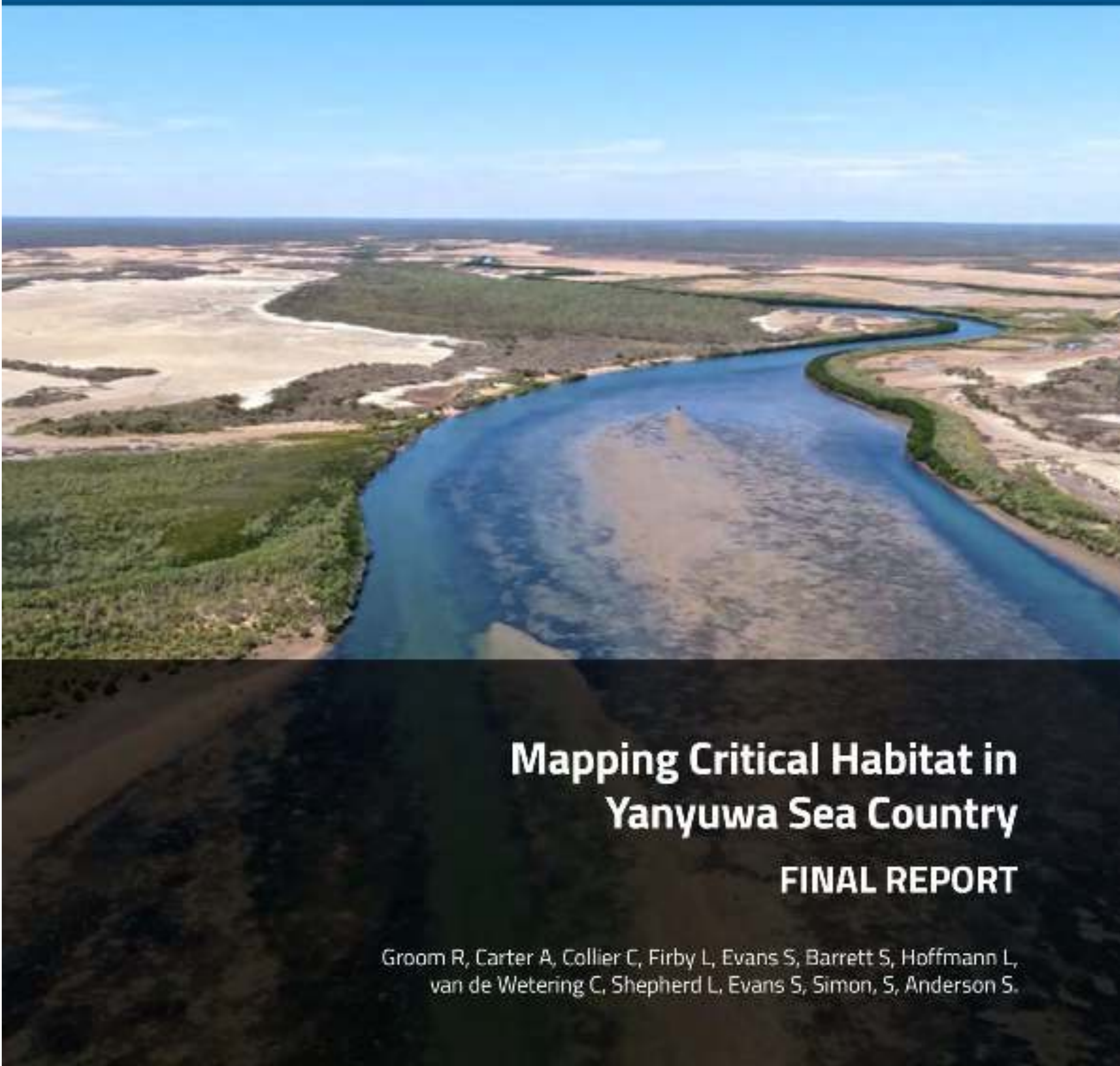
Marine and Coastal

National Environmental Science Program

RESEARCH REPORT
Project 1.12



Mapping Critical Habitat in Yanyuwa Sea Country

FINAL REPORT

Groom R, Carter A, Collier C, Firby L, Evans S, Barrett S, Hoffmann L, van de Wetering C, Shepherd L, Evans S, Simon, S, Anderson S.

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NESP Marine and Coastal Hub partners

The Australian Institute of Marine Science, Bioplatforms Australia, Bureau of Meteorology, Charles Darwin University, Central Queensland University, CSIRO, Deakin University, Edith Cowan University, Flinders University, Geoscience Australia, Griffith University, Integrated Marine Observing System, James Cook University, Macquarie University, Murdoch University, Museums Victoria, NSW Department of Planning and Environment (Environment, Energy and Science Group), NSW Department of Primary Industries, South Australian Research and Development Institute, The University of Adelaide, University of Melbourne, The University of Queensland, University of New South Wales, University of Technology Sydney, The University of Sydney, University of Western Australia, The University of Wollongong

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Cover images

Intertidal seagrass in Yanyuwa Sea Country. TropWATER, JCU.

This report is available for download on the NESP Marine and Coastal Hub website:

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Acknowledgements

We acknowledge the Yanyuwa Traditional Owners of the sea country on which the research took place. We pay our respects to Yanyuwa Elders past, present and future. We honour their continuing culture, knowledge, beliefs and spiritual relationship and connection to country.

We recognise Aboriginal and Torres Strait Islander peoples as the Traditional Owners of the unceded land and sea around Australia, and as Australia's first knowledge holders.

This project was undertaken as a collaboration between the Ii-Anthawirriyarra Sea Ranger Unit, researchers from Charles Darwin University, TropWATER (James Cook University), and Yanyuwa families.

This project was funded by the Commonwealth Migratory Species Section, Biodiversity Conservation Division, Department of Climate Change, Energy, the Environment and Water; Mabunji Aboriginal Resource Indigenous Corporation, National Environmental Science Programme (NESP) Marine and Coastal Hub; Charles Darwin University and James Cook University.

We give our sincere 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, Gaylene Te Hatu and Corrine Coombes (Mabunji Aboriginal Resource Indigenous Corporation); North Australian Helicopters (Tom Speed, Joshua Donoghue and Dallas Coben).

We are grateful to the Yanyuwa elders who were able to see their country from the helicopter and share their story with us. We extend our gratitude to Steven Anderson, jungkayi for eastern Vanderlin Island for joining our survey and providing guidance on cultural protocols for the survey.

In accord with the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) guidelines, this survey was conducted under CDU Human Research Ethics Approval: H22063 and NLC permit: 114809.

Executive summary

Yanyuwa country is in the south-west Gulf of Carpentaria (GoC), an area of land and sea that includes the Sir Edward Pellew Islands in the Northern Territory (NT). This intertidal habitat survey was conducted at the request of Yanyuwa Traditional Owners and the li-Anthawirriyarra Sea Ranger Unit to support their sea country planning and management aspirations. This survey forms part of a larger collaborative project that documents marine benthic habitats in Yanyuwa country.

A total of 16,128 ± 679 ha of seagrass was mapped in Yanyuwa sea country across 180 individual meadows. This included a series of meadows that stretched ~130 km along the mainland coast. In most instances, meadows extended from the coastal mangroves to the offshore edge of the intertidal zone. The intertidal bank ranged in width from several hundred meters to several kilometres along the mainland coast. Seven seagrass species were recorded on survey with the dominant species being *Halodule uninervis,* a pioneer species that is a preferred food for dugong and turtle.

All five algae functional groups were recorded, with many sites featuring a mix of groups. Algae was present at 33% of the survey sites and accounted for up to 100% of benthic cover at an individual site. Erect macrophyte algae was the most common algal type and was found throughout the survey area. Hard corals were common along the exposed northern coastlines at Mathandurla, Watson Island, Barranyi (North Island), Limiyamila, and along the northern and eastern coast of Vanderlin Island. Soft corals were less common and recorded along the northern coast lines of Mathandurla, Limiyamila and Watson Island. Sponges were present throughout the survey area, including along the mainland coast. Oysters and barnacles were common around the islands, particularly the rocky coastlines of western Vanderlin Island, southern Barranyi (North Island), and around Mathandurla, WanarrWanarr and Barranyi (Centre Island).

Seagrasses and benthic habitats support highly productive and diverse ecosystems. They are vitally important because they store blue carbon, are a source of food and shelter for marine organisms, oxygenate water, trap sand, recycle nutrients, and provide breeding habitats and nursery areas for many marine organisms. The seagrass habitat reported on here is within the intertidal zone, an area largely owned by Yanyuwa people.

Yanyuwa people are seeking opportunities for greater protection of Yanyuwa country that respect their cultural practice, support intergenerational knowledge transfer and are sustainable. Understanding the distribution of values important to Yanyuwa people is fundamental for decision-making and delineating areas for greater protection. Considering Yanyuwa people's aspirations for greater protection, we recommend the following in consultation with Yanyuwa people: synthesise and spatially analyse relevant eco-cultural and biodiversity data for Yanyuwa country to identify areas of significance; and work with Yanyuwa people to establish rules for greater protection over these areas to reflect their values in a robust manner. Yanyuwa people should then be supported in discussions with government to mobilise their protection aspirations for greatest impact through regulatory management tools.

Introduction

Yanyuwa sea country

The Yanyuwa and Marra people in the south-western GoC are custodians of the most significant seagrass habitat in the NT. The western scientific knowledge of seagrass in this region is limited and has not been extensively mapped. The area is culturally rich and has high biodiversity values, including the highest dugong abundance in the NT (Groom et al., 2017, Groom, 2020, Griffiths et al., 2020, Marsh et al., 2008), extensive habitat for green turtles from the northern Great Barrier Reef and GoC stocks (Patterson, R. *in review*), and four species of coastal dolphin (Griffiths et al., 2020, Grech et al. 2014, Bradley et al., 2007).

Yanyuwa people have identified many current threatening processes and activities directly affecting benthic habitats in the region. These include commercial and recreational vessel traffic (through habitat scarring), habitat loss through increased frequency and severity of extreme weather events (storms and cyclones), sedimentation of coastal waters (from upstream influences, e.g., mining waste), sea level rise and warming waters. These processes are poorly studied in this region and so remain an unquantified impact. Increased water extraction is considered an emerging threat where rivers adjacent to the coast will be drawn down to support mining and agriculture developments. This activity has the potential for downstream impacts on coastal species (Plaganyi-Lloyd et al. 2022). These processes in isolation and cumulatively, have the potential to significantly impact the health and function of the coastal environment.

Ecological interactions within coastal environments are complex and rarely linear. Research suggests that in areas where turtle and dugong populations are healthy, they play an important role in the regulation of seagrass meadows by alleviating the negative effects of eutrophication by stimulating seagrass production and concomitant nutrient uptake (Christianen et al. 2012). They further assist by transporting seeds to new locations and enhancing germination; dugongs and green turtles improve the connectivity and genetic diversity of seagrass meadows, thereby helping them recover from disturbances, such as cyclone damage. By better protecting large herbivores in coastal systems, the integrity of their associated habitats is supported. Identifying management measures that improves protection of coastal habitats and species and reduces impacts to benthic habitats is necessary to safeguard this rapidly changing environment.

Understanding the distribution and composition of marine habitats is a necessary step in supporting the aspirations of the Yanyuwa people to sustainably manage sea country, maintain their strong connection to place, contribute to a blue carbon inventory and enable informed decisions by government regarding coastal development.

This project was co-designed with the li-Anthawirriyarra rangers and Yanyuwa families to support management decisions and develop a long-term seagrass monitoring program for the Yanyuwa Indigenous Protected Area (Figure 1). The Yanyuwa term to describe all seagrass is maraman. This project surveyed the intertidal area of Yanyuwa sea country where the major maraman beds track the coastline. This intertidal maraman is called ma-lhanngu. This term includes the following species: *Syringodium isoetifolium*, *Halodule uninervis, Halophila ovalis* (small and large) and *Halophila spinulosa* (Bradley et al., 2007). Importantly, the coast of the Yanyuwa Indigenous Protected Area (IPA) is mostly Aboriginal-owned land or land with native title rights granted. The Yanyuwa people are therefore primary owners and decision-makers of this maraman estate. The seagrass beds and reefs are seen to be country which is identifiable by name and therefore known; it is owned. The underwater country has clan association, and thus it too is intertwined within the social working of the jungkayi (guardians) and ngimarringki (custodians) system (Bradley et al., 2007). Most seagrass beds which follow the coast are associated with the Wurdaliya and Wuyaliya clans, with smaller areas associated with the Rrumburriya and Mambaliya-Wawukarriya clans. Many of the more northerly reefs that have seagrass areas belong to the Rrumburriya clan.

This project is a collaboration with li-Anthawirriyarra rangers, Charles Darwin University (CDU) and James Cook University (JCU). It was funded by the Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW) Migratory Species Section, Mabunji Aboriginal Resources Indigenous Corporation, and the National Environmental Science Program (NESP).

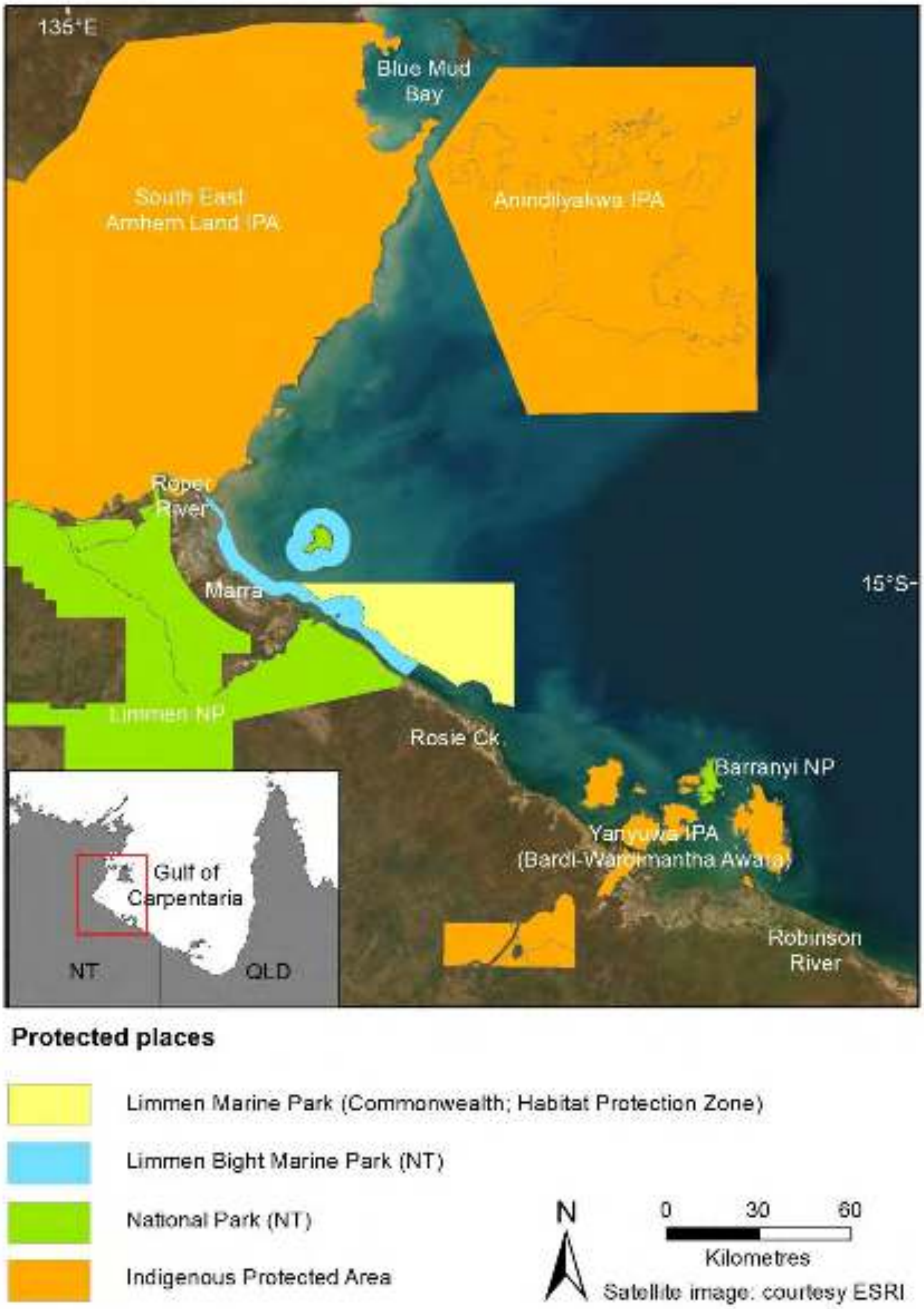

Figure 1. Protected areas in the survey area.

This project relates to other partnership projects with Aboriginal Traditional Owner groups and custodians in the GoC which includes subtidal benthic habitat mapping in Yanyuwa sea country, intertidal and subtidal mapping in the Limmen Bight Marine Park (NT Government) and Limmen Marine Park (Commonwealth Marine Park), and intertidal mapping in the South East Arnhem Land IPA (Figure 1). Spatial data from this project links with a recent synthesis of four decades of seagrass spatial data from Torres Strait and the GoC to build the publicly available spatial database for the region (Carter et al., 2022).

The focus on this region reflects the significance of seagrass habitats and the desire of Traditional Owners to use new datasets to inform their management. This research engaged Yanyuwa and Marra people throughout project planning, data collection, analysis, and dissemination of information. The project worked in accordance with the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) code of ethics and was conducted under CDU Human Research Ethics approval: H22063 and under the Northern Land Council permit: 114809.

Biodiversity values

The south-west GoC supports a rich diversity of plants and animals. The Yanyuwa people's knowledge, and more recently western scientific knowledge, of this region demonstrates its relative significance in Australia. The coastal vegetated ecosystems in the GoC are expansive and include vast areas of seagrass, mangroves, and saltmarsh that buffer the coastline. These ecosystems have important ecological roles in regulating climate function through carbon storage and stabilising the coast (Duarte et al., 2013), and in providing habitat for fish and crustaceans (Coles et al., 1985; Blaber et al., 1994; Robertson and Duke 1987), six listed threatened marine turtle species and four listed migratory marine mammal species. This region is also listed as an Important Marine Mammal Area (IMMA) by the International Union for the Conservation of Nature (IUCN) (https://www.marinemammalhabitat.org/imma-eatlas/).

With increasing pressure on species and coastal environments from land-based developments and climate change e.g., warming oceans, sea-level rise, increased intensity of severe weather leading to habitat decline and degradation, and species population declines (Halpern et al., 2016); improving our knowledge on the coastal environment is critical to predict and mitigate impacts, maintain resilience of ecosystem function, protect culture and ensure coastal communities have sufficient natural resources to thrive. Seagrass underpins many of the biodiversity values noted here and is therefore a habitat that can be reliably used as an indicator of environmental health (Roca et al., 2016).

Knowledge of seagrass in Yanyuwa country has been transferred through generations of people on country and includes a fine-scale understanding of meadow distribution and ecology; and Yanyuwa names for the seagrass species. The Yanyuwa people perceive that there is a strong relationship between seagrass and the dugong and sea turtle; it is best evidenced in the expression 'walya nyiki-naanji ki-maramanngku' 'the dugong and sea turtle they are kin to the seagrass' (Charlie Miller, 1980; Bradley et al., 2007). In Yanyuwa, the term nganji kin is used to describe relationships between species where a co-dependency is perceived. It is said by the Yanyuwa people that without the seagrass there would be no sea turtles or dugong; but likewise, it is said that without the dugong and sea turtle, there would be no seagrass, as the feeding upon it keeps it healthy (Bradley et al., 2007). There is a term in Yanyuwa, na-wurndarnda, that describes the line of mangroves that fringe the seagrass beds and the actual seagrass beds. It is a zone recognised by the Yanyuwa as important for the wellbeing of all the islands because it is here that the immature fish and prawns live, and it is where nutrients are washed into the sea to nurture both the immature species that live there but also the seagrass beds. For Yanyuwa people these are important places that demonstrate important biological relationships. As is typical in any understanding of Yanyuwa perceptions of the environment there are threads of connection that weave through the entire environment. Without the na-wurndarnda region all living things would suffer (Bradley, 2007).

Seagrass in the GoC has been mapped with a western science perspective in an ad-hoc way since the early 1980s. Seagrass adjacent to Karumba's port in the south-east GoC has been monitored annually since 1994 (Scott et al., 2023), and at Weipa in the north-east since 2000 (Reason et al., 2022). This monitoring provides a long-term but spatially limited reference for GoC seagrass dynamics. Other regions have limited data. A recent synthesis of historical Torres Strait and GoC seagrass data compiled and standardised data from 40 years of field surveys and highlights the limited spatial and temporal coverage of seagrass survey data for the NT (Figure 2; Carter et al., 2022).

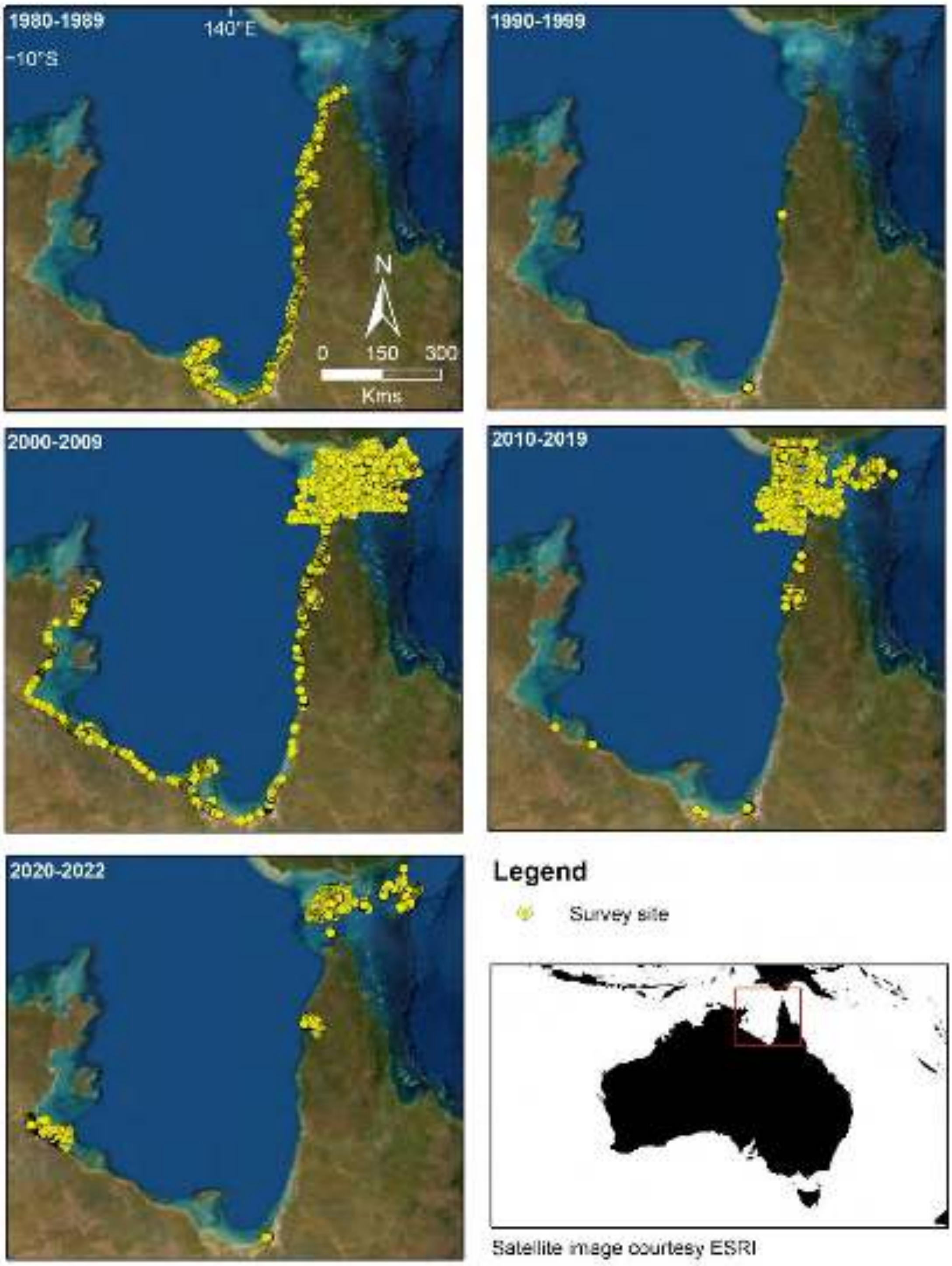

Figure 2. Seagrass presence and absence at individual sampling sites across Torres Strait and the Gulf of Carpentaria, 1983–2022, excluding this study.

Aims

To address benthic habitat information gaps, a collaboration was developed with the li-Anthawirriyarra Sea Rangers, Mabunji Aboriginal Resource Indigenous Corporation, DCCEWW, CDU and JCU to survey this significant region. The aims of this project were to:

- Engage with the Yanyuwa community in two-way knowledge sharing of information about sea country.
- Increase technical capacity of li-Anthawirriyarra rangers in coastal planning and management, including establishing research objectives and designing and planning benthic habitat surveys.
- Map the intertidal benthic habitats of Yanyuwa sea country and assess the seagrass biomass and diversity in the region at a time of high biomass (early October 2022).
- Provide recommendations to all with responsibility for managing the area including Yanyuwa people, Commonwealth Government, and the NT Government.

These surveys are embedded within an International, Commonwealth and NT policy context which regards the recognition and protection of Indigenous people's resources (e.g., Articles 26-29, UNDRIP) and the identification of high value habitat areas to improve protection of listed threatened and list marine species under Commonwealth and NT legislation. By providing a robust baseline, this survey enables informed decision-making by Yanyuwa people and relevant government agencies in their joint-management responsibilities.

Methods

Study region

The study region included intertidal waters adjacent to the Yanyuwa (Barni-Wardimantha Awara) IPA and Barranyi (North Island) National Park (Figure 1). The main features of the coast in this shallow shelf region of the south-western GoC include (Poiner et al., 1987; Short, 2020):

- Expansive intertidal areas (Figure 3a)
- Shallow bathymetry (Figure 3b)
- 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 GoC, but in Yanyuwa Sea Country sediments are generally sandy or muddy (Somers & Long, 1994)
- Low to moderate wave energy
- Tidal ranges of approximately 2–3 m
- Creeks and rivers draining into the GoC deliver freshwater, nutrients and sediments (Figure 3c)

The survey area included some sites that are sacred and were inappropriate to survey or required 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 Yanyuwa people, in particular Shaun Evans and Yanyuwa elders who collaborated in surveys and survey design. We recognise that no single person can speak for Yanyuwa country, and we sought to engage the community more broadly through community forums and individual discussions.

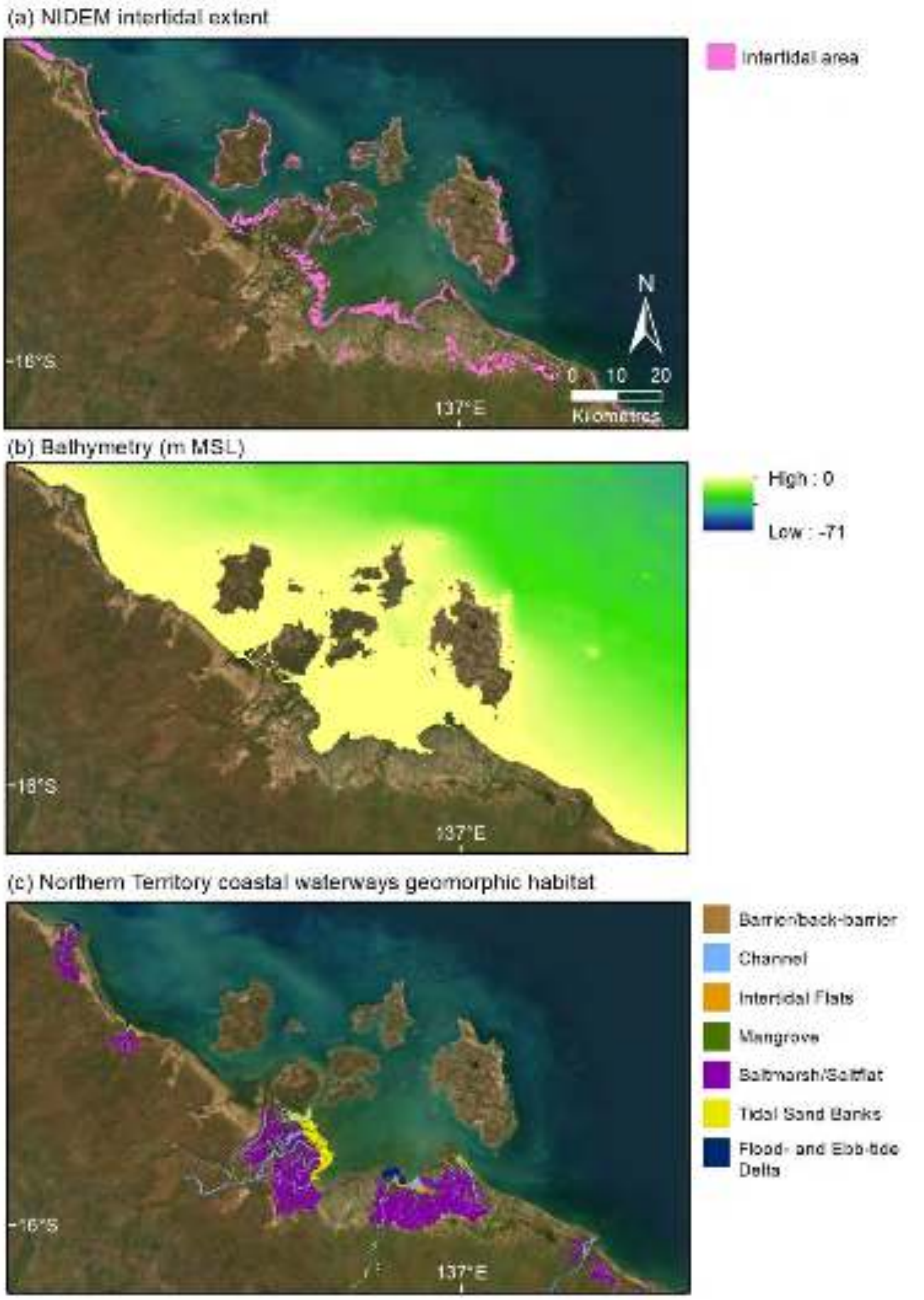

Figure 3. Features of the Gulf of Carpentaria - Yanyuwa region. (a) National Intertidal Digital Elevation Model (NIDEM) intertidal extent (Bishop-Taylor et al., 2019), (b) bathymetry (http://www.ga.gov.au/metadata-gateway/metadata/record/71989/), and (c) geomorphic habitat (http://www.ozestuaries.org; Dyall et al., 2004). NB, fine scale bathymetry data is not available among the Islands.

Community consultation

Prior to conducting field surveys, the project was first presented to the Yanyuwa Indigenous Protected Area Advisory Committee (YIPAAC). This committee includes representatives of all clans in Yanyuwa country. The YIPAAC were satisfied with the project and the next steps which regarded detailed consultation with Yanyuwa jungkayi (guardians) and ngimaringki (owners).

A consultation workshop was held with Yanyuwa jungkayi and ngimaringki which included:

- Free, prior, and informed consent process
- Discussion of the project research agreement
- Identify areas for inclusion and exclusion on survey

Discussions centred around a large canvas map developed by Yanyuwa families and John Bradley which is held by the li-Anthawirriyarra rangers. The map is over two metres wide and illustrates the entirety of Yanyuwa country with cultural details including songlines. The map was marked up by Yanyuwa people with multi-coloured 'blu-tac'. Marked areas included places of importance to Yanyuwa people and places they wanted to be surveyed, e.g., important dugong and turtle feeding areas, sacred sites, and areas where they had concerns e.g., high recreational boat traffic. Yanyuwa people also identified sacred sites where researchers were prohibited from entering or areas where photographs should not be taken, and areas where the Jungkayi needed to be present on the survey.

Daily call-ins were made to the li-Anthawirriyarra rangers to inform them of the specific survey locations for the day and checking the survey plan was still approved. At the end of the intertidal survey, a presentation was provided to the rangers and photos shared. Older community members flew in the survey helicopter over their home country.

A results workshop and presentation will be held in mid-June 2023 in Borroloola where the combined data from this survey and the subtidal habitat survey will be presented.

Data collection

Benthic habitat assessments were conducted by helicopter at 3,245 sites in October 2021 and October 2022 between Rosie Creek and the Robinson River, plus all islands in the Yanyuwa IPA (Figure 4). There were no major weather events during that period impacting this region and the results of the survey in any significant way. Three sites were added to the data set that were surveyed by boat on high tide in October 2022 for a separate subtidal survey (Groom et al., in prep), but were located within the intertidal extent for Yanyuwa sea country (Bishop-Taylor et al., 2019). Survey month was selected to coincide with the peak seagrass growing period that occurs in spring and early summer in northern Australia (Chartrand et al., 2018; York et al., 2015). This ensures data are comparable among years and with other survey locations in northern Australia. Survey site coordinates and survey dates are included in the GIS shapefiles produced for this project.

Figure 4. Intertidal survey sites in Yanyuwa Sea Country, October 2021 and October 2022.

Habitats were assessed following methods used in intertidal benthic surveys of adjacent Marra sea country in 2021 (Collier et al., 2022). At each site, latitude and longitude were recorded by GPS. Sediment was described using broad categories (e.g., mud, sand, rubble). Where more than one sediment category was used, the sediment is listed from the most dominant to the least dominant type.

Benthic habitat observations

Exposed intertidal areas including mud banks, reef-tops and around islands were surveyed by helicopter, which allows for rapid surveys across large areas (Figure 5). Intertidal sites were surveyed 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 (refer to Carter et al. 2023).

Figure 5. (a) Intertidal sites were surveyed by helicopter at low hover. (b) Seagrass was ranked in three replicate quadrats and (c) data recorded in real time.

Maraman (seagrass) biomass

Seagrass above-ground biomass was estimated from three 0.25 m^2 replicate quadrats within each intertidal site (Figure 5). 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, 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 replicate quadrats to provide mean total seagrass above-ground biomass, and contribution to total above-ground biomass for each species, for each site.

Miyalmiyal (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 6a)
- Filamentous – thin, thread-like algae with little cellular differentiation (Figure 6b)
- Encrusting – algae that grows in a sheet-like form attached to the substrate or benthos, e.g., coralline algae (Figure 6c)
- Turf mat – algae that forms a dense mat on the substrate (Figure 6d)
- Erect calcareous – algae with erect growth form and high level of cellular differentiation containing calcified segments, e.g., *Halimeda* species (Figure 6e)

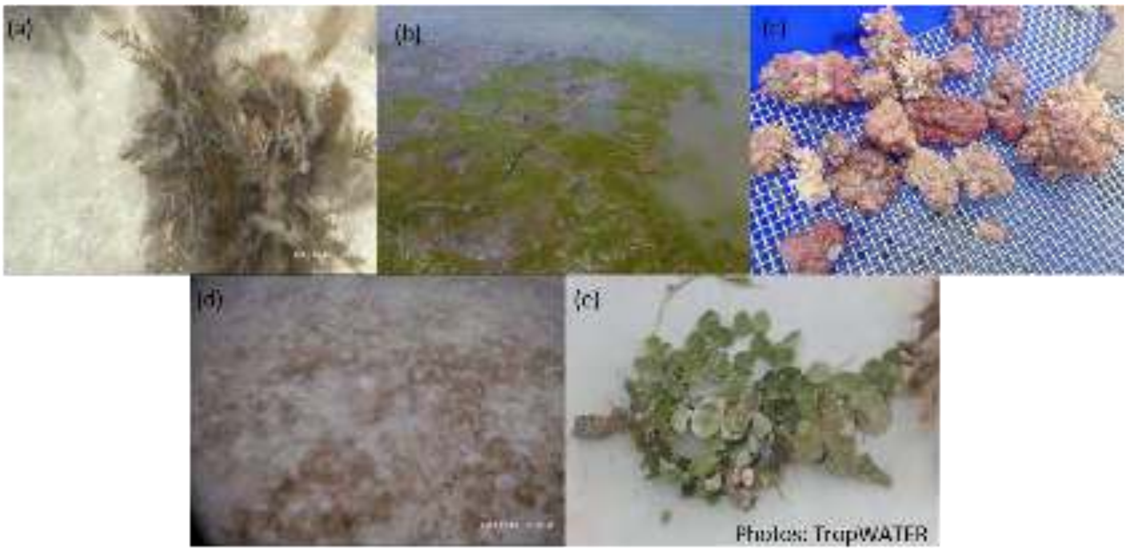

Figure 6. Examples of algae functional groups (a) erect macrophyte, (b) filamentous, (c) encrusting, (d) turf mat and (e) erect calcareous.

Invertebrate communities

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

- Hard coral, which was all scleractinian corals including massive, branching, tabular, digitate and mushroom
- Octocorals i.e., corals lacking a hard calcareous skeleton

- Sponge
- Other BMI – any other BMI identified, e.g., hydroids, ascidians, barnacles, oysters, and habitat-forming molluscs such as clams. Other BMI categories are listed in the “comments” column of the GIS site layer

Additional Information

Sea cucumbers were counted at each site and are included in the data set but are not included as a habitat-forming invertebrates in percent benthic cover assessments.

Dugong feeding trails (presence/absence) were recorded at each site surveyed by helicopter. This data is available in the Groom et al. (in prep) Yanyuwa subtidal seagrass report as per the request of Traditional Owners.

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 delineate habitats in 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
- Sediment type
- Habitat information – percent cover of each benthic category
- 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 (and/or dugong feeding trails) or dolphin at the site (reported on in Groom et al. In prep)
- Meadow identification (ID) code
- Comments

Maraman (seagrass) meadow layer

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. Rectified colour satellite imagery of the survey region 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/), the intertidal extent model (Bishop-Taylor et al., 2019), 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 mapping precision estimate was used to calculate an error buffer around each meadow (Table 1). 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. Moderate density of mapping and survey sites.

Meadow community type was determined according to seagrass species composition. Species composition was based on the percent each species' biomass contributed to mean meadow biomass. A standard nomenclature system was used to categorize each meadow (Table 2). This nomenclature also included a measure of meadow density categories (light, moderate, dense) determined by mean biomass of the dominant species within the meadow (Table 3).

Table 2. Nomenclature for intertidal seagrass meadow community types.

Community type	Species composition
Species A	Species A is 90-100% of composition
Species A with Species B	Species A is 60-90% of composition
Species A with Species B/Species C	Species A is 50% of composition
Species A/Species B	Species A is 40-60% of composition

Table 3. Density categories and mean above-ground biomass ranges for each species used in determining intertidal seagrass meadow community density.

Mean above-ground biomass (g DW m^{-2})				
Density	*H. uninervis* (narrow)	*H. ovalis* *H. decipiens*	*H. uninervis (wide)* *C. serrulata* *C. rotundata* *S. isoetifolium*	*E. acoroides*
Light	< 1	< 1	< 5	< 40
Moderate	1-4	1-5	5-25	40-100
Dense	> 4	> 5	> 25	> 100

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.), mapping precision, meadow area ± reliability estimate (r) in hectares, persistence, dominant species, and number of total and biomass sites within the meadow
- Tidal zone
- Habitat sampling method
- Dugong feeding trail presence in meadow (intertidal meadows only)
- Vessel name
- Comments

Maraman (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

Maraman (seagrass)

Seagrass was present at 44% of the 3,248 sites surveyed (Figure 7). Seagrass was most frequently found along the mainland coast between Rosie Creek and Milrila (Fat Fellow Creek), and in protected bays of the islands (Figure 7). Seagrass was less common along the exposed coastline between Milrila and the Robinson River where seagrass was found in sheltered creeks behind the main dune system. Seagrass was also less common along the north-eastern coastlines of Vanderlin Island and Barranyi (North Island), and the north-west side of Mathandurla (West Island).

Figure 7. Maraman (seagrass) presence and absence at survey sites.

Seven seagrass species from two families were identified during the survey (Figure 8). These were *Halodule uninervis* (wide and narrow leaf morphology), *Syringodium isoetifolium*, *Cymodocea rotundata*, *Cymodocea serrulata*, *Halophila ovalis*, *Enhalus acoroides* and *Halophila decipiens*.

Figure 8. Maraman (seagrass) species present during the surveys.

Seagrass species diversity was greatest at Mathandurla and the adjacent mainland coast near Bing Bong port, where less common species such as *S. isoetifolium* (20 survey sites), *C. rotundata* (56 sites), and *C. serrulata* (40 sites) were most frequently found (Figure 9). *H. uninervis* was the most common species (1,081 sites) and was present throughout the survey area. The narrow leaf morphology of *H. uninervis* dominated the narrower intertidal meadows around the islands and along the mainland between Rosie Creek and WanarrWanarr (South West Island). On the large intertidal banks south-east of Rabunthu (Port McArthur) and the McArthur River the wide leaf morphology of *H. uninervis* was more common (Figure 9, Figure 10). However, it is important to note that there is not a specific threshold for defining the narrow leaf and wide leaf form and that the distinction is made to classify the density categories of the meadows (Table 3). *H. ovalis* was the second most common species (942 sites) and was present throughout the survey area. *E. acoroides* was present at 9 sites; this species was only found on islands and generally in very small patches (Figure 9, Figure 11). *H. decipiens*, a common subtidal species, was present at only 3 sites.

Figure 9. Seagrass species composition at survey sites.

Figure 10.Yanyuwa coastal seagrass including (a) dense *H. uninervis* in tidal channels west of Bing Bong port and (b) south-east of Rabunthu (Port McArthur). (c) Sparse *H. uninervis* and *H. ovalis* and (d) red brown *H. uninervis* from intertidal exposure west of Bing Bong port. (e) Seagrass growing on banks at the mouth of (e) the McArthur River and (f) patchy seagrass.

Figure 11. Seagrass at (a) Survey Bay Barranyi (Centre Island) and (b) Vanderlin Island at the southern end looking west. (c) *E. acoroides* and (d) *H. ovalis* near Wawinda Islet on the western side of Vanderlin Island. (e) Seagrass at Labu Islet near Barranyi (Centre Island) and (f) dense *H. uninervis* in Victoria Bay, Vanderlin Island.

A total of 16,128 + 679 ha of seagrass was mapped across 180 individual meadows (Figure 12). This includes a series of meadows that stretched ~130 km from Rosie Creek to Milrila along the mainland coast, with small breaks between intertidal meadows due to narrow deep creeks. In most instances meadows extended from the coastal mangroves to the edge of the intertidal zone, with that distance ranging from several hundred meters to several kilometres along the mainland coast (Figure 12). Intertidal edges around the islands were narrower and meadows were patchier. Subtidal seagrass was visible by helicopter adjacent to many of the intertidal meadows. These were mapped several weeks after this intertidal survey (Groom et al., in prep). Of the 180 meadows, the meadow community was dominated by *H. uninervis* in 62% of meadows, including most meadows along the mainland coast. *H. ovalis* dominated the community type in 33% of meadows, most commonly around Barranyi (Centre and North Islands), Watson and Vanderlin Islands. There were only two *C. serrulata* communities, but these meadows accounted for the majority of seagrass on Mathandurla, including a 333 + 12 ha meadow along the east coast, and 211 + 11 ha meadow along the south coast (Figure 12).

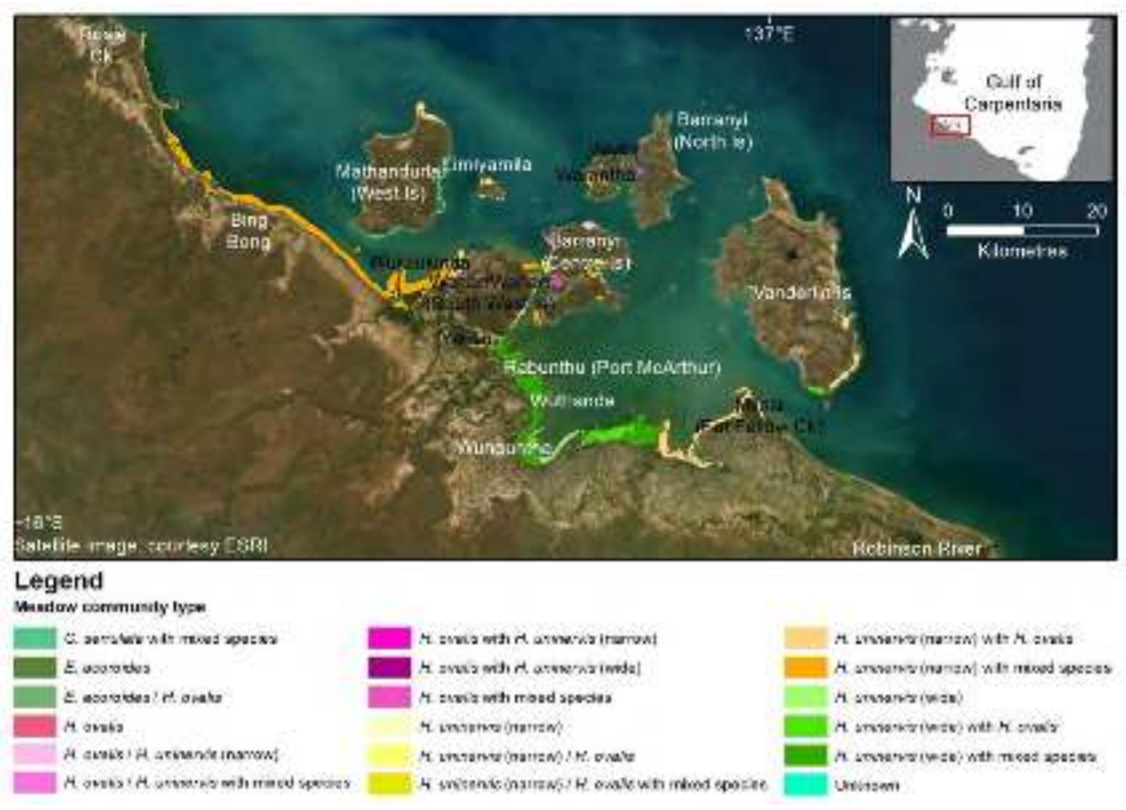

Figure 12. Seagrass meadow type in the survey area.

Seagrass biomass hotspots were more prevalent along the mainland coast, particularly in the largest meadow between WanarrWanarr and Bing Bong where biomass reached 122 gDW m^{-2} at individual sites and mean meadow biomass was 36 $\pm$ 3 gDW m^{-2} (Figure 14). Other high biomass sites (>40 gDW m^{-2}) also were in this meadow, and in some of the meadows around Mathandurla, WanarrWanarr, and the adjacent mainland coast. High biomass seagrass was also recorded in river mouths and protected creeks (Figure 13). Only 3 meadows had mean biomass >50 gDW m^{-2}; these meadows were all very small areas (<10 ha) with very high biomass *E. acoroides* or *H. uninervis*. Mean meadow biomass was generally much lower, <10 gDW m^{-2} in more than half of the meadows.

Figure 13. Seagrass grew in the tidal channels, creeks and rivers in Yanyuwa including in a tidal inlet near the mouth of Bing Bong Creek (a), Rawali Inlet (b), and near Robinson River in eastern Yanyuwa (c and d).

Figure 14. Variation in seagrass biomass across meadows.

Miyalmiyal (algal) communities

Algae cover in the survey area was extensive along the mainland between Rosie Creek and WanarrWanarr, and around the islands (Figure 15). Algae communities were not common along the mainland between Rabunthu and the Robinson River. Algae was present at 33% of the survey sites and accounted for up to 100% 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 (present at 26% of sites) and found throughout the survey area. Turf algae was present as 12% of sites and most common around Barranyi (Centre and North Islands), and along the western coast of Vanderlin Island. Filamentous algae was present at 5% of sites and commonly found along the mainland coast between Rosie Creek and WanarrWanarr, and around all of the islands in the survey area. Erect calcareous algae (e.g., *Halimeda* sp.) was present at 2% of sites and most common on Mathandurla, Limiyamila and Barranyi (Centre) Islands. Encrusting algae (e.g., Corallinaceae family) was present at <1% of sites and restricted to the east coast of Barranyi (North Island) (Figure 15).

Figure 15. Algae cover and composition at survey sites.

Invertebrate communities

Diverse invertebrate communities were recorded in intertidal habitats throughout the survey area (Figure 16). Hard corals were present at 105 sites, and common along the exposed northern coastlines at Mathandurla, Watson Island and Barranyi (North Island), Limiyamila, and along the northern and eastern coast of Vanderlin Island. Octocorals were less common (present at 9 sites) and recorded along the northern coast lines of Mathandurla, Limiyamila and Watson Island. Sponges were present at 55 sites and present throughout the survey area, including along the mainland coast between Bing Bong and WanarrWanarr. Distribution of “other” invertebrates (234 sites), primarily oysters and barnacles, were common around the islands, particularly the rocky coastlines of western Vanderlin Island, southern Barranyi (North Island), and around Mathandurla, WanarrWanarr and Barranyi (Centre) Islands (Figure 16).

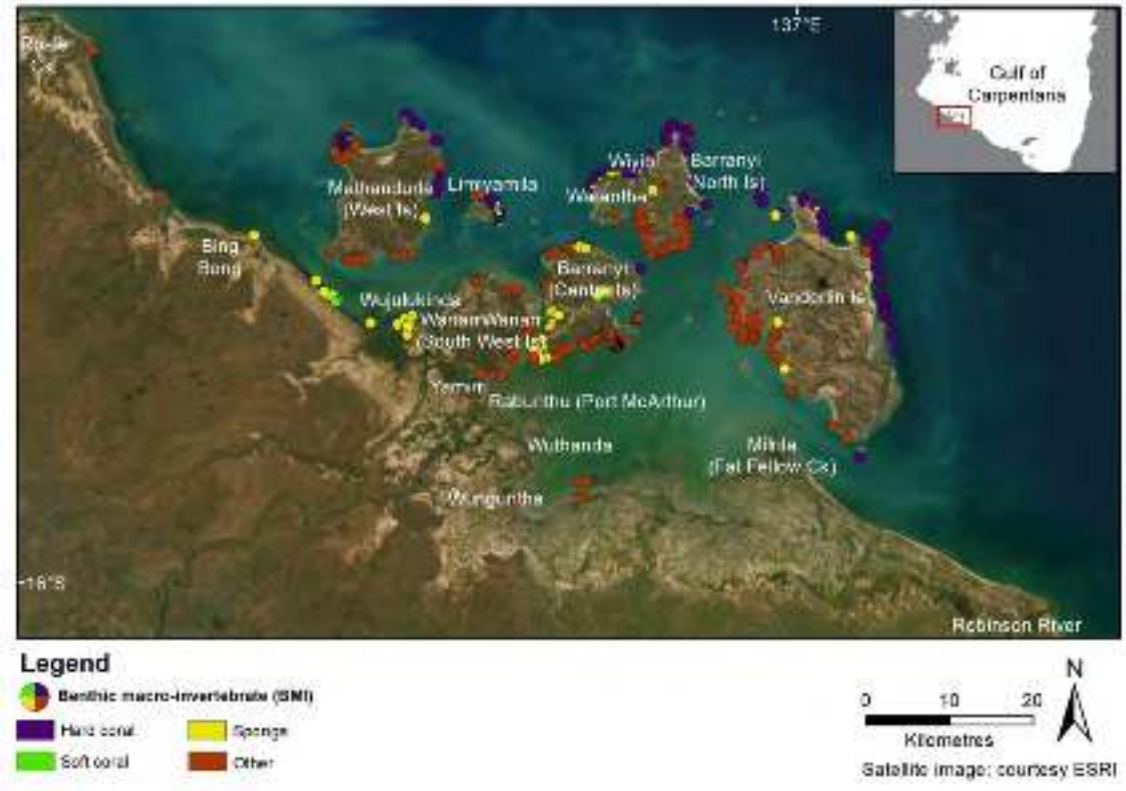

Figure 16. Benthic macroinvertebrate presence and composition at survey sites.

Discussion

Benthic habitats in Yanyuwa sea country

Maraman (seagrass)

The benthic survey documented extensive intertidal maraman (seagrass) in Yanyuwa sea country, or ma-lhanngu in Yanyuwa language. Seven maraman (seagrass) species were identified on the ma-lhanngu (intertidal) survey: *H. uninervis* (wide and narrow leaf morphology), *S. isoetifolium*, *H. ovalis, C. rotundata* (na-wirralbirral Yanyuwa observe as inshore reef species), *C. serrulata (*na-julangal – Yanyuwa observe as offshore reef species*)*, ma-warladaji (*E. acoroides)* and *H. decipiens*.

The results from this survey are broadly similar with previous observations (Poiner et al., 1987; Roelofs et al., 2005, Bradley et al., 2008), although we note that methods, survey intensity and survey area are inconsistent across years. This survey is the most comprehensive and broadscale intertidal benthic habitat study in Yanyuwa country to date and was a low rainfall year (512 mm in 2022 compared to long-term median of 900 mm at Borroloola airport, Bureau of Meteorology) and thus serves as a suitable 'baseline' for ongoing monitoring because seagrass was not significantly disturbed by severe weather or high sedimentation loads that would usually follow extreme weather.

Seagrass was most frequently found along the relatively sheltered mainland coast between Rosie Creek and Milrila (Fat Fellow Creek), and in protected bays of the islands. Less seagrass was observed in the more exposed locations which accords with decades of observations in Yanyuwa country. The surveyed seagrass distribution is consistent with Yanyuwa people's documentation of seagrass presence and with areas documented as significant for dugong and turtle feeding (Bradley et al., 2008).

Seagrass species diversity was greatest at Mathandurla (West Island) and the adjacent mainland coast near Bing Bong, where species such as *S. isoetifolium*, *C. rotundata* and *C. serrulata* were most frequently found. These species were relatively rare in the Yanyuwa survey, but *S. isoetifolium and C. serrulata* were common in adjacent Marra sea country (Collier et al., 2023). Seagrass biomass hotspots were more prevalent along the mainland coast, particularly in the largest meadow between WanarrWanarr and Bing Bong. This area of high biomass is also regarded as a significant dugong and turtle foraging area (Bradley et al., 2007; Groom et al., 2017; Groom, 2020; Griffiths et al., 2020). The maximum biomass observed in this meadow was high (122 gDW m^{-2}). This is comparable to the highest values observed in adjacent Marra sea country (Collier et al., 2023) and in meadows with similar environmental conditions and species composition in coastal seagrass communities in Queensland (Carter et al., 2022; Carter et al., 2021).The average biomass in this coastal meadow (36 gDW m^{-2}) was greater than the 'desired state' these coastal communities exhibit on Queensland's east coast, courtesy of unusually dense *H. uninervis* in Yanyuwa sea country (Carter et al., 2022b). Seagrass biomass and extent vary seasonally and inter-annually according to climatic conditions, disturbances such as floods and cyclones, 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 et al., 2022; Collier et al., 2020; Lambert et al., 2021). Several years of monitoring would be required to measure changes in meadow extent and the ranges in biomass for the meadow in order to understand how representative these biomass values are for the meadow over the long term.

The intertidal zone is an environment of extremes. There are gradients in how frequently the intertidal zone is exposed to the air. Low tide exposure of the intertidal area where seagrass typically grows occurs over brief windows of around six days once or twice a month during spring tides but some areas of seagrass are exposed more rarely. Exposure brings a risk of desiccation and heat stress. The water was observed to be mostly clear in the tidal inlets, turbid in the creeks, and ranging from clear through to milky or turbid in the coastal zone and in the sheltered areas of the islands, and clear again in the well-flushed areas of the islands (Figure 10, Figure 13). Low tide exposure can therefore also bring relief from low light in turbid areas. 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 in the more turbid areas and this could combine with periods of very high temperature. While critical temperature thresholds are unknown for this region, experimental research suggests that temperatures 40°C and over impact seagrass growth and mortality with species-specific differences. After 2-3 days of temperature over 43°C complete seagrass mortality was observed (Collier and Waycott, 2014). Climate projections for northern Australia suggest increasing temperatures which are likely to put these intertidal habitats under increasing pressure, increasing the risk of seagrass decline. Management actions in Yanyuwa country should reflect this risk and conservatively protect these habitats where possible.

Understanding why and where seagrass species grows provides insight into what environmental conditions and pressures can be addressed for protection, rehabilitation, and restoration of coastal habitats. The species *H. uninervis* and, to a lesser extent, *H. ovalis* dominated intertidal habitats. 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. The larger wide-leaf form of *H.uninervis* occurred in the more sheltered areas of the coast such as around Rabunthu (Port McArthur) and the tidal inlets where some water is generally retained in pools. The dominance of these species in intertidal meadows is typical of other locations in the southern GoC (Rasheed & Unsworth, 2011, Collier et al., 2023). In turbid intertidal habitats energy reserves build up when there is sufficient light at low tide (Petrou et al., 2013) and can sustain growth during periods of low light. Combined with morphological and physiological plasticity, this might enable *H. uninervis* to tolerate a broad range of intertidal exposure, turbidity, and hydrodynamic conditions in Yanyuwa sea country (Collier et al., 2016; Collier et al., 2012). 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). Protection can be guided by seagrass ecology to ensure the most vulnerable and high value areas are afforded greatest protection. Understanding the spatial variability and responses to changing conditions can also enable adaptive management at a local scale, e.g., reducing hunting effort in years of poor seagrass growth.

Intertidal seagrass meadows in Yanyuwa sea country are an important food source for dugong and turtle. Evidence of herbivory by turtles and dugongs was observed on the survey with dugong feeding trails and cropping prevalent (Figure 17). Dugongs have been shown to exhibit a preference for small and soft pioneer species such as *Halodule* spp. and *Halophila* spp. (Adulyanukosol & Poovachiranon, 2006), however they are also considered seagrass generalists and are known to consume almost all species within their range. Seagrasses that occurred in Yanyuwa sea country such as *H. ovalis, H. uninervis, C. rotundata, C. serrulata, S. isoetifolium* and *T. hempricii* showed more evidence of being grazed than high fibre seagrasses such as *E. acoroides*, which was observed in small patches only around the islands (Aragones et al., 2006; Tol et al., 2016). In addition, intertidal seagrasses are likely more nutritious compared to subtidal meadows due to higher nitrogen contents and higher digestibility (Lanyon, 1991; De Iongh et al., 1995; Preen, 1998; Yamamuro & Chirapart, 2005; Sheppard et al., 2007).

The most recent survey of dugong in the GoC by Griffiths et al. (2020) estimated the dugong population to be 3390 (SE ± 1092) (using the Hagihara analysis method, incorporating dugong dive behaviour and availability). The survey block encompassing the Sir Edward Pellew Group which includes the Yanyuwa IPA contained the highest population estimate, 2059 (± 1068) representing over 60% of the NT GoC population, as well as the highest proportion of groups with calves. In this block and the adjacent Limmen block, the population has been variable and generally stable over decades. The other GoC survey blocks indicate variability and decline; however, the confidence intervals are high and so the estimates must be interpreted with caution. For all previous surveys over decades in the GoC, NT, the Pellews-Yanyuwa IPA region has had the highest population of dugongs.

Turtle density was recorded on the dugong aerial surveys in the 2015 NT-wide aerial survey by Groom et al. (2017). The highest densities (corrected for detection and availability) of turtles (per km^2) in the NT were recorded in the Marra (Limmen Bight) and Yanyuwa (Sir Edward Pellew) regions, with 18.7 turtles km^{-2} and 16.3 turtles km^{-2} respectively.

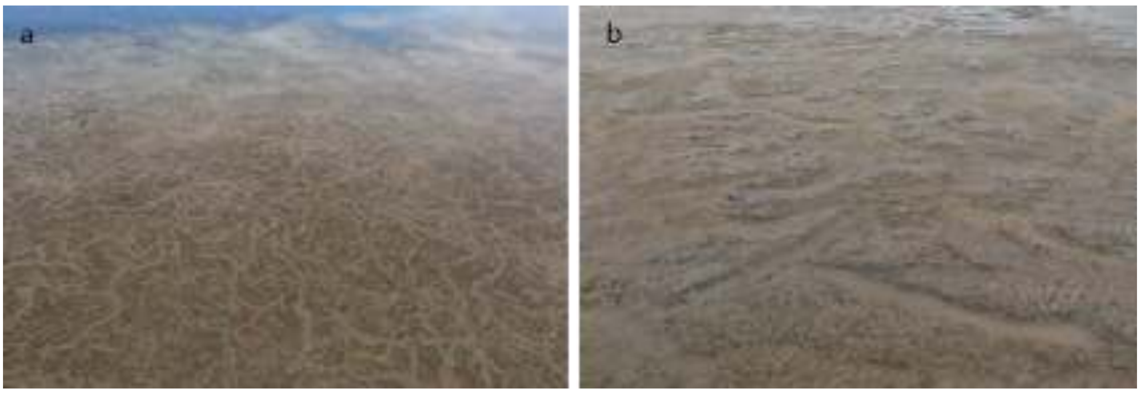

Figure 17. Dugong feeding trails on the coastline line south-west of the McArthur River mouth.

Grazing by turtles and dugongs increases plant nutrient content (Fourqurean et al., 2019), and although productivity may initially increase (Christianen et al., 2014) it declines when grazing intensifies and/or is prolonged (Hernandez and Tussenbroek, 2014; Christianen et al., 2014). Grazing by turtles and dugongs has been significant in this region over many decades and there is no indication of productivity decline. Green turtles respond to changes in seagrass composition and abundance with extraordinary flexibility in feeding strategies that allow them to exploit new meadow resources while maintaining site-fidelity (Shimada et al., 2020). When available forage declines for dugongs, they respond by moving, and sometimes large distances, as observed following largescale seagrass dieback from severe weather events. Where sufficient forage is not available close by, dugongs may delay reproduction as they will not be able to reach breeding condition and, if severe, mortality may result. The decades of dugong aerial survey data suggest that the NT GoC is relatively stable, though given the increasing pressure on habitats from climate change remain vulnerable to population decline.

Miyalmiyal (algae)

Algae communities provide habitat critical for ecosystem function including food and shelter for juvenile and adult fish and invertebrate communities (Wilson et al., 2011; Lim et al., 2016; McNeil et al., 2021). Algae cover in the survey area was extensive along the mainland between Rosie Creek and WanarrWanarr, and around the islands. Algae communities were present in more than a third of the survey sites, demonstrating an important role in benthic habitat function. All five algae functional groups were recorded, with many sites featuring a diversity of groups. Algae is known to occur in food samples from dugongs (Heinsohn & Birch, 1972; Marsh et al., 1982; Erftemeijer, 1994; Preen, 1995) but its presence in the diet is mostly described as incidental (Marsh et al., 1982) or linked to large-scale losses of seagrass (Spain & Heinsohn, 1973; Marsh et al., 1982; Preen & Marsh, 1995). Dugongs foraging on algal covered rocky reefs has been observed in the Darwin region, NT (Whiting, 2002). Adult green turtles are known to display either seagrass or algae preference in their foraging habits or fidelity to their foraging sites which, in turn, influences their migrations and the availability of forage. With an abundant supply of seagrass and algae, Yanyuwa sea country provides significant feeding grounds for green turtles.

Invertebrates

Diverse invertebrate communities were recorded in intertidal habitats throughout Yanyuwa sea country, including hard and soft corals and sponges. Hard corals were most prevalent in relatively clearer waters along the northern and eastern sides of the Yanyuwa IPA islands, similar to where intertidal coral communities were recorded in Marra sea country around Maria and Beatrice Islands (Collier et al., 2023). Both surveys provide an important baseline of coral cover in a region where there is little information on coral habitats outside of deep submerged reefs (Harris et al., 2008). Other invertebrates, primarily oysters and barnacles, were common around the islands, particularly the rocky coastlines of western Vanderlin Island, Barranyi (Centre Island and southern North Island), and around Mathandurla and WanarrWanarr (Figure 18).

Figure 18. Invertebrate communities along rocky shores and headlands often featured barnacles and oysters in Yanyuwa sea country.

Next steps and future priorities

This baseline of intertidal benthic habitats in Yanyuwa country is being compiled with existing data on turtles, dugongs, and other significant species, culturally important information provided by the community, and spatial information on threats to the Yanyuwa IPA for inclusion in the Yanyuwa intertidal and subtidal seagrass report (Groom et al., in prep). This information will support Yanyuwa people with their sea country planning and management. Yanyuwa people for decades have been working towards greater protection of their sea country. By having current and robust data layers, Yanyuwa people are empowered to delineate and negotiate areas for protection, e.g., cultural, and ecological values and resource management.

The spatial data are publicly available and can support decision-making on environmental impact assessment, conservation prioritisation and management by all levels of government. For example, this work supports the government to meet its commitments under the global biodiversity framework, namely protecting 30 per cent of land and sea by 2030, and the objectives and associated goals of Australia's Strategy for Nature 2019-2030 (https://www.australiasnaturehub.gov.au/sites/default/files/2020-11/australias-strategy-for-nature.pdf). These goals include: (1) connecting all Australians with nature, (2) caring for nature in all its diversity, and (3) sharing and building knowledge. This data captures the most important dugong and green turtle foraging habitat in the NT and will be critical in the current revision process of updating Biologically Important Areas in line with the Commonwealth legislative reform. A Biologically Important Area (BIA) is a spatially defined area where aggregations of individuals of a species are known to display biologically important behaviour such as breeding, foraging, resting or migration (http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf). This data, therefore, plays an important role in informing management of this region for the Commonwealth Government.

This intertidal mapping also provides a foundation to:

- Estimate the blue carbon stored within the seagrass meadows of the GoC. This is likely to become increasingly recognised as a value that needs a high level of protection as impacts from climate change and carbon emissions increase.
- Assess exposure to risk (e.g., industry, tourism, water quality, climate change) and cumulative impacts.
- Build on already available data (Carter et al., 2022) that will be used to produce more robust models of seagrass distribution, communities, and connectivity.

A Yanyuwa sea country monitoring program should be established so that changes in benthic habitats, particularly seagrass, are identified and enable management responses (these are often indirect, e.g., reduce fishing or hunting pressure). Co-design of the monitoring program that incorporates Traditional Owner values and knowledge as well as western scientific approaches is essential, and should consider:

- Annual seagrass monitoring of Yanyuwa sea country.
- Monitoring of priority areas based on areas of cultural values and pressures.
- Measuring seasonal variability in a subset of monitoring sites.
- Linking seagrass condition to changes in dugong, turtle and fisheries populations. This would require parallel monitoring of seagrass-associated species.
- Measuring pressures such as water temperature and benthic light.
- The use of technology (e.g., drones) for ranger-led intertidal seagrass, turtle and dugong monitoring.

Yanyuwa people are seeking opportunities for greater protection of Yanyuwa country that respect their cultural practice, support intergenerational knowledge transfer and are sustainable. Understanding the distribution of values important to Yanyuwa people is fundamental for decision-making and delineating areas for greater protection. Considering Yanyuwa people's aspirations for greater protection, we recommend the following in consultation with Yanyuwa people:

- Synthesise and spatially analyse relevant eco-cultural and biodiversity data for Yanyuwa country to identify areas of significance.
- Work with Yanyuwa people to establish robust rules for greater protection over these areas to reflect their values.
- Support Yanyuwa people in discussions with government to mobilise their protection aspirations for greatest impact through regulatory management tools.

Glossary (Yanyuwa)

Barni-Wardimantha Awara	Don’t spoil the country
Jungkayi	Guardians of Yanyuwa country
Ngimarringki	Custodians of Yanyuwa country
li-Anthawirriyarra	People of the sea; also, the name of the Sea Ranger Unit
ma-lhanngu	Intertidal seagrass
Maraman	Seagrass
Marra	Aboriginal traditional owners and custodians of the Limmen Bight region, adjacent to Yanyuwa country
Miyalmiyal	Algae
na-julangal	Yanyuwa observe as offshore seagrass species near reef
na-wurndarnda	The line of mangroves that fringe the seagrass beds and the actual seagrass beds. A zone recognised by the Yanyuwa as important for the wellbeing of all the islands because it’s where the immature fish and prawns live, and where nutrients are washed into the sea to nurture both the immature species that live there but also the seagrass beds.
Yanyuwa clan groups	Wurdaliya, Wuyaliya, Rrumburriya and Mambaliya-Wawukarriya
Yanyuwa	Aboriginal traditional owners and custodians of the Sir Edward Pellew Islands and the surrounding seas and coastal environment (including rivers and creeks).
Walya nyiki-na:anji ki-maramanngku	‘The dugong and sea turtle they are kin to the seagrass'
Walya	Dugong and sea turtle'
Barranyi	North and Centre Island (big place name)
Limiyamila	Black Islet
Mathandurla	West Island
Milrila	Fat Fellow Creek
WanarrWanarr	South West Island
Rabunthu	Port McArthur
Wujulukinda	Carrington River mouth
Wuthanda	Dugong nursery location
Wunguntha	Crooked River mouth

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Appendix A

Appendix 1. Identification codes for intertidal meadows in Yanyuwa sea country, and table of meadow attributes.

Meadow ID	Biomass (mean)	Biomass (SE)	Sites (n)	Area (ha)	R (ha)	Density	Community Type
BI108	4.61	0.77	10	105.4098	3.0720	Moderate	*H. uninervis* (narrow) with *H. ovalis*
BI109	3.83	0.00	1	0.6758	0.1555	Moderate	*H. ovalis* with *H. uninervis* (narrow)
BI110	3.46	0.00	1	2.2754	0.2752	Moderate	*H. ovalis*
BI111	10.57	3.35	4	13.8357	1.7937	Dense	*H. uninervis* (narrow)
BI112	16.31	1.87	4	12.5188	1.2436	Dense	*H. uninervis* (narrow)
BI113	7.73	2.31	4	8.7054	1.0838	Dense	*H. uninervis* (narrow)
CI73	5.25	2.71	4	13.6741	1.0558	Moderate	*H. uninervis* (narrow) with *H. ovalis*
CI74	4.51	1.46	9	42.5147	1.8121	Moderate	*H. ovalis* with *H. uninervis* (narrow)
CI75	12.74	3.24	15	44.4993	2.0074	Dense	*H. uninervis* (narrow) with mixed species
CI76	3.63	0.00	1	0.6447	0.1505	Moderate	*H. ovalis*

CI77	3.08	0.00	1	0.1923	0.0890	Moderate	*H. ovalis*
CI78	4.00	2.01	3	3.7786	0.3883	Moderate	*H. ovalis*
CI79	2.76	2.76	2	5.4902	0.5209	Moderate	*H. ovalis* / *H. uninervis* (narrow)
CI80	2.08	1.77	5	6.8785	0.5858	Moderate	*H. uninervis* (narrow) with *H. ovalis*
CI81	6.81	0.87	57	260.6213	11.7765	Dense	*H. ovalis* with mixed species
CI82	8.09	2.29	10	77.5221	2.2241	Moderate	*H. uninervis* (narrow) / *H. ovalis* with mixed species
CI83	9.53	1.22	16	102.5815	4.0603	Dense	*H. ovalis* / *H. uninervis* with mixed species
CI84	7.44	0.00	1	5.2723	0.4178	Dense	*H. ovalis*
CI85	0.00	0.00	1	1.2580	0.2092	Light	*H. ovalis*
CI86	6.11	0.88	24	143.4874	2.9946	Moderate	*H. ovalis* / *H. uninervis* (narrow)
CI87	13.13	4.73	4	5.4602	0.7809	Dense	*H. uninervis* (narrow) with *H. ovalis*
CI88	6.62	1.14	3	3.3226	0.4670	Moderate	*H. ovalis* with mixed species
CI89	8.61	1.90	6	6.2112	0.9427	Dense	*H. uninervis* (narrow) with *H. ovalis*
CI90	0.00	0.00	1	0.8912	0.1861	Unknown	*H. ovalis*
CI91	0.00	0.00	2	1.5739	0.2953	Unknown	*H. ovalis*
CI92	2.81	0.85	3	5.5229	0.4748	Moderate	*H. ovalis* with *H. uninervis* (narrow)
CI93	2.07	2.07	2	4.5231	0.4275	Moderate	*H. ovalis*
CI94	9.97	1.02	48	204.5559	6.4668	Dense	*H. uninervis* (narrow) with mixed species
HI70	0.67	0.47	2	0.4082	0.1215	Light	*H. ovalis*
HI71	0.00	0.00	1	0.0919	0.0228	Unknown	*H. uninervis* (narrow)
HI72	1.24	0.42	3	2.2202	0.3949	Light	*H. uninervis* (narrow) with *H. ovalis*
LI95	15.67	1.85	18	115.5955	3.9911	Dense	*H. uninervis* (narrow) with mixed species
LVI1	2.20	0.90	3	7.4158	0.8034	Moderate	*H. ovalis* with *H. uninervis* (narrow)
NI1	4.67	0.85	23	48.3085	6.3825	Moderate	*H. ovalis* with *H. uninervis* (wide)
NI18	3.74	0.00	1	0.0658	0.0095	Moderate	*H. ovalis*

NI19	5.17	0.00	1	0.0688	0.0138	Dense	*H. ovalis*
NI2	3.16	0.00	1	0.3336	0.1116	Moderate	*H. ovalis*
NI3	1.20	0.00	1	0.1226	0.0127	Moderate	*H. ovalis*
NI4	3.94	0.00	1	1.0141	0.2283	Moderate	*H. uninervis* (narrow) / *H. ovalis*
NI5	19.24	0.00	1	1.6087	0.2447	Moderate	*H. uninervis* (wide)
NI6	12.31	0.00	1	2.7294	0.3531	Moderate	*H. uninervis* (wide)
NI7	2.93	0.62	4	5.4269	0.6798	Light	*H. uninervis* (wide)
SI1	8.96	1.40	25	193.4306	8.3477	Dense	*H. uninervis* (narrow) with mixed species
SI2	12.86	3.07	5	19.9468	1.5530	Dense	*H. uninervis* (narrow) with mixed species
SI3	0.72	0.00	1	1.4777	0.2280	Light	*H. ovalis*
SI4	3.76	2.43	2	3.2644	0.4532	Moderate	*H. uninervis* (narrow) with *H. ovalis*
SW100	15.81	1.64	48	317.6570	14.0047	Dense	*H. uninervis* (narrow) with *H. ovalis*
SW101	23.30	1.56	41	448.5263	7.8802	Dense	*H. uninervis* (narrow) with mixed species
SW102	0.22	0.00	1	0.1307	0.0738	Light	*H. ovalis*
SW103	0.00	0.00	0	0.0959	0.0671	Unknown	Unknown
SW104	4.65	0.00	1	0.2574	0.1056	Dense	*H. uninervis* (narrow)
SW105	0.00	0.00	0	0.1528	0.0827	Unknown	Unknown
SW106	8.56	0.00	1	1.4954	0.2496	Dense	*H. uninervis* (narrow) with *H. ovalis*
SW107	5.62	0.00	1	0.1293	0.0745	Dense	*H. uninervis* (narrow) with *H. ovalis*
SW96	6.16	1.20	20	141.1245	2.7132	Moderate	*H. uninervis* (narrow) with mixed species
SW97	12.47	1.92	16	160.8691	8.6070	Dense	*H. uninervis* (narrow) with *H. ovalis*
SW98	8.71	2.23	17	69.6844	7.8508	Dense	*H. uninervis* (narrow) with *H. ovalis*
SW99	25.41	5.01	7	27.7234	2.4039	Dense	*H. uninervis* (narrow) with *H. ovalis*
VI1	22.23	8.62	5	14.2644	0.8035	Dense	*H. uninervis* (narrow)
VI10	15.53	5.52	5	32.8089	1.3435	Moderate	*H. uninervis* (wide) with *H. ovalis*

VI11	2.85	0.00	1	0.0148	0.0047	Moderate	*H. ovalis*
VI12	4.21	1.00	3	0.7733	0.2910	Moderate	*H. ovalis*
VI13	4.72	0.70	8	9.1233	0.9754	Moderate	*H. ovalis* with *H. uninervis* (wide)
VI14	4.16	0.22	4	7.4067	0.6898	Moderate	*H. ovalis*
VI15	3.94	0.00	1	0.0348	0.0100	Moderate	*H. ovalis*
VI16	4.41	4.41	2	0.0738	0.0155	Light	*E. acoroides*
VI17	8.97	0.00	1	0.0028	0.0022	Light	*E. acoroides*
VI18	8.74	0.00	1	0.0775	0.0107	Dense	*H. ovalis*
VI19	4.05	0.45	2	0.4724	0.1552	Moderate	*H. ovalis*
VI2	3.39	1.05	6	47.9623	1.9179	Moderate	*H. ovalis*
VI20	4.69	1.08	3	1.6686	0.4009	Moderate	*H. ovalis*
VI21	0.00	0.00	1	0.1269	0.0129	Unknown	*H. ovalis*
VI22	4.27	0.00	1	0.3867	0.1181	Moderate	*H. ovalis*
VI23	4.29	0.88	2	0.4452	0.1892	Moderate	*H. ovalis*
VI24	3.54	1.34	4	3.3084	0.4194	Moderate	*H. ovalis*
VI25	5.28	0.00	1	0.0191	0.0053	Moderate	*H. ovalis*
VI26	4.39	0.00	1	1.3520	0.2300	Moderate	*H. ovalis*
VI27	4.12	1.05	2	7.8290	0.6446	Moderate	*H. ovalis*
VI28	3.89	0.00	1	0.0002	0.0003	Light	*E. acoroides*
VI29	0.00	0.00	1	0.0050	0.0028	Unknown	*H. uninervis* (wide)
VI3	10.63	2.49	13	177.0740	8.5386	Dense	*H. uninervis* (narrow) with *H. ovalis*
VI4	7.27	1.57	16	352.4592	13.8835	Dense	*H. uninervis* (narrow) with *H. ovalis*
VI5	11.68	1.10	22	117.6596	3.9217	Moderate	*H. uninervis* (wide) with *H. ovalis*
VI6	13.10	0.00	1	0.5069	0.1477	Moderate	*H. uninervis* (wide)
VI7	4.94	1.39	12	60.5851	5.6469	Moderate	*H. ovalis* with mixed species
VI8	3.66	0.79	6	31.3528	1.5200	Moderate	*H. ovalis*
VI9	0.00	0.00	1	0.0687	0.0125	Unknown	*H. ovalis*

Wal1	7.56	2.53	8	21.9725	2.3307	Dense	*H. uninervis* (narrow) with mixed species
Wal2	12.76	0.00	1	3.2121	0.3465	Dense	*H. uninervis* (narrow)
Wal3	2.09	0.27	2	5.5876	0.5371	Moderate	*H. ovalis* with *H. uninervis* (narrow)
Wal4	1.46	0.12	2	10.9467	0.8563	Moderate	*H. ovalis* with *H. uninervis* (narrow)
Wal5	8.37	1.80	11	64.2668	3.2334	Dense	*H. ovalis* with mixed species
Wal6	6.05	3.11	4	15.3704	1.8092	Light	*E. acoroides* / *H. ovalis*
WI110	7.17	1.63	17	287.1243	6.6666	Dense	*H. uninervis* (narrow) with *H. ovalis*
WI111	4.71	3.19	2	3.3934	0.3717	Dense	*H. uninervis* (narrow)
WI112	0.74	0.00	1	1.0646	0.2021	Light	*H. ovalis*
WI113	101.61	11.68	2	0.0837	0.0219	Dense	*E. acoroides*
WI114	6.28	0.00	1	0.7402	0.1700	Dense	*H. ovalis*
WI115	7.42	0.00	1	1.0544	0.2250	Dense	*H. uninervis* (narrow) with *H. ovalis*
WI116	1.72	0.00	1	0.9627	0.1825	Moderate	*H. ovalis*
WI117	0.22	0.00	1	3.0258	0.3503	Light	*H. ovalis*
WI118	10.30	2.13	39	332.6139	11.5920	Moderate	*C. serrulata* with mixed species
WI119	16.38	3.89	22	210.5072	10.5436	Moderate	*C. serrulata* with mixed species
WI120	58.79	6.35	5	3.2350	1.0885	Dense	*H. uninervis* (wide)
WI121	0.41	0.00	1	0.0748	0.0215	Light	*H. uninervis* (narrow) with *H. ovalis*
WI122	3.51	0.00	1	0.0336	0.0149	Moderate	*H. ovalis* with *H. uninervis* (narrow)
WI123	7.74	0.00	1	0.0474	0.0174	Dense	*H. uninervis* (narrow)
WI124	7.09	0.00	1	0.0277	0.0139	Dense	*H. ovalis*
WI125	6.11	0.00	1	0.0308	0.0144	Dense	*H. uninervis* (narrow)
WI126	2.99	0.00	1	0.0066	0.0034	Moderate	*H. uninervis* (narrow)
YS1	8.95	0.90	66	1109.5230	76.3859	Dense	*H. uninervis* (narrow) with mixed species
YS10	17.79	4.42	5	5.9648	0.8071	Dense	*H. uninervis* (narrow) with *H. ovalis*

YS12	20.96	0.00	1	0.0200	0.0063	Dense	*H. uninervis* (narrow) with *H. ovalis*
YS14	33.53	15.63	3	6.0115	0.3767	Moderate	*H. uninervis* (wide) with mixed species
YS15	14.94	0.00	1	1.1540	0.0935	Dense	*H. uninervis* (narrow)
YS16	6.47	4.10	2	2.4915	0.2230	Dense	*H. uninervis* (narrow)
YS17	11.14	5.29	3	4.0443	0.4139	Dense	*H. ovalis* / *H. uninervis* (narrow)
YS18	25.33	1.09	2	3.0980	0.1711	Dense	*H. uninervis* (narrow)
YS19	10.02	2.19	2	7.3674	0.3079	Dense	*H. ovalis* with *H. uninervis* (narrow)
YS2	16.89	0.00	1	19.9900	0.6117	Dense	*H. uninervis* (narrow)
YS20	18.77	0.00	1	1.2972	0.0875	Dense	*H. uninervis* (narrow)
YS21	30.43	0.00	1	24.3180	1.4584	Dense	*H. uninervis* (wide) with *H. ovalis*
YS22	22.51	3.35	6	10.6942	0.7608	Dense	*H. ovalis* with *H. uninervis* (wide)
YS23	35.17	0.00	1	0.3576	0.0443	Dense	*H. ovalis* / *H. uninervis* (narrow)
YS24	20.55	7.04	4	13.2001	0.3620	Dense	*H. uninervis* (wide) with mixed species
YS25	21.75	4.96	6	29.3435	0.6812	Dense	*H. uninervis* (narrow)
YS26	25.04	4.44	9	35.8122	0.9147	Dense	*H. uninervis* (narrow) with *H. ovalis*
YS27	16.37	1.39	3	30.1822	0.7334	Dense	*H. uninervis* (narrow)
YS28	15.49	1.09	2	4.2146	0.2889	Dense	*H. uninervis* (narrow)
YS29	25.53	1.00	11	56.4399	0.9422	Dense	*H. uninervis* (narrow) with mixed species
YS3	18.81	5.11	23	489.7760	15.2415	Dense	*H. uninervis* (narrow) with mixed species
YS30	0.00	0.00	1	0.9156	0.0781	Unknown	*H. uninervis* (narrow) with *H. ovalis*
YS31	19.46	0.00	1	17.7357	0.4455	Moderate	*H. uninervis* (wide)
YS32	19.84	3.21	8	202.7742	3.6333	Moderate	*H. uninervis* (wide) with mixed species
YS33	8.35	3.11	3	17.7269	0.4199	Moderate	*H. uninervis* (wide) with mixed species
YS34	22.80	3.81	15	313.5918	5.9220	Moderate	*H. uninervis* (wide) with mixed species
YS35	18.01	0.00	1	3.5946	0.1636	Moderate	*H. uninervis* (wide)

YS36	9.19	2.32	3	32.6868	0.6137	Moderate	*H. uninervis* (wide) with mixed species
YS37	21.09	2.40	32	778.3734	24.1683	Moderate	*H. uninervis* (wide) with mixed species
YS38	8.68	2.16	31	506.7880	20.0010	Moderate	*H. uninervis* (wide) with mixed species
YS39	7.38	1.54	13	125.2576	11.0958	Moderate	*H. uninervis* (wide) with mixed species
YS4	29.31	5.46	14	505.0492	14.0655	Dense	*H. uninervis* (narrow) with mixed species
YS40	11.60	2.60	13	118.5624	7.7538	Moderate	*H. uninervis* (wide) with mixed species
YS41	14.27	3.15	14	136.5069	9.4289	Moderate	*H. uninervis* (wide) with mixed species
YS42	10.57	1.33	5	134.5780	6.0335	Moderate	*H. uninervis* (wide) with *H. ovalis*
YS43	8.44	0.32	3	38.1082	0.6909	Moderate	*H. uninervis* (wide)
YS44	13.65	0.00	1	4.5291	0.2215	Moderate	*H. uninervis* (wide)
YS45	18.23	3.01	2	30.9947	0.7270	Moderate	*H. uninervis* (wide)
YS46	8.84	1.61	24	406.4044	14.0861	Moderate	*H. uninervis* (wide) with mixed species
YS47	13.43	2.66	3	21.7446	0.3797	Moderate	*H. uninervis* (wide) with *H. ovalis*
YS48	7.58	0.75	33	343.8052	21.2088	Moderate	*H. uninervis* (wide)
YS49	15.44	0.00	1	0.8215	0.1114	Moderate	*H. uninervis* (wide)
YS5	36.06	2.53	77	1412.5268	50.8974	Dense	*H. uninervis* (narrow) with mixed species
YS50	13.54	9.71	2	1.7009	0.2054	Moderate	*H. uninervis* (wide)
YS51	3.88	0.84	2	6.9380	0.2347	Light	*H. uninervis* (wide)
YS52	9.56	1.69	21	143.2779	11.9485	Moderate	*H. uninervis* (wide) with *H. ovalis*
YS53	14.23	1.52	37	656.1904	22.1949	Moderate	*H. uninervis* (wide) with *H. ovalis*
YS54	18.52	1.66	30	1089.7157	25.4969	Moderate	*H. uninervis* (wide) with mixed species
YS55	12.09	0.00	1	4.7824	0.1670	Moderate	*H. uninervis* (wide)
YS56	17.64	1.44	37	740.1198	29.9350	Dense	*H. uninervis* (narrow) with *H. ovalis*
YS57	5.40	2.98	2	34.5324	1.3621	Dense	*H. uninervis* (narrow) with *H. ovalis*
YS58	11.93	3.27	10	115.9836	5.6896	Dense	*H. uninervis* (narrow) with *H. ovalis*

YS59	14.67	4.84	4	16.9693	2.0881	Dense	*H. uninervis* (narrow) with *H. ovalis*
YS6	21.84	2.54	29	169.3194	10.0622	Dense	*H. uninervis* (narrow) with mixed species
YS60	5.37	1.91	2	13.7775	0.8226	Dense	*H. uninervis* (narrow) with *H. ovalis*
YS61	8.44	0.00	1	4.0961	0.1972	Dense	*H. uninervis* (narrow)
YS62	17.45	3.50	13	189.5959	9.1519	Dense	*H. uninervis* (narrow) with *H. ovalis*
YS63	23.21	3.12	13	226.8143	10.3701	Dense	*H. uninervis* (narrow) with *H. ovalis*
YS64	25.33	0.00	1	4.0451	0.1630	Dense	*H. uninervis* (narrow) / *H. ovalis*
YS65	18.86	2.46	18	320.4435	16.3395	Dense	*H. uninervis* (narrow) with *H. ovalis*
YS66	13.48	1.82	3	55.5930	2.5996	Dense	*H. uni*nervis (narrow) / *H. ovalis*
YS67	19.40	5.39	7	55.1549	2.2090	Moderate	*H. uninervis* (wide) with mixed species
YS68	50.92	12.99	3	9.6627	0.7345	Dense	*H. uninervis* (wide)
YS69	27.72	0.00	1	1.3276	0.0846	Dense	*H. uninervis* (wide)
YS7	15.12	6.16	3	3.1305	0.2833	Dense	*H. uninervis* (narrow) with *H. ovalis*
YS70	15.51	1.03	3	10.4742	0.4299	Dense	*H. ovalis*
YS71	4.36	1.86	5	30.6252	1.1491	Dense	*H. uninervis* (narrow) with mixed species
YS72	30.80	0.00	1	0.1395	0.0198	Dense	*H. uninervis* (narrow)
YS8	23.95	2.42	56	717.5805	34.6451	Dense	*H. uninervis* (narrow) with mixed species
YS9	24.38	1.93	8	8.6562	0.6628	Dense	*H. uninervis* (narrow) with *H. ovalis*

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