

## DATA ARTICLE

**Seagrass spatial data synthesis from north-east Australia, Torres Strait and Gulf of Carpentaria, 1983 to 2022**

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**Scientific Significance Statement**

Seagrass meadows are a key habitat of northern Australian tropical waters. They are nursery grounds for fish and crustaceans and contribute to commercial fisheries productivity. They are food for populations of dugong and green turtles, species that are deeply significant for coastal Aboriginal and Torres Strait Islander people's culture and heritage. Spatial data on seagrass have been collected across the Torres Strait and Gulf of Carpentaria since the 1980s but data have often been poorly curated and in some instances lost. Data in most cases have not been publicly available. In recognizing this and the urgent need to improve our understanding of habitats in a rapidly changing global climate we compiled and validated historical spatial data to create a publicly available database. This is a region of the world identified as having relatively low anthropogenic impacts but, like all tropical coastal regions, it is exposed to the effects of climate change. We provide a validated baseline for the seagrass, one of the region's most important marine habitats.

**Abstract**

The Gulf of Carpentaria and Torres Strait in north-eastern Australia support globally significant seagrass ecosystems that underpin fishing and cultural heritage of the region. Reliable data on seagrass distribution are critical to understanding how these ecosystems are changing, while managing for resilience. Spatial data on seagrass have been collected since the early 1980s, but the early data were poorly curated. Some was not publicly available, and some already lost. We validated and synthesized historical seagrass spatial data to create a publicly available database. We include a site layer of 48,612 geolocated data points including information on seagrass

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presence/absence, sediment, collection date, and data custodian. We include a polygon layer with 641 individual seagrass meadows. Thirteen seagrass species are identified in depths ranging from intertidal to 38 m below mean sea level. Our synthesis includes scientific survey data from 1983 to 2022 and provides an important evidence base for marine resource management.

## Background and Motivation

Seagrasses are one of the key marine ecosystems in northern Australia, with extensive areas of seagrass surveyed and mapped in the Torres Strait and Gulf of Carpentaria (Poiner et al. 1989; Green and Short 2003; Roelofs et al. 2005; Carter et al. 2014, 2021a; Huisman et al. 2021; Coles et al. 2022). The ecosystem goods and benefits these seagrass communities provide include substrate stabilization and water quality improvements, and baffling wave and tidal energy, which reduces suspended particulate matter and improves water clarity (Costanza et al. 2014; Nordlund et al. 2016; Lamb et al. 2017; Bainbridge et al. 2018). Seagrass meadows play a critical role as food and shelter for fish and crustaceans, which support the livelihoods and well-being of coastal peoples of the region (Hayes et al. 2020; Jänes et al. 2020a, 2020b). They are also important carbon sinks, sequestering and capturing carbon in the sediments, helping to offset the impacts of carbon emissions (Macreadie et al. 2021). They provide food for dugongs (*Dugong dugon*) and green sea turtles (*Chelonia mydas*) (Marsh et al. 2011; Kelkar et al. 2013; Tol et al. 2016; Scott et al. 2018, 2020). These species have significant spiritual, economic and ceremonial importance for the Traditional Owners and custodians of Sea Country in the Gulf of Carpentaria and Torres Strait (Bradley 1997; Butler et al. 2012).

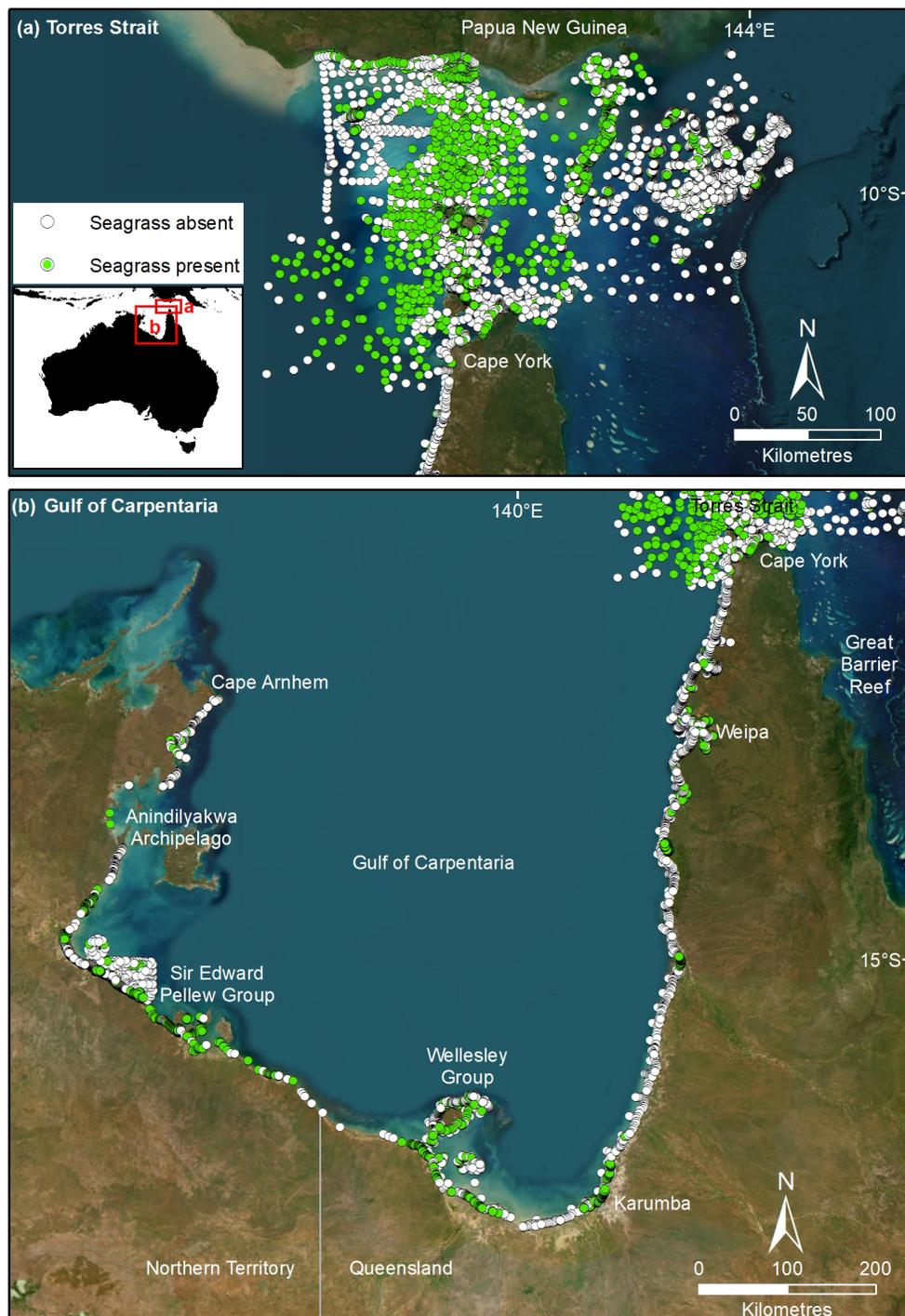
A strong body of evidence has established that globally, there has been a net decline in seagrass meadows in recent decades, particularly near-shore meadows influenced by coastal processes and human impact (Waycott et al. 2009; Dunic et al. 2021; Turschwell et al. 2021). Climate change-induced increases in water temperature and frequency and severity of tropical storms have the potential to exacerbate this decline (Strydom et al. 2020; Serrano et al. 2021; Carter et al. 2022b). Access to reliable data at a range of spatial and temporal scales are critical to understand the challenges marine ecosystems such as seagrass face around the world. This data can be used for assessing the present condition of ecosystems and for understanding long-term trends. It can be used to define the desired state of the diversity of habitats (Collier et al. 2020; Carter et al. 2022b), establish ecologically relevant targets to maintain resilience (Brodie et al. 2017; Lambert et al. 2021) and to implement effective management frameworks (Levin and Möllmann 2015; Hallett et al. 2016; O'Brien et al. 2017; York et al. 2017).

The Torres Strait and Gulf of Carpentaria are remote from Australia's major population centers. The Gulf of Carpentaria is an extensive (~300,000 km<sup>2</sup>) and low energy shallow semi-enclosed sea. It is characterized by complex, mangrove-lined creeks and estuaries and extensive seagrass meadows that

grow along the coast (Poiner et al. 1987; Roelofs et al. 2005; Wightman 2006; Duke et al. 2020, 2021, 2022) (Fig. 1). Tides can range up to a maximum of nearly 4 m but tidal regimes vary throughout the Gulf of Carpentaria and can be influenced by strong trade winds in June and July. The Gulf includes three major island groups, the Wellesley Group in the south-east, Sir Edward Pellew Group in the south-west, and the Anindilyakwa archipelago off the south west coast. Seagrass grows around all these islands, which are known dugong habitat (Marsh et al. 2008; Groom et al. 2017; Kyne et al. 2018; Griffiths et al. 2020; Udyawer et al. 2021). The three island groups are captured within the southern Gulf of Carpentaria's Important Marine Mammal Area, a region recognized by the International Union for Conservation of Nature for having significant populations of marine mammals (<https://www.marinemammalhabitat.org/portfolio-item/southern-gulf-carpentaria/>). There are several major river systems that flow into the Gulf of Carpentaria with most of the river flow restricted to the seasonal monsoon.

The Torres Strait is a shallow water body with a complex hydrodynamic environment between north-east Australia's Cape York Peninsula and Papua New Guinea (Saint-Cast 2008; Wolanski et al. 2013; Fig. 1). The area covers more than 48,000 km<sup>2</sup> and is prone to high velocity tidal currents, with many shoals, reefs and islands. Like the Gulf of Carpentaria, the tidal range can be as high as 4–5 m (mean spring tide range of 3.6 m) in eastern Torres Strait, but tides are highly variable and hard to predict due to the complexity of the reef topography (Brander et al. 2004). There is little influence from river input to Torres Strait from the Australian coast, but the northern region is exposed to limited outflow from Papua New Guinea rivers (Waterhouse et al. 2021). Mangroves are widespread but notably abundant in the northern areas like the large mangrove islands of Boigu and Saibai (Duke et al. 2015). Seagrass meadows are common throughout Torres Strait, but are most abundant in nearshore waters, on and surrounding reefs and in subtidal waters in the western region (Haywood et al. 2008; Carter et al. 2014, 2022b; Carter and Rasheed 2016).

The remoteness of north-eastern Australia means data collection have been sporadic and costly in both time and dollar value. It is important that the value of existing information is exploited to its full extent. Torres Strait and Gulf of Carpentaria seagrass research extends back to the 1970s (Moriarty 1977; Bridges et al. 1982), but survey coverage was limited in the early years. Data collection in a consistent manner and with a spatial/mapping focus commenced in the early



**Fig. 1.** Seagrass presence and absence at individual survey sites across Torres Strait and the Gulf of Carpentaria, 1983–2022. Map with all survey locations listed in Table 1 in Data S1. Satellite image courtesy: ESRI.

1980s in the Gulf of Carpentaria (Coles and Lee Long 1985; Poiner et al. 1987) and early 2000s in Torres Strait (Scott and Rasheed 2021). Mapping and spatially explicit monitoring projects since then range from surveys quantifying seabed benthic cover across the entire Torres Strait and Gulf of

Carpentaria coast, to more targeted seagrass assessments at smaller spatial scales (Table 1). There is a risk that older data are in danger of being lost if not secured, compiled, validated, and made available in a contemporary readily available format to potential data users.

**Table 1.** Spatial data used in seagrass data compilation for sites and meadows, 1983–2022.

| Survey purpose/data location                             | Years            | Site (S)<br>Meadow (M) | Reference  |
|--|------------------|------------------------|--|
| Region-scale baseline surveys                            |                  |                        |  |
| GOC intertidal   | 2004             | S, M                   | Roelofs et al. (2005)                                  |
| GOC  | 1986             | S, M                   | Coles et al. (2004, 2022)                              |
| Torres Strait inter-reefal benthic assemblages           | 2005             | S                      | Haywood et al. (2008)                                  |
| Torres Strait seagrass monitoring                        |                  |                        |  |
| Dungeness Reef intertidal                                | 2016–2021        | S, M                   | Carter et al. (2021e)                                  |
| Dungeness Reef subtidal                                  | 2017–2022        | S                      | Carter et al. (2021e)                                  |
| Orman Reef intertidal                                    | 2017–2021        | S, M                   | Carter et al. (2021e)                                  |
| Orman Reef subtidal                                      | 2017–2022        | S                      | Carter et al. (2021e)                                  |
| Masig Island intertidal                                  | 2020–2021        | S, M                   | Carter et al. (2021e)                                  |
| Dugong Sanctuary subtidal                                | 2011–2022        | S                      | Carter et al. (2021e)                                  |
| Poruma Island PM1  | 2016–2022        | S                      | Carter et al. (2021e)                                  |
| Poruma Island PM2  | 2016–2022        | S                      | Carter et al. (2021e)                                  |
| Iama Island IM1  | 2010–2022        | S                      | Carter et al. (2021e)                                  |
| Iama Island IM2  | 2010–2022        | S                      | Carter et al. (2021e)                                  |
| Mer Island MR1   | 2009–2022        | S                      | Carter et al. (2021e)                                  |
| Mer Island MR2   | 2009–2022        | S                      | Carter et al. (2021e)                                  |
| Mua Island MU1   | 2011–2022        | S                      | Carter et al. (2021e)                                  |
| Mua Island MU3   | 2011–2022        | S                      | Carter et al. (2021e)                                  |
| Mabuyag Island MG1                                       | 2009–2021        | S                      | Carter et al. (2021e)                                  |
| Mabuyag Island MG2                                       | 2009–2021        | S                      | Carter et al. (2021e)                                  |
| Badu Island BD1  | 2010–2022        | S                      | Carter et al. (2021e)                                  |
| Badu Island BD2  | 2010–2022        | S                      | Carter et al. (2021e)                                  |
| Targeted seagrass mapping surveys                        |                  |                        |  |
| Dungeness Reef subtidal, Torres Strait                   | 2017             | S, M                   | Carter et al. (2017)                                   |
| North-west Torres Strait and PNG                         | 2015–2016        | S, M                   | Carter and Rasheed (2016)                              |
| Eastern Cluster, Torres Strait                           | 2020             | S, M                   | Carter et al. (2021c)                                  |
| Northern Dugong Sanctuary and Orman Reefs, Torres Strait | 2020             | S, M                   | Carter et al. (2021b)                                  |
| Dugong Sanctuary, Torres Strait                          | 2010             | S, M                   | Taylor and Rasheed (2010b)                             |
| Limmen Bight Marine Park and Limmen Marine Park          | 2021             | S, M                   | Collier et al. (in prep)                               |
| Ugar Island and surrounding reefs, Torres Strait         | 2022             | S, M                   | Reason et al. (in prep)                                |
| Love River, GOC  | 1999             | S, M                   | Rasheed (2000)   |
| Wellesley Group, GOC                                     | 1983–1984, 2007  | S, M                   | Coles and Lee Long (1985); Taylor et al. (2007)        |
| Port Musgrave, GOC                                       | 2009–2010        | S, M                   | Chartrand and Rasheed (2010)                           |
| Boyd Bay, GOC  | 2007–2008        | S, M                   | Rasheed and Unsworth (2008)                            |
| Skardon River, GOC                                       | 2002, 2003, 2010 | S, M                   | Roelofs et al. 2002, 2004; Thomas and Chartrand (2010) |
| Kirke River, GOC   | 1999, 2001       | S, M                   | Rasheed (2000); Sheppard et al. (2001)                 |
| Badu Island, Torres Strait                               | 2010             | S, M                   | Taylor and Rasheed (2010a)                             |
| Mua/Moa Island, Torres Strait                            | 2011             | S, M                   | Taylor (2011)  |

(Continues)

**Table 1.** Continued

| Survey purpose/data location                                  | Years     | Site (S)<br>Meadow (M) | Reference                                     |
|---|-----------|------------------------|---|
| Mabuyag Island, Torres Strait                                 | 2009      | S, M                   | Chartrand et al. (2009)                       |
| Orman Reefs, Torres Strait                                    | 2004      | S, M                   | Rasheed et al. 2006a, 2008                    |
| Prince of Wales and Adolphus Shipping Channels, Torres Strait | 2002–2006 | S, M                   | Rasheed et al. (2006b)                        |
| Poruma to Ugar Islands, Torres Strait                         | 2008      | S, M                   | Taylor et al. (2008)                          |
| Kirkcaldie Reef to Bramble Cay, Torres Strait                 | 2009      | S, M                   | Taylor et al. (2009)                          |
| Moa Island to Mabuig Island, Torres Strait                    | 2010      | S, M                   | Taylor et al. (2010)                          |
| No. 2 Reef to Mabuig Reef, Torres Strait                      | 2011      | S, M                   | Taylor et al. (2011)                          |
| Woiz Reef to Kaliko Reef, Torres Strait                       | 2012      | S, M                   | Taylor and McKenna (2012)                     |
| Seo Reef to Kai-Wareg Reef, Torres Strait                     | 2013      | S, M                   | Carter et al. (2013)                          |
| Queensland ports seagrass monitoring                          |           |                        |   |
| Karumba, GOC  | 1994–2021 | S, M                   | Scott et al. (2022)                           |
| Weipa, GOC  | 2000–2021 | S, M                   | McKenna et al. (2021)                         |
| Thursday Island, Torres Strait                                | 2002–2021 | S, M                   | Scott and Rasheed (2021)                      |
| Other surveys (incidental seagrass data)                      |           |                        |   |
| Torres Strait sea cucumber                                    | 2000–2010 | S                      | Murphy et al. (2010);<br>Skewes et al. (2010) |
| Torres Strait rock lobster                                    | 2000–2014 | S                      | Plaganyi-Lloyd et al. (2016)                  |
| Gulf of Carpentaria mangrove                                  | 2017      | S                      | Duke et al. (2020)                            |

GOC, Gulf of Carpentaria.

In this data article, we compiled several hundred seagrass data sets into a standardized form with site- and meadow-specific spatial and temporal information. This process was a collaboration among diverse data custodians to assemble a publicly available database of all the seagrass information collected, from the early 1980s to the present that we could validate and be assured is reliably accurate. Data, metadata, and an interactive website are available via eAtlas at <https://doi.org/10.26274/2CR2-JK51> (Carter et al. 2022a). This provides a valuable resource for management agencies, rangers, Traditional Owners and custodians, ports, industry, and researchers with a long-term spatial resource describing seagrass populations over four decades against which to evaluate environmental stress and to assess change.

### Data description

The spatial database include compiled and standardized data from field surveys conducted from 1983 to 2022. It includes (1) a site layer with 48,612 geolocated data points with features such as seagrass species presence/absence, depth, dominant sediment type, collection date, and data custodian; and (2) a meadow layer that includes 641 individual seagrass meadows with features including meadow persistence (sensu Kilminster et al. 2015), meadow depth (intertidal/subtidal), meadow density based on mean biomass and/or mean percent

cover, meadow area, meadow area range (based on the composite of seagrass meadows across different survey dates at the same location), dominant seagrass species, seagrass species present, survey dates, and survey method. We include records collected under commercial contracts being made available here for the first time, and previously unpublished data. We have summarized data over many years and in locations where multiple surveys or monitoring were conducted. Each data set has an associated custodian listed in the spatial layers and original reports listed in Table 1 who should be contacted for additional details.

Data were originally collected for five main purposes (Table 1): (1) region-scale mapping; (2) Torres Strait seagrass monitoring including small-scale transect (3 × set transects within a 50 × 50 m area) and block-based monitoring (random camera drops within 3 × ~350 ha survey blocks) by rangers; (3) targeted mapping projects such as within marine parks and other protected areas; (4) seagrass monitoring for Queensland ports (Karumba, Weipa, Thursday Island) that were generally conducted annually; and (5) incidental seagrass data collected during other survey activities.

Following the approach taken by Carter et al. (2021a), mapping data for 1980s records were transcribed from original logged and mapped data based on coastal topography, dead reckoning fixes and RADAR estimations. More recent data (1990s onwards) is GPS located. All spatial data were

converted to shapefiles with the same coordinate system (GDA 1994 Geoscience Australia Lambert), then compiled into a single point shapefile and a single polygon shapefile (seagrass meadows) using ArcMap (ArcGIS version 10.8 Redlands, CA: Environmental Systems Research Institute, ESRI). Some early spatial data were offset by several hundred meters and where this occurred data were repositioned to match the current coastline projection. The satellite base map used throughout this report is a courtesy from ESRI 2022.

## Methods

### Survey methods

The data were collected using a variety of survey methods to describe and monitor seagrass sites and meadows (see Carter et al. 2021a for description of methods). Survey methods and technology have evolved over the decades included in this data synthesis, and we refer data users to the original reports listed in Table 1 for details on specific data sets. For intertidal sites/meadows, these include walking, observations from helicopters in low hover and observations from hovercraft when intertidal banks were exposed. For subtidal sites/meadows, methods included free diving, SCUBA diving, video transects from towed cameras attached to a sled with/without a sled net, video drops with filmed fixed-size quadrats, trawl and net samples and van Veen grab samples. These methods were selected and tailored by the data custodians to the location, habitat surveyed, and technology available. Important site and method descriptions and contextual information is contained in the original reports and publications for each data set provided in Table 1. For monitoring data, only the most recent report is referenced.

### Seagrass site layer

This includes information on data collected at assessment sites, and include:

- Temporal survey details—survey month and year.
- Spatial position—latitude/longitude.
- Survey name.
- Depth for each subtidal site is meters below mean sea level (MSL). Depth for each site was extracted from the Australian Bathymetry and Topography Grid, June 2009 (Whiteway 2009). This approach was taken due to inconsistencies in depth recordings among data sets, for example, converted to depth below MSL, direct readings from depth sounder with no conversion, or no depth recorded. Depth for intertidal sites was recorded as 0 m MSL, with an intertidal site defined as one surveyed by helicopter, walking, or hovercraft when banks were exposed during low tide.
- Seagrass information including presence/absence of seagrass (Fig. 1), number of species recorded at a site, and whether individual species were present/absent at a site (Fig. 2; Data S1). Thirteen species are present in the data: *Cymodocea serrulata*, *Cymodocea rotundata*, *Enhalus acoroides*, *Halophila capricorni*, *Halophila decipiens*, *Halophila ovalis*,

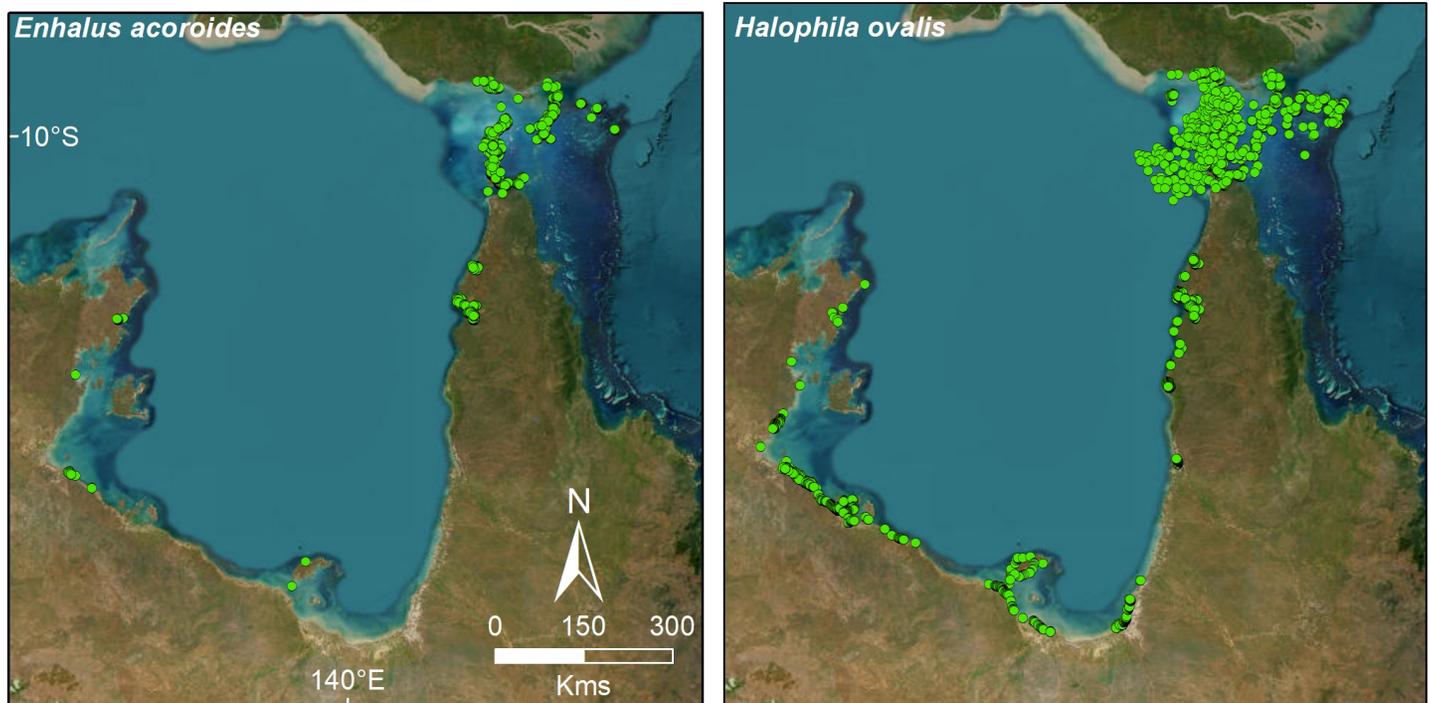
*Halophila spinulosa*, *Halophila tricostata*, *Halodule uninervis*, *Syringodium isoetifolium*, *Thalassodendron ciliatum*, *Thalassia hemprichii*, and *Zostera muelleri* subsp. *capricorni* (abbreviated to *Z. capricorni* throughout). Seagrass taxonomy has changed through time and species names have been updated to meet recent taxonomic changes and to ensure consistency in species names in the data. To address these issues, we amalgamated some species into complexes: *Halophila ovata*, *Halophila minor*, and *Halophila ovalis* are included as *Halophila ovalis*. *Halodule pinifolia* is grouped with *Halodule uninervis*.

- Dominant sediment type—Sediment type in the original data sets were based on grain size analysis or deck descriptions. For consistency, in this compilation we include only the most dominant sediment type (mud, sand, shell, rock, and rubble), removed descriptors such as “very fine” etc., and replaced redundant terms, for example, “mud” and “silt” are termed “mud.”
- Survey methods—In this compilation, we have updated and standardized the terms used to describe survey methods from the original reports.
- Data custodians.

### Seagrass meadow layer

The seagrass meadow layer is a composite of all the spatial polygon data we could access where meadow boundaries were mapped as part of the survey (Data S1). All spatial layers were compiled into a single spatial layer using the Arc Toolbox “merge” function in ArcMap. Where the same meadow was surveyed multiple times as part of a monitoring program (e.g., Data S1), the overlapping polygons were compiled into a single polygon using the ArcMap “merge” function. Seagrass meadows are frequently determined by seagrass presence/absence and/or geographic features (e.g., reef edges, islands, intertidal extent, and infrastructure), but may also be limited by management boundaries (e.g., Torres Strait Dugong Sanctuary) and survey limits (e.g., Torres Strait—Northern Dugong Sanctuary and Orman Reefs (Table 1)). In the latter, meadows often have straight edges. Because of this, seagrass meadows should be interpreted in conjunction with the seagrass site data. Meadow data include:

- Temporal survey details—survey month and year, or a list of survey dates for meadows repeatedly sampled.
- Survey methods.
- Meadow persistence—classified into three categories (unknown, enduring, transitory). *Unknown*—unknown persistence as the meadow was surveyed less than five times. *Enduring*—seagrass is present in the meadow in  $\geq 90\%$  of the surveys. This threshold was selected because it allows for an average of one significant environmental impact to seagrass meadows to occur every 10 years (e.g., tropical cyclone or significant flood), thereby allowing for decadal-scale cycles of seagrass loss and recovery typical in tropical seagrass



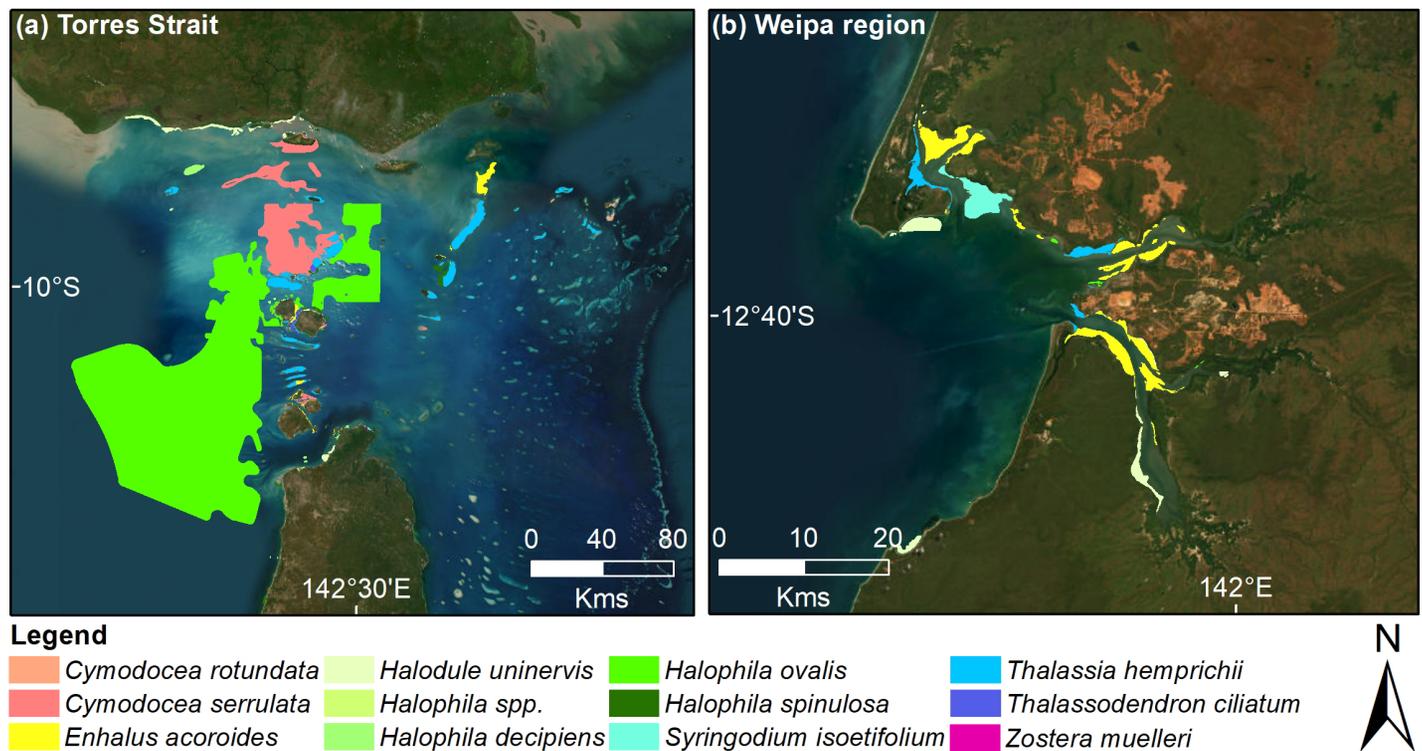
**Fig. 2.** Distribution of *Enhalus acoroides* and *Halophila ovalis* (green dots) throughout Torres Strait and the Gulf of Carpentaria in the site data, 1983–2022. Satellite image courtesy: ESRI. Maps of all 13 species distributions in Data S2 and S3.

systems that occur even in enduring meadows (Carter et al. 2022b). *Transitory*—seagrass is present in the meadow in <90% of the surveys.

- Meadow depth—classified into three categories. *Intertidal*—meadow was mapped on an exposed bank during low tide, for example, Karumba monitoring meadow. *Subtidal*—meadow remains completely submerged during spring low tides, for example, Dugong Sanctuary meadow. *Intertidal–Subtidal*—meadow includes sections that expose during low tide and sections that remain completely submerged, for example, meadows adjacent to the Thursday Island shipping channel.
- Dominant species of the meadow based on the most recent survey (Fig. 3).
- Presence or absence of individual seagrass species in a meadow.
- Meadow density categories—seagrass meadows were classified as light, moderate, dense, or variable based on the consistency of mean above-ground biomass of the dominant species among all surveys, or percent cover of all species combined (Data S1). For example, a *Halophila ovalis* dominated meadow would be classed as “light” if the mean meadow biomass was always <1 g dry weight  $m^{-2}$  ( $g DW m^{-2}$ ) among years, “variable” if mean meadow biomass ranged from 1 to 5  $g DW m^{-2}$ , and “dense” if mean meadow biomass was always >5  $g DW m^{-2}$  among years. For meadows with density assessments based on both percent cover (generally from older surveys) and biomass, we assessed density categories

based on the biomass data as this made the assessment comparable to a greater number of meadows, and comparable to the most recent data. Meadows with only 1 year of data were assigned a density category based on that year but no assessment of variability could be made.

- Mean meadow biomass range measured in  $g DW m^{-2}$  ( $\pm$  standard error if available), or the mean meadow biomass if surveyed once.
- Mean meadow percent cover range, or the mean meadow percent cover if surveyed once.
- Meadow area (hectares; ha) of each meadow was calculated in the GDA 1994 Geoscience Australia Lambert projection using the “calculate geometry” function in ArcMap. For meadows that were mapped multiple times, meadow area represents the total extent for all surveys. Being a synthesis our polygons may represent multiple surveys and this is likely to overestimate the meadow area that would be found in any individual survey. Meadow boundaries can be determined by many different methods. Original reports listed in Table 1 include details of these methods specific to individual surveys.
- Meadow area range for meadows surveyed more than once. Where possible, we retained area range data reported in the original shapefiles (and calculated using original projections). Where area data did not exist in original shapefiles (e.g., 1986 Gulf of Carpentaria surveys; Coles et al. 2004), we calculated area using the ArcMap “calculate geometry”



**Fig. 3.** Dominant species in seagrass meadows at a selection of locations in Torres Strait and Gulf of Carpentaria. Seagrass meadow edges are determined by seagrass presence/absence and geographical features, but may be limited by management boundaries or survey limits. Seagrass meadow maps should be interpreted in conjunction with the seagrass site data. Satellite image courtesy: ESRI.

function in the GDA 1994 Geoscience Australia Lambert projection.

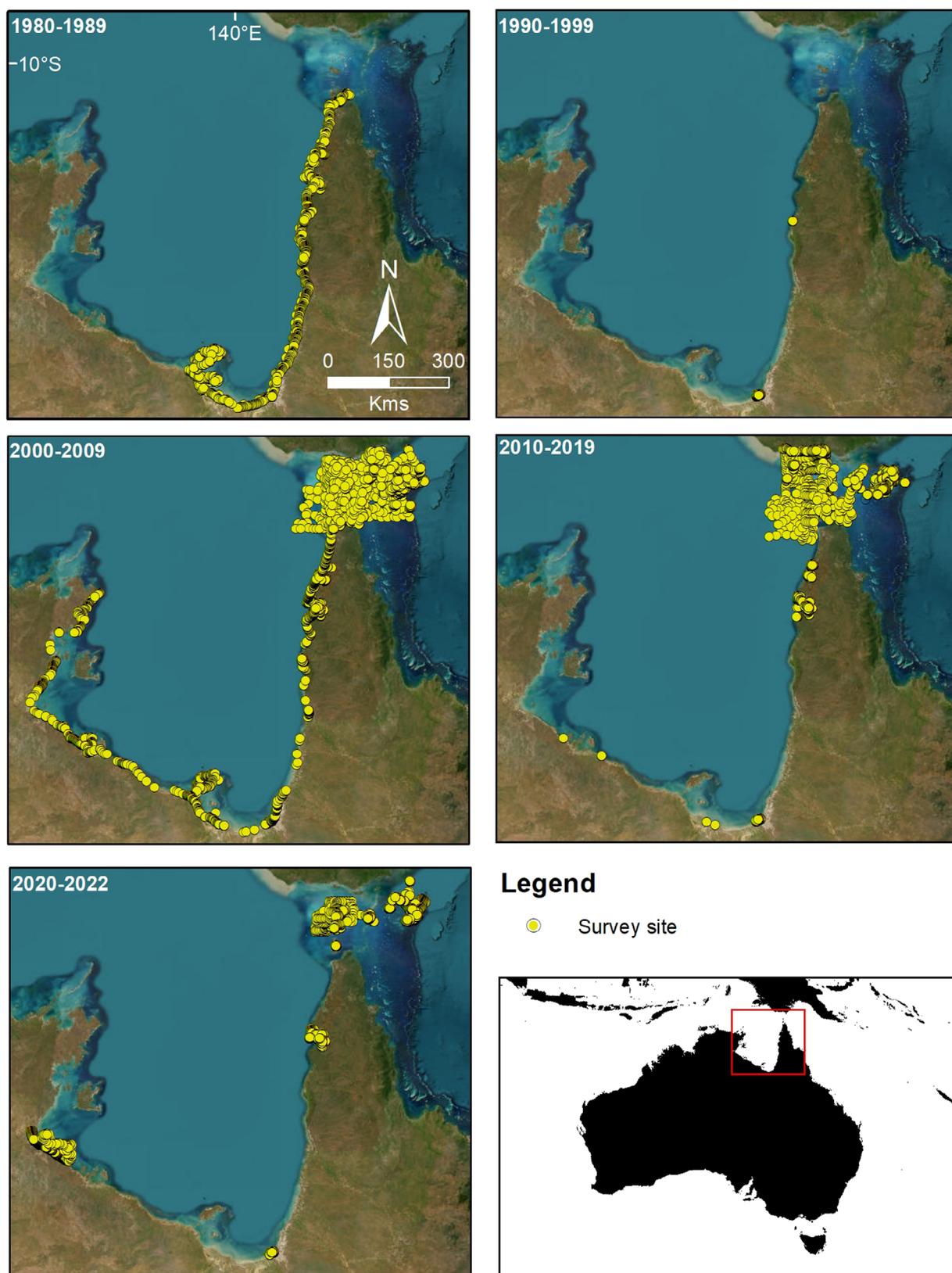
- Data custodians.

### Technical validation

The data included extend back to the early 1980s. Large parts of the coast have not been mapped for seagrass presence since that time (Fig. 4). Technology and methods for mapping and position fixing have improved dramatically in 40 years. Some early data included here had been checked and re-entered and previously included in other spatial platforms (Carter et al. 2014; McKenzie et al. 2014; Coles et al. 2022). For early data (1980s and 1990s), each data point were again reviewed and compared with original trip logs and recollections of trip participants, where possible. We have only included point and polygon (meadow) data in this report where we are confident, we have the most reliable interpretation of that early data. Since the original surveys in the 1980s, there have been changes to the shoreline, the most obvious being movement of mangrove forests and shoreline alterations for port development and access. We have not edited seagrass point or meadow layers to prevent older data from overlapping these features.

Seagrass data came from a variety of surveys conducted for different purposes. Early seagrass data mostly comes from broad-scale vessel-based surveys. This has been built on in the past two decades by extensive boat and helicopter surveys in the Torres Strait, eastern Gulf of Carpentaria, and in Limmen Bight. Three ports in our area of our study—Thursday Island, Weipa, Karumba—have been surveyed annually for more than 20 years. Seagrass data from the port at Alyangula (Groote Eylandt) could not be accessed for this project. Data from Torres Strait Rangers' intertidal monitoring at Badu, Mabuyag, Mua, Iama, Poruma, and Mer Islands is comprehensive over time, with surveys occurring up to four times in a year, but the data included here are not spatially resolved beyond a single latitude/longitude to identify the  $50 \times 50 \text{ m}^2$  area where three replicate transects are surveyed. This is also the case for the Torres Strait Ranger's subtidal monitoring; where only the starting latitude/longitude is included for the 10 quadrats surveyed along a transect.

Data sets with large temporal and spatial coverage all have some survey-specific limitations and nuances beyond what can easily be described in this report. For example, seagrasses may form transitory meadows (Kilminster et al. 2015), where seagrass presence and species composition fluctuate over time. Most seagrass data included here were collected during the seagrass growing season. Annual species like *H. decipiens* and



**Fig. 4.** Distribution of survey sites (yellow dots) throughout Torres Strait and the Gulf of Carpentaria in 10-years increments, 1983–2022. Satellite image courtesy: ESRI.

*H. tricostata* may not be present for considerable parts of the year during the senescent season (York et al. 2015; Chartrand et al. 2017). This is important to understand if these data are used to compare annual changes in seagrass distribution. We recommend checking the survey month in the data sets and contacting the data custodians (listed in the shapefile attribute tables, and in Table 1) when using this data to ensure those limitations are understood.

Significant differences in seagrass distribution and species presence can occur between high rainfall La Niña years and drier El Niño periods in northern Australia (Rasheed and Unsworth 2011; Lambert et al. 2021; Carter et al. 2022b). In the Gulf of Carpentaria, monitoring in Weipa has highlighted that decadal cycles of daytime tidal exposure can have major impacts on seagrass condition (Unsworth et al. 2012), and nearly 30 years of monitoring in Karumba has shown seagrass condition is strongly linked to rainfall and flooding of local rivers (Rasheed and Unsworth 2011). It is important to understand the implications these cycles have on seagrass condition, including lag times and recovery responses for different species. These cycles, while the result of natural phenomena, have implications for the animals that rely on seagrass meadows for shelter and food, including turtles (Flint et al. 2015, 2017) and dugong (Flint and Limpus 2013; Wooldridge 2017).

#### Data exclusions

Our synthesis excludes several historical data sets to ensure that the information we present is as accurate as possible and all data custodians agreed to publication. Data were excluded for the following reasons:

- The original survey data from published reports was lost over the years. This includes the extensive spatial data collected between Crab Island (western Cape York) and Cape Arnhem in 1982–1984 and is only available as a published illustration of meadows (Poiner et al. 1987, 1989).
- We were unable to establish that the information was verified at the time of collection. For example, data were excluded from recent field observations taken during mangrove surveys in the Gulf of Carpentaria (Duke et al. 2020) where aerial photographs with spatial information were taken of likely seagrass meadows but no sample was taken to verify this, or spatial information was not available for photographs.
- Permission for public distribution from data custodians was not provided.
- Published seagrass meadow information and online data sets had insufficient metadata for us to include. Examples include data compiled by the United Nations Environment World Conservation Monitoring Centre (<https://data.unep-wcmc.org/datasets/7>) and CSIRO's Coastal and Marine Resources Information System (<https://data.csiro.au/collections/collection/CIcsiro:12640v1>).

#### Data use and recommendations for reuse

This project makes publicly available a comprehensive tropical seagrass data set for north-eastern Australia. We include location information not just for sites that were surveyed, and seagrass recorded, but also location information where surveys did not find seagrass. Figure 4 highlights extensive areas that have never been surveyed or where survey data are now decades old. The management and conservation of marine ecosystems requires accurate spatial data at scales that match human activities and impacts (Hughes et al. 2005; Halpern et al. 2008; Visconti et al. 2013; Lagabriele et al. 2018). A key strategy to assist this at a global scale is to ensure data are validated and reliable despite being collected over years or decades (Rajabifard et al. 2005). By building on our previous work (and using the same approach) compiling 35 years of seagrass spatial site data and 30 years of seagrass meadow data for the Great Barrier Reef World Heritage Area and adjacent estuaries (Carter et al. 2021a), we provide a synthesis that can be used to inform marine spatial planning and ecosystem-based management, identify priority areas for future surveys, and support research and education for a large part of northern Australia.

#### Comparison with existing data sets

The immediate scientific value of projects like this have been demonstrated on Queensland's east coast, where the Great Barrier Reef World Heritage Area (GBRWHA) data synthesis (Carter et al. 2021a) has been used to answer a number of key ecological questions, including the probability of seagrass distribution and communities (Carter et al. 2021d), defining the desired state of seagrass communities in the Townsville region (Collier et al. 2020) and GBRWHA (Carter et al. 2022b), examining management targets for rivers influencing seagrass habitat (Collier et al. 2021; Lambert et al. 2021), and in designing a Great Barrier Reef-scale monitoring program (Udy et al. 2019). Seagrass data has also been used on the Great Barrier Reef to model risk exposure (Grech et al. 2011; Grech et al. 2012; Bainbridge et al. 2018); propagule distribution (Grech et al. 2016; Schlaefer et al. 2022); developing a National Ocean Account in Australia (<https://www.abs.gov.au/articles/towards-national-ocean-account>); and connectivity among meadows (Tol et al. 2017; Grech et al. 2018). We now make available data for the Gulf of Carpentaria and Torres Strait to answer similarly important questions for this region. These data are already being used to initiate hydrodynamic modeling approaches to better understand seagrass connectivity and resilience in the Torres Strait (Schlaefer et al. 2022). By ensuring consistency in the structure of both point and polygon (meadow) data sets for the Great Barrier Reef and this project, and making these publicly available on eAtlas, we provide a mechanism for additional data to be added, archived, and easily compared.

#### Data availability statement

URL of the data set with permanent identifier: Data and metadata are available at eAtlas: <https://doi.org/10.26274/2CR2-JK51>. Data use is licensed by James Cook University for

use under a Creative Commons Attribution 4.0 International license. For license conditions see: <https://creativecommons.org/licenses/by/4.0/>. Code URL with permanent identifier: N/A. Measurement(s): Location (latitude/longitude), presence/absence, seagrass species identification, dominant sediment type, depth below mean sea level, date of collection. Technology Type(s): Collected using a range of methods and available in an interactive spatial database or as a downloadable GIS shapefile. Temporal range: 1983 to 2022. Frequency or sampling interval: Multiple time scales mostly seasonal or annual. Spatial scale: Regional database including Torres Strait and the Gulf of Carpentaria, Queensland and Northern Territory, Australia. Data was limited to that collected in the Gulf of Carpentaria between Cape Arnhem (Northern Territory) and Cape York (Queensland) (Fig. 1). Torres Strait data were restricted to north of Queensland's Great Barrier Reef World Heritage Area boundary and includes data collected along parts of the Papua New Guinea coastline.

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