tidal inlets of Marra country that fell outside of our survey area, but where benthic habitats were observed. There are of cultural and economic importance.
- Improve understanding of baseline environmental conditions, resilience, and threats and explore adaptation opportunities.
- Discuss opportunities for supporting aspirations for adjoining sea country by finding synergies in management frameworks, and identifying ways to partner and support each other for monitoring and management.
- Identify deficiencies in areas of protection in the Gulf of Carpentaria based on these findings and seek to improve this with partners and stakeholders.
- Use this information and other environmental datasets to support a Marra-led zoning scheme within the Limmen Bight Marine Park.
- Find funding for at least one Marra or Aboriginal person to progress the aspirations of Marra people and coordinate future project work with partners.

Monitoring

A need for monitoring has been expressed by Traditional Owners and custodians for the Limmen Bight and Limmen Marine Parks as part of the Marra Healthy Country Planning process and through meetings with Commonwealth and NT government partners and researchers. It is understood by Marra people that the two Parks are connected and so the monitoring suggested reflects the connection of coastal and offshore environments. Monitoring to understand the health of the environment has been noted as important by Marra people. Maintaining the environmental integrity of the coastal area will likely benefit the waters offshore as species move between these areas. Discussions on monitoring have centred around the following themes:

Important cultural places

Sacred sites, cultural fishing areas, waters near outstations, Marra family use areas

Important cultural and socio-economic species

Barramundi, threadfin salmon, mangrove jack, queenfish, mud crabs, mud mussels, longbums, turtle and dugong

Important habitats or areas under pressure

Mangrove dieback has concerned and saddened Marra people. The long-term loss of this habitat in the Limmen region may impact coastal stability and nearshore water quality and habitats.

Seagrass supports many culturally and economically important species.

Coral and rocky reef communities: Look at species using these areas and the health of the habitat, e.g., bleaching.

Rivers and creeks: water flows and water quality, monitor and manage to ensure any upstream impacts don't impact downstream values, monitor barramundi and other fish and crabs are available for Marra people.

Following agreement on a co-designed approach, additional workshops will be required to co-design a marine park monitoring program that incorporates Traditional Owner and custodian values and knowledge as well as western scientific approaches that can build robustness into the design to detect change and allow for adaptive management.

Due to historical displacement of Marra people from their country, many people are now scattered between distant communities., There is work to be done re-engaging young people with sea country (Bradley, 2018). The monitoring program can contribute to this aspiration.

Several possible monitoring approaches could be taken subject to Marra peoples' interests and priorities, including:

- annual mapping of benthic habitats including seagrass, corals and invertebrate communities, and mangrove habitats of Marra country
- monitoring priority areas based on areas of cultural significance or pressures
- measuring seasonal variability in key habitats
- measuring fish communities
- linking changes in habitat to changes in dugong, turtle, and fisheries populations.

- measuring pressures such as water temperature, environmental flows, and benthic light within inshore habitats where other data sources (satellite imagery, modelling) are less accurate.

Research priorities

In understanding the monitoring priorities of Marra people, the following research themes were discussed with Marra Traditional Owners and custodians. The themes reflect an opportunity to grow knowledge on matters that people care about and want to better understand to improve management. This study has identified the need to better understand:

- how people's connection to country and cultural practice (and health) can increase over time by having an Indigenous-led marine park
- Determine habitat loss and refugial habitats under changing climate scenarios, e.g. sea level rise
- how to mobilise novel and efficient monitoring tools to better empower ranger and community monitoring in remote areas
- the role of habitat connectivity in maintaining overall ecological health and to support the identification of priority areas for protection and/or restoration as needed
- the influence of inshore water flows, quality and water temperature on the distribution of habitats, their abundance, and their resilience
- updated population data on key species (e.g. dugong, turtle, mud crabs, barramundi, demersal fish)
- extent of seasonal variability in habitats and key species
- the extent and importance of deep-water seagrass communities in the Gulf of Carpentaria including comparative studies inside and outside of the Limmen Marine Park.
- the role of herbivory in maintaining seagrass condition, particularly by dugong and green turtles given their high density in the area i.e. to better understand ecological resilience
-

Conclusions

Marra sea country, including the Limmen Marine Park and Limmen Bight Marine Park is an area of high biological diversity. The extent, diversity and abundance of seagrass habitats and complex invertebrate communities including soft bottom and reef-building corals have been documented for the first time in this survey. The region is subject to mounting pressures from climate change and extreme weather events, commercial fishing, and land-based developments. Monitoring will be needed to understand the influence of these pressures over the region. The monitoring program needs to be co-designed with Traditional Owners using culturally appropriate methods. Preliminary discussions on these matters have begun in various forums however, they require more detailed discussion to be fully informed. The partnerships, monitoring, research and management should consider the region as a whole and reflect the ecosystems and protection areas connected to Marra country in the southern Gulf of Carpentaria.

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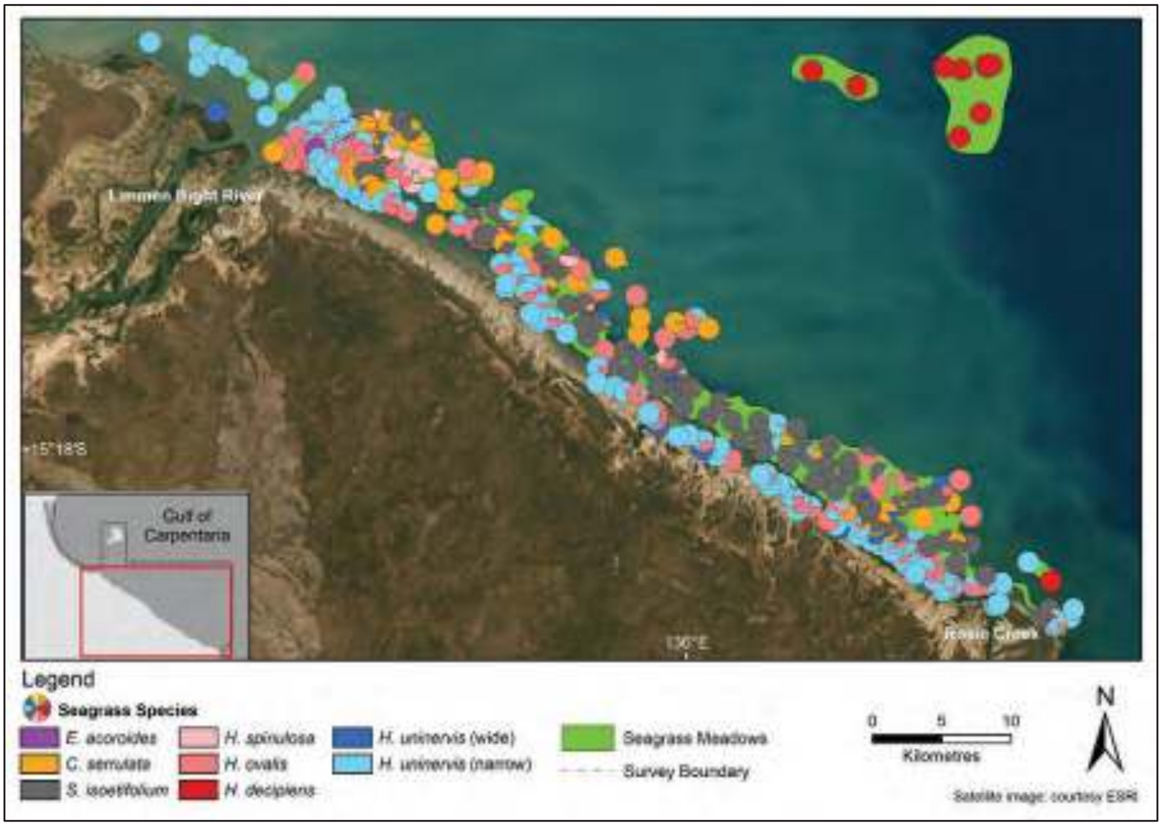
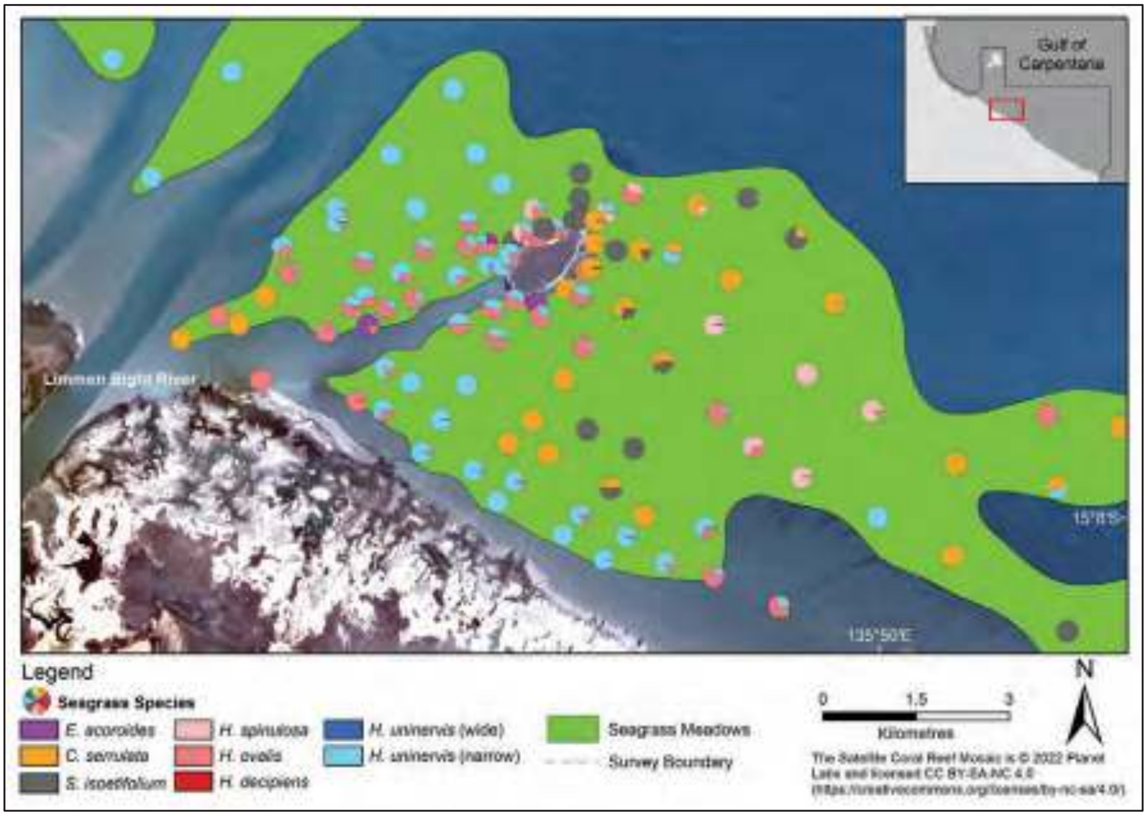
Appendices

Appendix 1. Seagrass species composition at survey sites within meadows in the survey area.

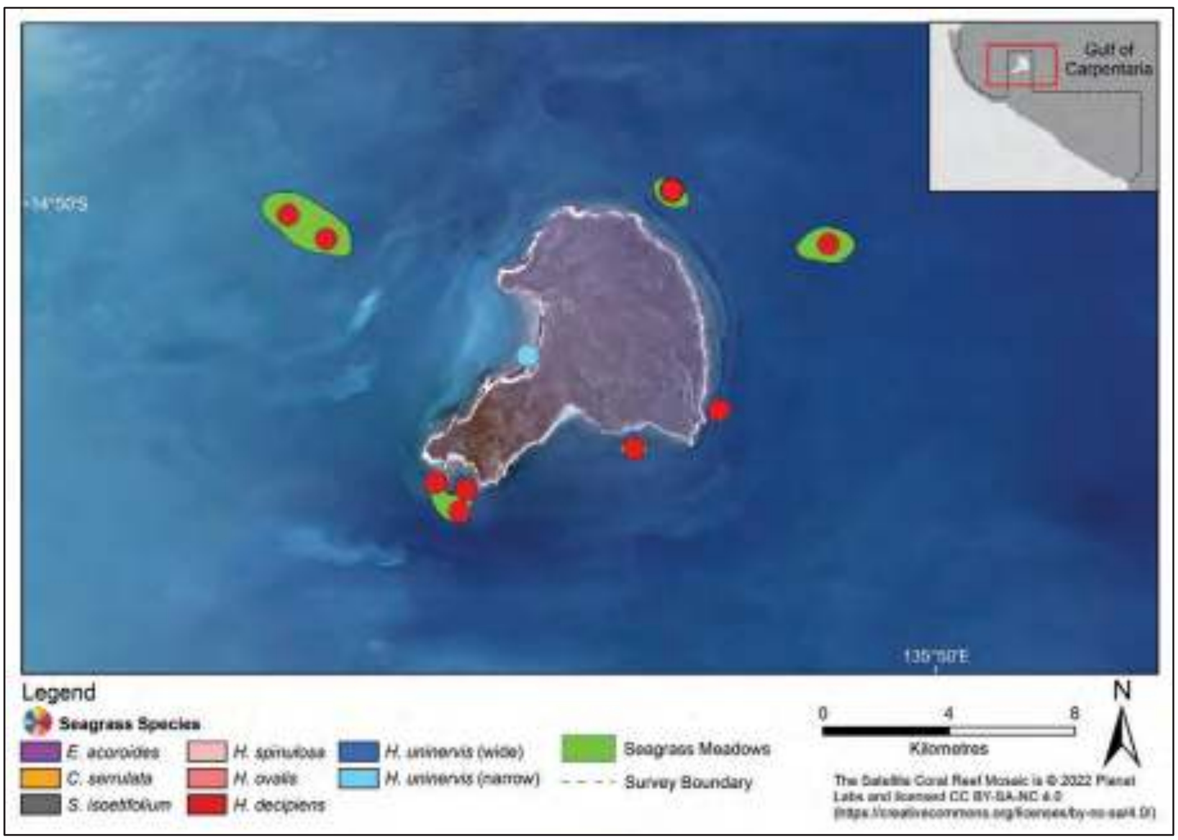
A1.1. Seagrass species composition at survey sites and within meadows near the Roper River.



A1.2. Seagrass species composition at survey sites and within meadows between Limmen Bight River and Rosie Creek.



A1.3. Seagrass species composition at survey sites and within meadows at Beatrice Island.



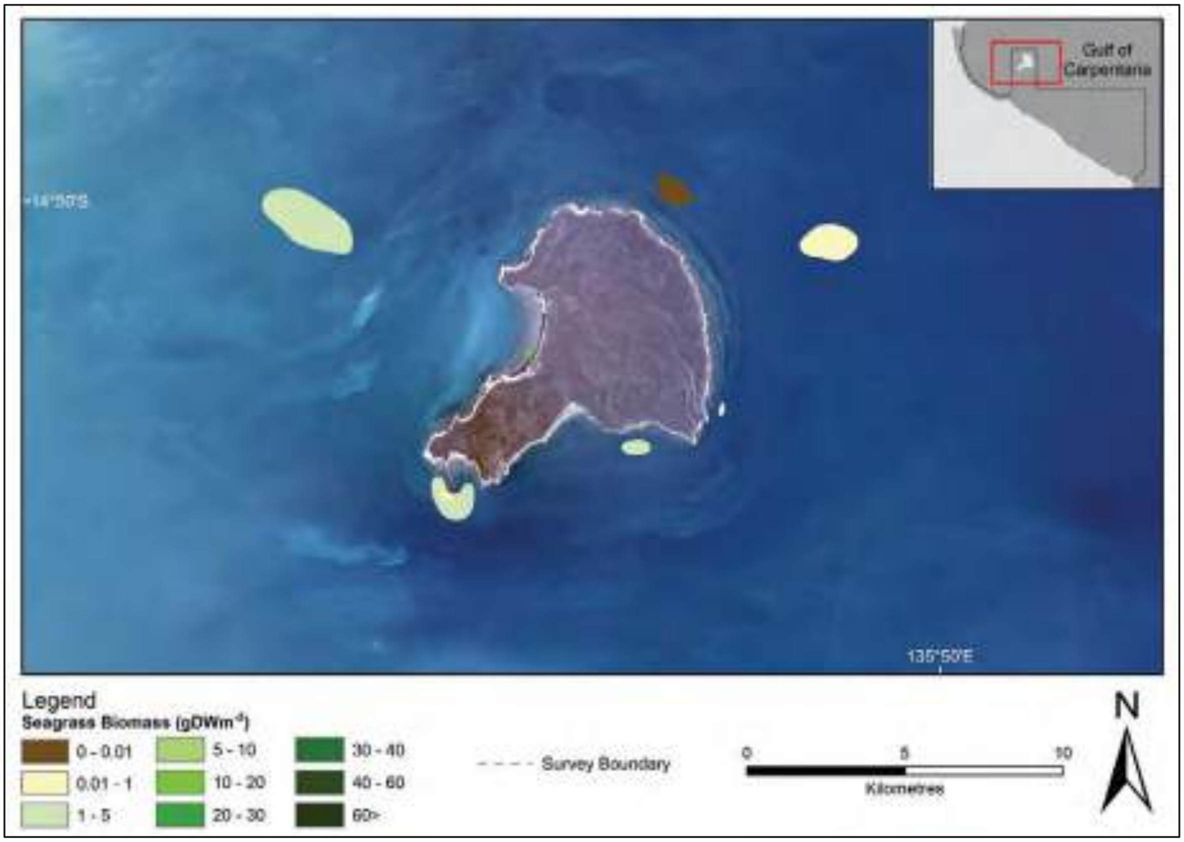
A1.4. Seagrass species composition at survey sites and within meadows at Maria Island.

Appendix 2. Variation in seagrass biomass within meadows.

A2.1. Seagrass above-ground biomass within meadows near the Roper River.

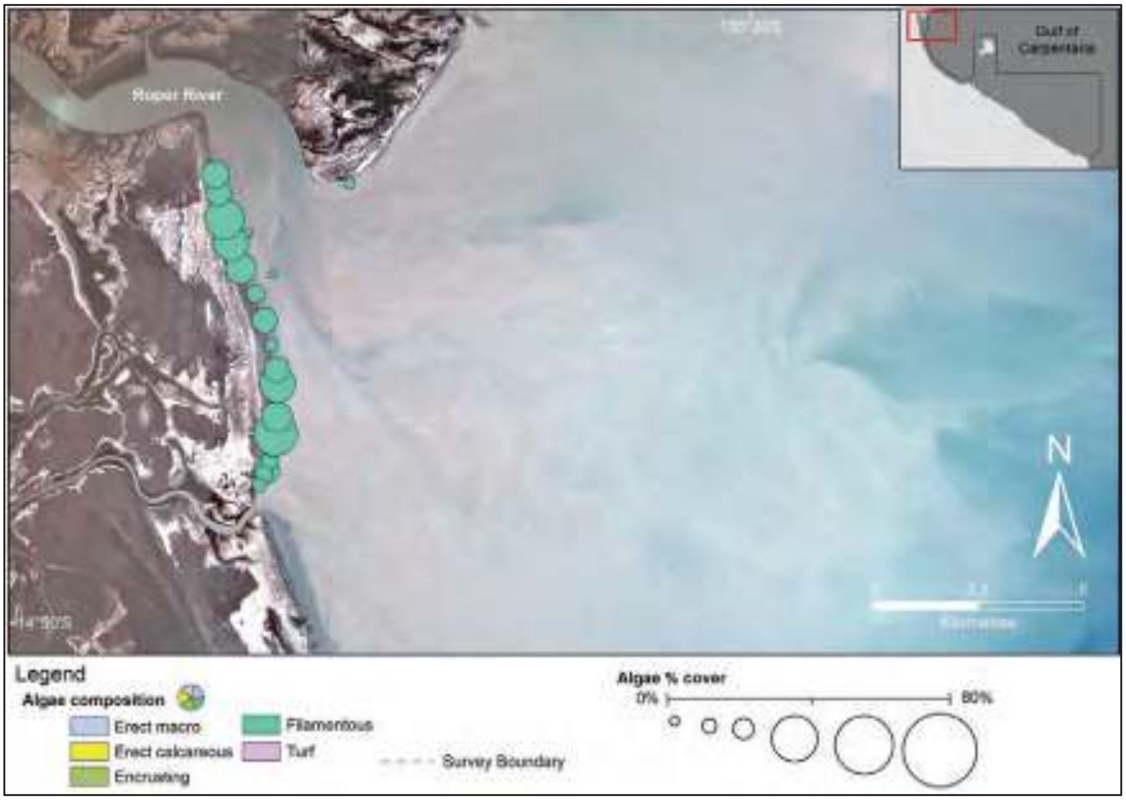
A2.2. Seagrass above-ground biomass within meadows between Limmen Bight River and Rosie Creek.

A2.3. Seagrass above-ground biomass within meadows at Beatrice Island.

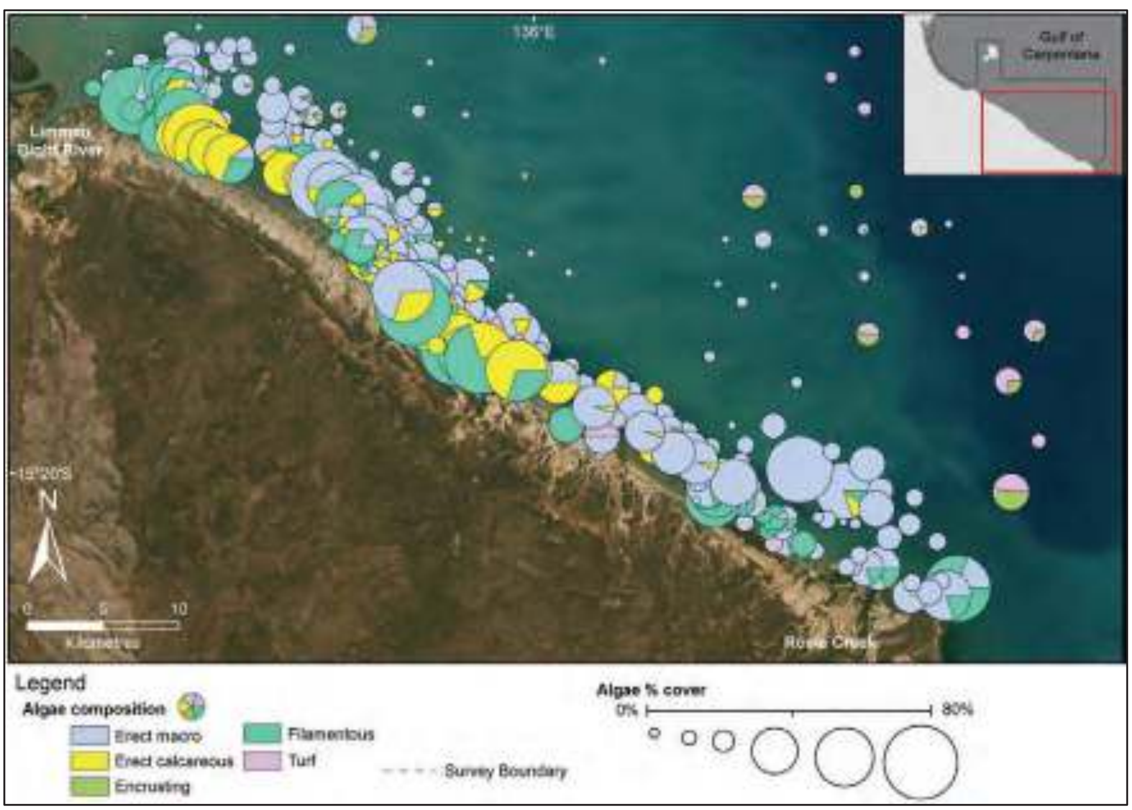


A2.4. Seagrass above-ground biomass within meadows at Maria Island.

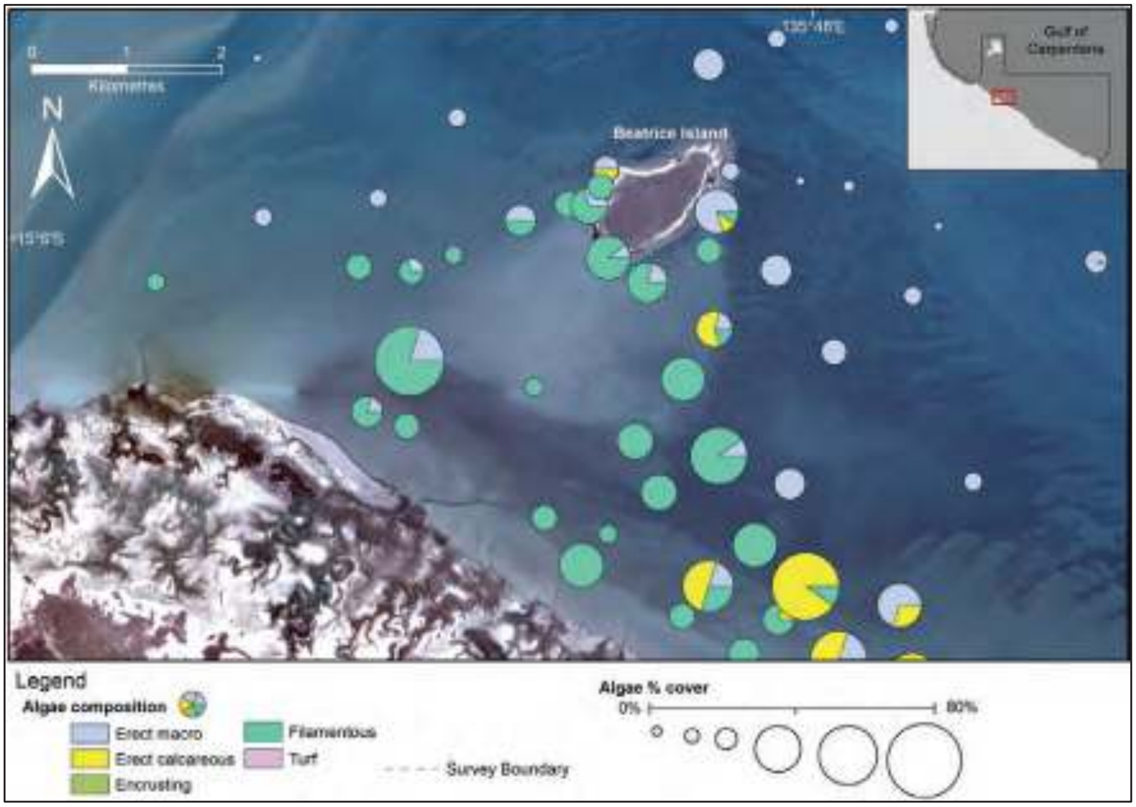
Appendix 3. Algae cover and composition at survey sites in the survey area.



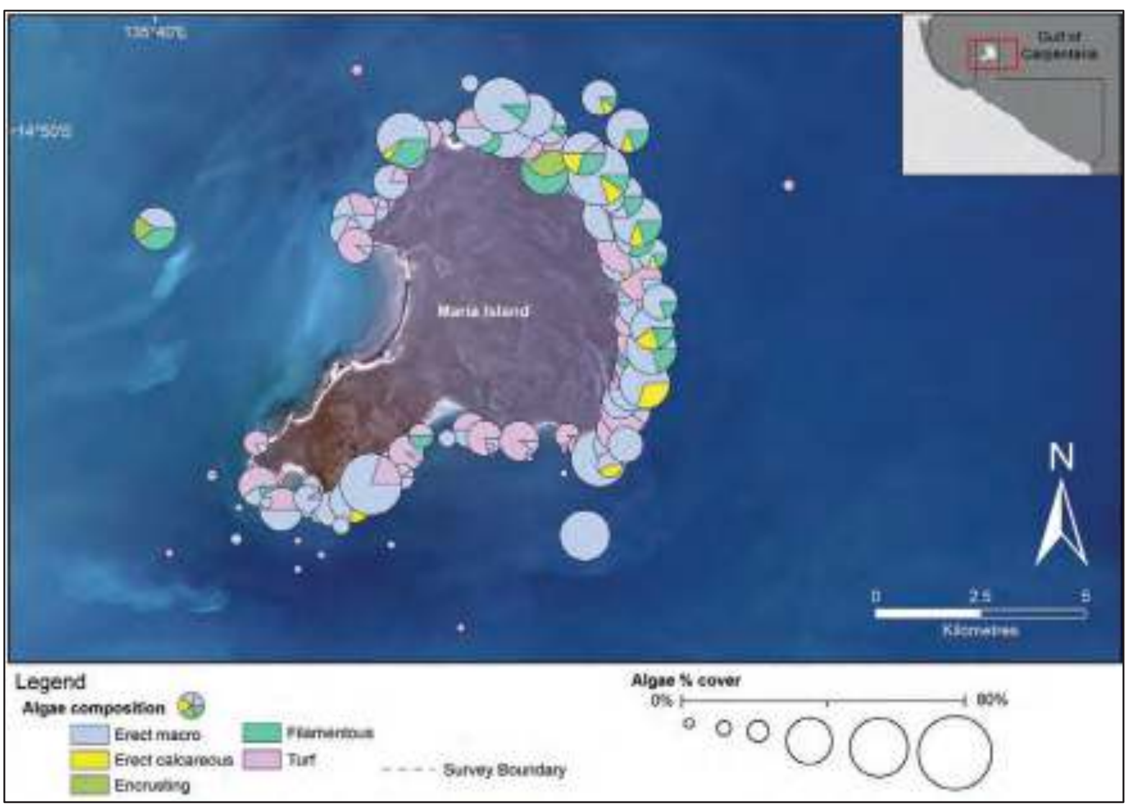
A3.1. Algae cover and composition at survey sites near the Roper River.



A3.2. Algae cover and composition at survey sites between Limmen Bight River and Rosie Creek.

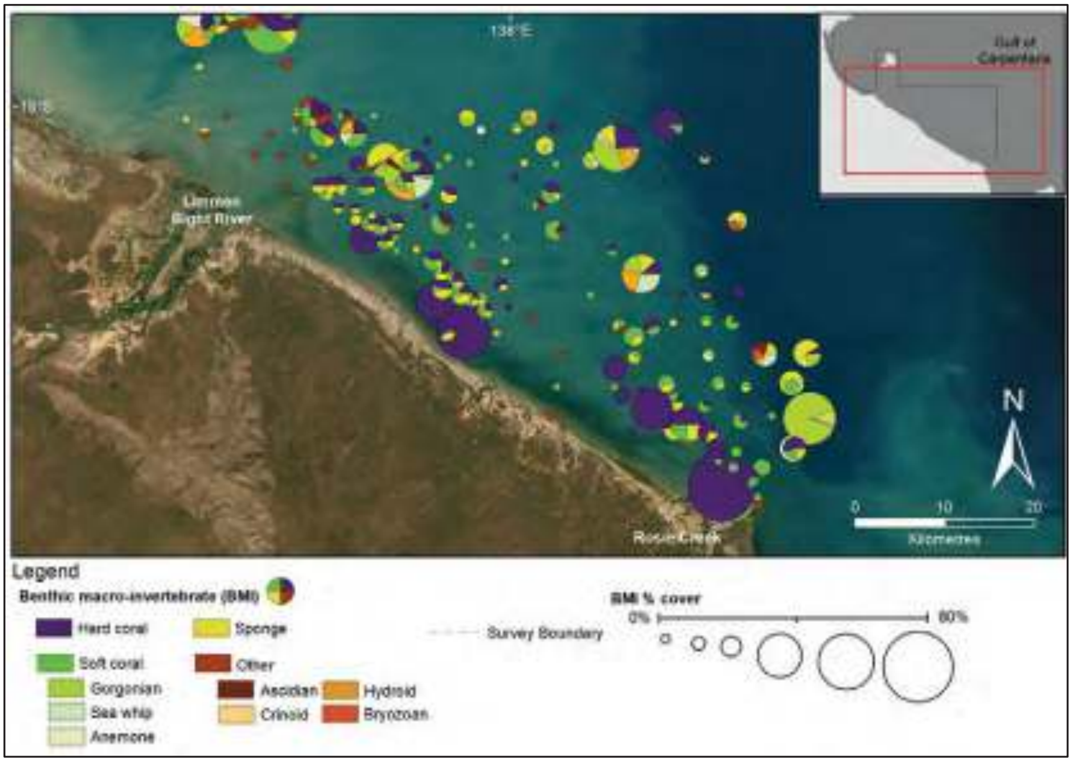


A3.3. Algae cover and composition at survey sites at Beatrice Island.

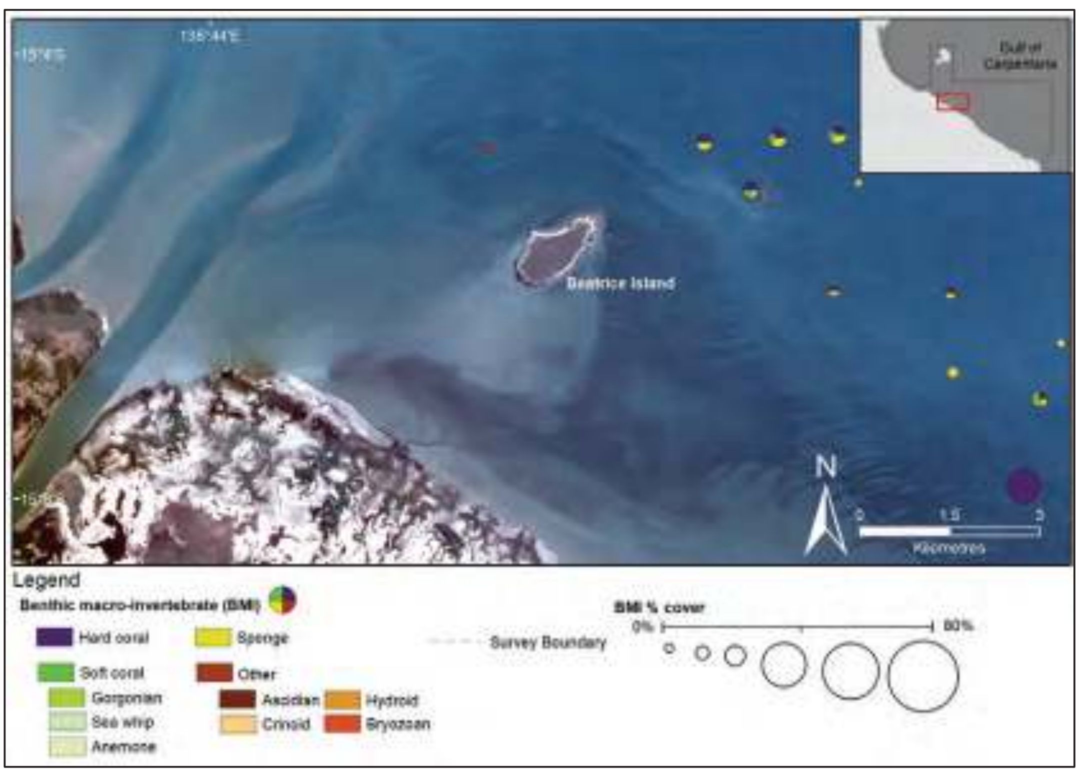


A3.4. Algae cover and composition at survey sites at Maria Island.

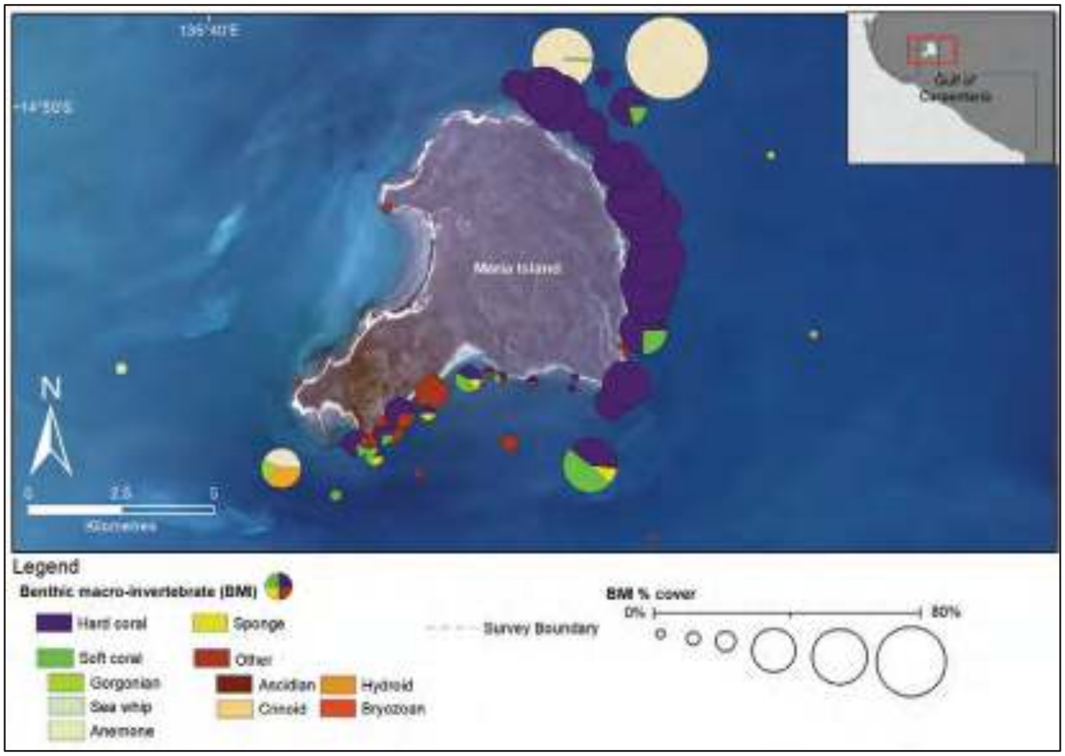
Appendix 4. Benthic macroinvertebrate cover and composition at sites in the survey area*.



A4.1. Benthic macroinvertebrate cover and composition at survey sites between Limmen Bight River and Rosie Creek.



A4.2. Benthic macroinvertebrate cover and composition at survey sites at Beatrice Island.



A4.3. Benthic macroinvertebrate cover and composition at survey sites at Maria Island.

A4.4. Bleaching observations in the Limmen Marine Park and Limmen Bight Marine Park.

Appendix 5. Sled net contents species list.

Algae	Chlorophyta (Green)	*Caulerpa sp1*
	Rhodophyta (Red)	Corallinaceae sp1 Rhodophyta sp2
Annelida	Annelida (Segmented Worms)	*Chloeia flava*
Bryozoa		Bryzoa sp1 Bryzoa sp2 *Iodictyum* sp1 *Nevianipora* sp1
Cnidaria	Actinaria (Sea anemones)	*Heteractis crispa*
	Alcyonaria (Soft Corals, Seawhips, Gorgonians)	*Carijoa sp1* *Ctenocella pectinata* *Echinogorgia sp1* *Junceella fragilis* *Melithaea sp1* *Menella sp1*
	Hydrozoa	Hydrozoa sp1 Hydrozoa sp2 Hydrozoa sp3
	Scleractinia (Hard Corals)	*Favites* sp1 *Turbinaria* sp1
	Scyphozoa (Jelly Fish)	*Aldersladia magnificus*
Crustacea	Amphipoda	Amphipod sp1
	Anomura (Hermit Crabs)	Brachyura sp1 *Dardanus megistos* Diogenidae sp1 *Galathea subsquamata*
	Brachyura (Crabs)	*Calappa* sp1 *Leucosia anatum* Majidae sp1 Palinuridae sp1 Parthenopidae sp1 Portunidae sp1 Portunidae sp2
	Penaeida (Prawns)	*Heteropaneus* sp1 *Penaeus* sp1
Echinodermata	Asteroidea (Starfish)	Asteroidea sp1 *Astropecten* sp2 *Stellaster childreni*
	Crinoidea (Featherstars)	Crinoid sp1 Crinoid sp2 Crinoid sp3

		Crinoid sp4 Crinoid sp5
	Echinoidea (Urchins)	*Arachnoides placenta* Cidaridae sp1 *Maretia planulata* *Salmacis belli*
	Holothuroidea (Sea Cucumbers)	*Holothuria leucospilota* *Holothuria* sp1 *Synaptula lamperti*
	Ophiuroidea (Brittle Star)	*Ophionereis* sp1 Ophiuroid sp1 Ophiuroid sp2 Ophiuroid sp3 Ophiuroid sp4 Ophiuroid sp5
Minor Phyla	Pycnogonida (Sea Spiders)	Pycnogonid sp1
Mollusca	Bivalvia (Clams + Scallops etc)	*Hyotissa inermis* *Malleus albus* *Nuculana* sp1 *Spondylus victoriae*
	Cephalopoda (Squid + Octopus)	*Sepia* sp1 Sepiolidae sp1 Sepiolidae sp2
	Gastropoda (Snails + Slugs)	*Doxander vittatus* *Euplica scripta* *Hypselodoris kanga* *Phalium areola* *Philine orientalis* *Syrinx aruanus*
Pisces	Pisces (Fish)	Monacanthidae sp1 *Paraplagusia* sp1 Pisces sp1 *Platycephalus* sp1 Soleid sp1 Tertarogidae sp1
Porifera	Porifera (Sponges)	*Darwinella sp1* Porifera sp1 Porifera sp2 Porifera sp3 Porifera sp4 Porifera sp5 Porifera sp6

		Porifera sp7 Porifera sp8
Urochordata	Urochordata (Ascidians)	Ascidian sp1 Ascidian sp2 Ascidian sp3 Ascidian sp4