SUBTIDAL SEAGRASS OF WESTERN TORRES STRAIT

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SUMMARY

- This report describes a baseline survey of subtidal seagrass in the Western Cluster of Torres Strait that occurred in December 2020, as a collaboration between the Torres Strait Regional Authority (TSRA) Land and Sea Management Unit (LSMU), Rangers and Traditional Owners from Badu, Mabuyag and Moa Islands, and James Cook University's Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER).
- Western Torres Strait has long been identified as an ecologically important region, with extensive seagrass habitat and high densities of dugong and green turtles. Despite this, large areas of the region had not been surveyed previously, and in other areas spatial data was more than a decade old.
- The survey was also a response to significant declines in seagrass condition in the Mabuyag-Orman Reefs area, particularly for subtidal seagrass, detected by long-term monitoring programs.
- Over 300,000 ha of subtidal seagrass was mapped across 27 meadows. This included large, continuous meadows north of Mabuyag Island to Buru Island, and east of the Orman Reefs to Gebar Island, and a large but patchy meadow in the north-east section of the Dugong Sanctuary. Nine seagrass species were recorded.
- Seagrass meadows in 2020 were generally patchier, smaller, and the previously dominant subtidal species *H. spinulosa* was gone from most sites in regions where previous survey data was available for comparison.
- This assessment of Western Cluster subtidal seagrass provides essential habitat information to the TSRA, Traditional Owners, and the Australian and Queensland governments. This information can be used for community-based Dugong and Turtle Management Plans
- Spatial data produced for this report is available on eAtlas (www.eatlas.org.au).
- We recommend: (1) ongoing Ranger-led subtidal seagrass monitoring on the western side of Orman Reefs and the north-eastern part of the Dugong Sanctuary, (2) expansion of subtidal monitoring to include meadows east of the Orman Reefs and/or close to Badu Island, and (3) undertake baseline subtidal surveys in areas adjacent to the December 2020 survey, particularly in the southern Dugong Sanctuary.

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1 INTRODUCTION

Seagrass meadows provide numerous ecosystem services, including food for megaherbivores (e.g. dugong and green turtle), macroherbivores (e.g. fish and urchins) and mesoherbivores (e.g. amphipods and gastropods) (Scott et al. 2018). Torres Strait seagrass meadows are abundant, widespread, and contain some of the greatest species diversity in the Indo-Pacific (Carter et al. 2014c; Coles et al. 2003; Poiner and Peterkin 1996). These seagrass habitats are of national significance due their large size, their role in sustaining fisheries, and as a food source for the iconic and culturally important species dugong and turtle, which play a vital role in the ecology and cultural economy of the region (TSRA 2016).

The dugong population in Torres Strait is the largest population in the world (Marsh et al. 2011). Dugong and green turtle have high conservation value as listed species under the *Environment Protection and Biodiversity Conservation Act* (1999), and immense cultural and spiritual significance as cultural keystone species for Torres Strait Islanders (Butler et al. 2012). Despite the significance of Torres Strait seagrass, large areas of Torres Strait's subtidal waters remain inadequately surveyed.

Western Torres Strait has long been identified as an ecologically important region, with large areas of seagrass (Carter et al. 2014b; Taylor and Rasheed 2010b) and high densities of dugong and turtles (Cleguer et al. 2016; Hagihara et al. 2016). Despite this, critical information on subtidal seagrass habitat is limited in some parts of western Torres Strait (Carter et al. 2014b). In other cases, spatial data is now relatively old as large-scale surveys of subtidal seagrass in the Dugong Sanctuary, Orman Reefs and Western Cluster Islands conducted more than a decade ago (Taylor and Rasheed 2010b; a; Taylor et al. 2010; Chartrand et al. 2009; Rasheed et al. 2006).

The Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER), in collaboration with the Torres Strait Regional Authority (TSRA) Land and Sea Management Unit (LSMU), have been collecting baseline seagrass data and conducting long-term monitoring in Torres Strait for almost two decades (Carter et al. 2014c; Figure 1). Significant declines in seagrass condition in the Mabuyag-Orman Reefs area of the Western Cluster, particularly for seagrass abundance (biomass/percent cover) were reported across three monitoring programs in the 2020 report card - the Ranger-led Torres Strait Seagrass Observers Program (Mabuyag Island), Ranger-led Subtidal Monitoring Program (Orman Reefs), and the meadow-scale intertidal Reef-top Monitoring Program (Orman Reefs). This report card highlighted significant concerns around the condition of subtidal seagrass in the Western Cluster, as biomass declines were most dramatic in this habitat and included the loss of the dominant species *Halophila spinulosa* (Carter et al. 2020). Knowledge gaps for the Western Cluster were also apparent, including the lack of baseline information between Orman Reefs and Buru (Turnagain) Island where dugong and green turtle densities are greatest, and a 2-year monitoring gap in of the Dugong Sanctuary. The objectives of this project were to:

- Conduct a baseline seagrass survey of subtidal waters in Torres Strait's Western Cluster. This includes a re-survey of the Dugong Sanctuary's north-eastern section (last surveyed in 2010) and previously unsurveyed waters between Orman Reefs and Buru Island. The survey area was informed by previous seagrass surveys, long-term monitoring locations, gaps analysis, and where dugong and turtle densities are greatest.
- Map important subtidal benthic habitat, including seagrass and algae.
- Produce a geographic information system (GIS) for the survey area.

- Identify the most important seagrass habitats in the survey area and areas suitable for potential future ongoing monitoring.
- Report on the state of seagrass in the Dugong Sanctuary, and shallow subtidal waters of the western cluster, by comparing new data with historical data.
- Assess seagrass distribution and species in previously unsurveyed regions.

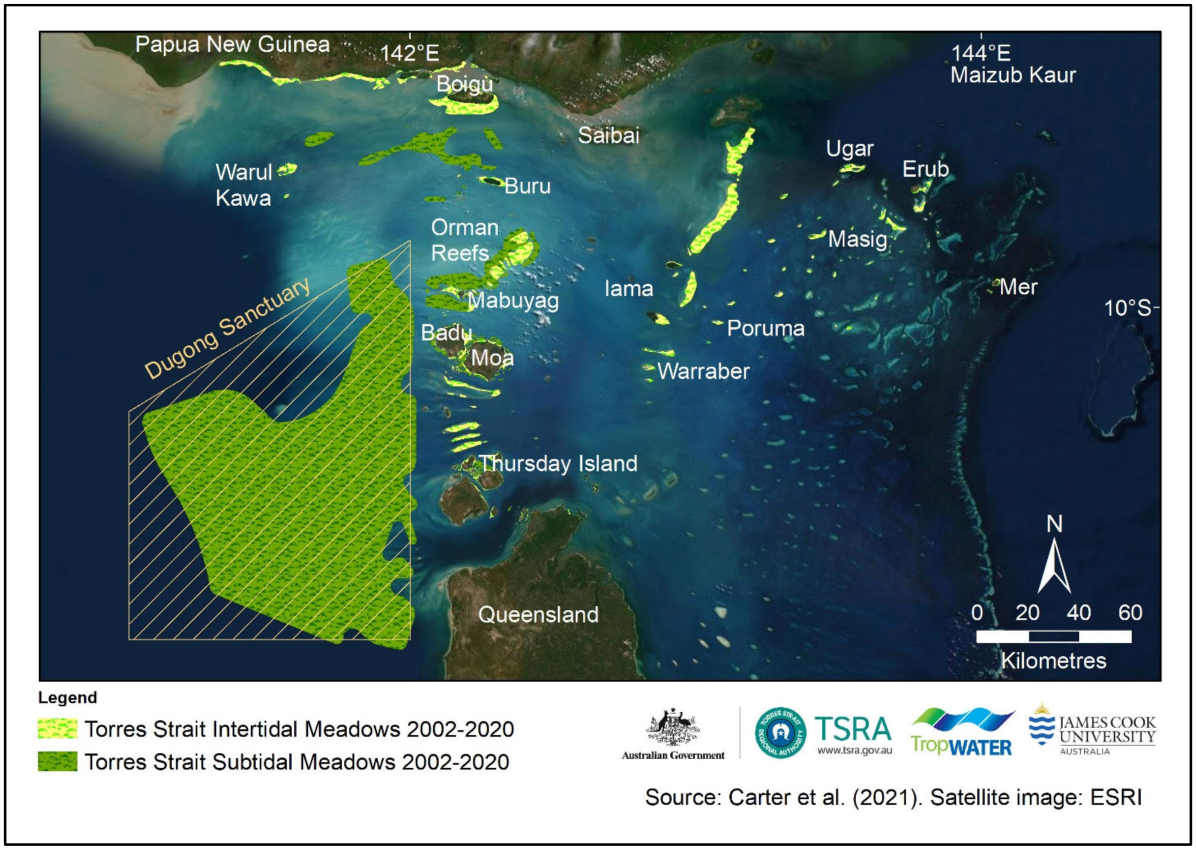

Figure 1. Intertidal and subtidal seagrass meadows mapped across Torres Strait, 2002-2020.

2 METHODS

2.1 Field surveys and site details

Sites were surveyed by the MV *Eclipse* (Figure 2a) and TSRA LSMU ranger vessel *Sager* (Figure 2b) in December 2020.

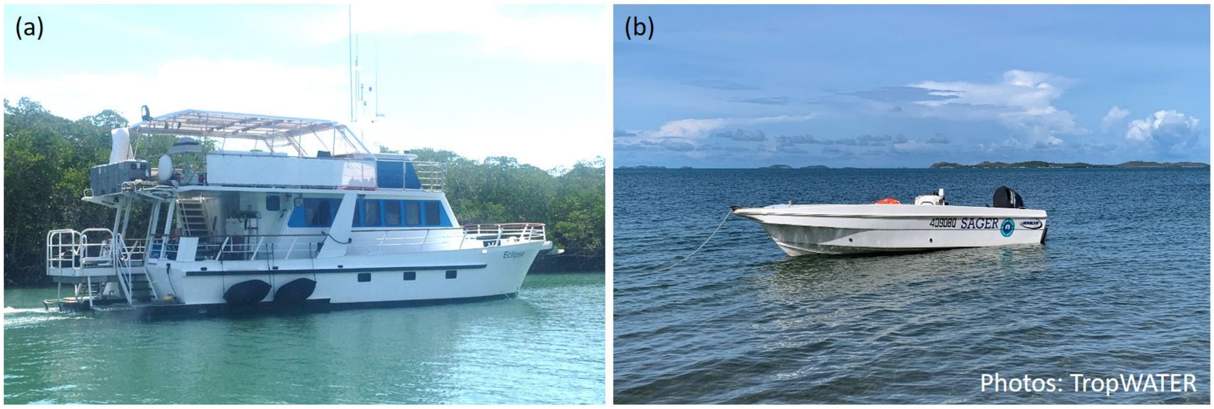

Figure 2. Subtidal seagrass surveys were conducted using (a) MV *Eclipse* and (b) Torres Strait Regional Authority Land and Sea Management Unit ranger vessel *Sager*.

Subtidal benthic habitat was surveyed following TropWATER's methods used in previous Torres Strait surveys, e.g. Thursday Island (Wells et al. 2019) and north-west Torres Strait (Carter and Rasheed 2016). At each site latitude and longitude was recorded by GPS. Depth was recorded and converted to depth below mean sea level (dbMSL) in metres. Sediment type was recorded. Benthic habitat was observed using a freediver with a 0.25m^2 quadrat, or a TV monitor connected to an underwater digital camera system with a frame that incorporated a 0.25 m^2 quadrat (Figure 3a, b). At each site, the frame and camera were lowered to the sea floor and benthic observations, including seagrass ranks, were conducted in real time. Three replicate freedives or camera "drops" were conducted approximately 5 m apart. A van Veen grab (grab area 0.0625 m^2) was used to collect a sample to confirm sediment type and seagrass species identification at each site (Figure 3c, d).

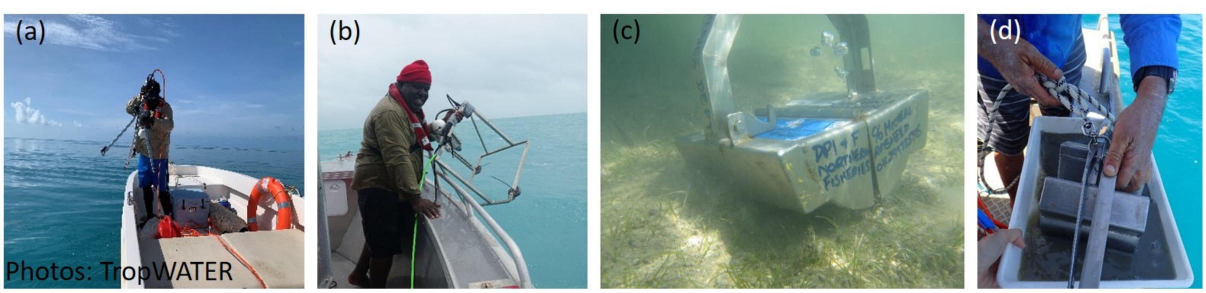

Figure 3. Subtidal mapping of seagrass meadows using (a, b) camera drops and (c, d) van Veen grab.

2.1.1 Seagrass

At each site observers estimated the percent cover of seagrass, then for three quadrats within each site, ranked seagrass biomass and estimated the percent contribution of each species to that biomass. Seagrass above-ground biomass was determined 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. Two separate biomass scales were used for this survey: low biomass and high biomass. The percent contribution of each seagrass species to total above-ground biomass within each quadrat was also recorded. At the completion of sampling, each observer ranked a series of calibration quadrats. A linear regression was then calculated for the relationship between the 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}).

2.1.2 Algae

Percent cover of algae at each site was recorded, and the percent contribution of five functional groups to algal cover. Functional groups were:

- Erect macrophyte – Macrophytic algae with an erect growth form and high level of cellular differentiation, e.g. *Sargassum*, *Caulerpa* and *Galaxaura* species (Figure 4a).
- Filamentous – Thin, thread-like algae with little cellular differentiation (Figure 4b).
- Encrusting – Algae that grows in sheet-like form attached to the substrate or benthos, e.g. coralline algae (Figure 4c).
- Turf mat – Algae that forms a dense mat on the substrate (Figure 4d).
- Erect calcareous – Algae with erect growth form and high level of cellular differentiation containing calcified segments, e.g. *Halimeda* species (Figure 4e).

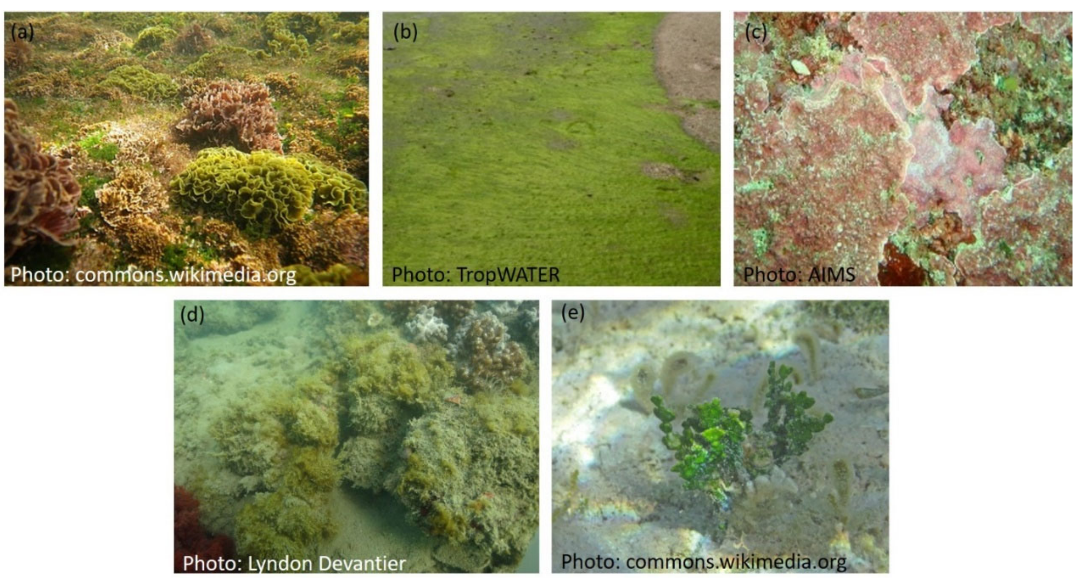

Figure 4. Algae functional groups (a) erect macrophyte, (b) filamentous, (c) encrusting, (d) turf mat and (e) erect calcareous.

2.1.3 Benthic macro-invertebrates

At each site percent cover of benthic macroinvertebrates (BMI) were recorded. Benthic macroinvertebrates were divided into four broad taxonomic groups:

- Hard coral – All scleractinian corals including massive, branching, tabular, digitate and mushroom (Figure 5a).
- Soft coral – All alcyonarian corals, i.e. corals lacking a hard limestone skeleton (Figure 5b).
- Sponge (Figure 5c).
- Other BMI – Any other BMI identified, e.g. hydroid, ascidian, barnacle, oyster, and mollusc (Figure 5d). Other BMI are listed in the “comments” column of the GIS site layer.

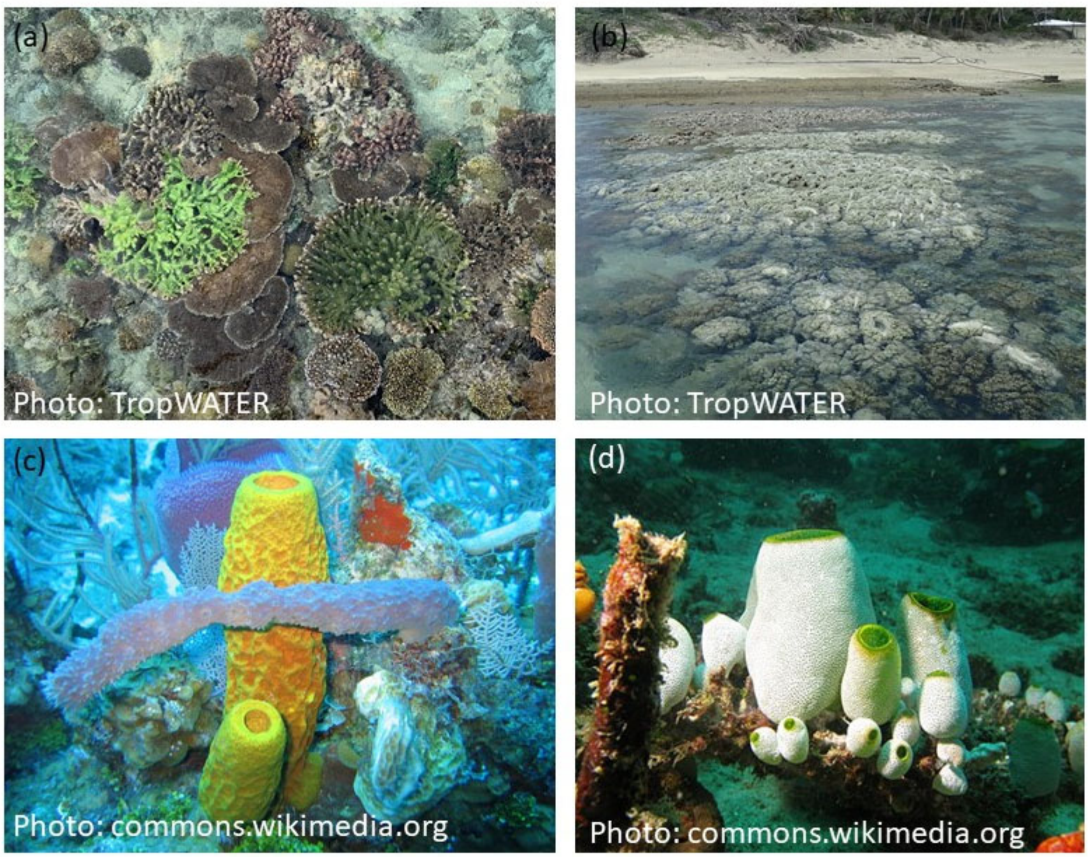

Figure 5. Benthic macroinvertebrates: (a) hard coral, (b) soft coral, (c) sponge and (d) ascidian.

2.2 Geographic Information System (GIS)

All survey data were entered into a Geographic Information System (GIS) developed for Torres Strait using ArcGIS 10.8©. Three seagrass GIS layers were created to describe spatial features of the region: a survey site layer, seagrass meadow layer, and seagrass biomass interpolation layer. All spatial layers are publicly available at eAtlas (eatlas.org.au).

2.2.1 Site layer

This layer contains data collected at each site, including:

- Temporal details – survey date and time.
- Spatial details – latitude/longitude, dbMSL.
- Habitat information – sediment type; seagrass information including presence/absence and above-ground biomass (total and for each species); percent cover of seagrass, algae, BMI and open substrate; percent contribution of algae functional groups and BMI categories.
- Sampling method, vessel name, and any relevant comments.

2.2.2 Seagrass meadow layer

Seagrass presence/absence site data were used to construct the meadow (polygon) layer. Rectified colour satellite imagery of Torres Strait (Source: ESRI, eAtlas), field notes and photographs taken during the survey were used to identify geographical features, such as reef tops, channels and deep-water drop-offs, to assist in determining seagrass meadow boundaries. The meadow layer provides summary information for all sites within each seagrass meadow, including:

1. Habitat information – seagrass species present, meadow community type, meadow density, mean meadow biomass ± standard error (s.e.), meadow area ± reliability estimate (R), and number of sites within the meadow.
2. Sampling methods and any relevant comments.

Meadow community type was determined according to seagrass species composition within each meadow. Species composition was based on the percent each species' biomass contributed to mean meadow biomass. A standard nomenclature system categorized each meadow's community type (Table 1). This also included a measure of meadow density categories (light, moderate, dense) determined by mean biomass of the dominant species within the meadow (Table 2).

Mapping precision estimates (in metres) were based on the mapping method used for that meadow (Table 3). Mapping precision estimates ranged from 50m for subtidal meadows with clear boundaries alongside reefs and islands, and up to 200m for patchy subtidal meadows. Subtidal meadow mapping precision estimates were based on the distance between sites with and without seagrass or distance to hard boundaries. The mapping precision estimate was used to calculate an error buffer around each meadow. The area of this buffer is expressed as a meadow reliability estimate (R) in hectares.

Table 1. Nomenclature for seagrass 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 2. Density categories and mean above-ground biomass ranges for each species used in determining seagrass community density.

	Mean above-ground biomass (gdw m^{-2})				
Density	*H. uninervis* (thin)	*H. ovalis* *H. decipiens*	*H. uninervis* (wide) *C. serrulata* *C. rotundata* *S. isoetifolium* *T. hemprichii*	*H. spinulosa*	*E. acoroides* *T. ciliatum*
Light	< 1	< 1	< 5	< 15	< 40
Moderate	1 - 4	1 - 5	5 - 25	15 - 35	40 - 100
Dense	> 4	> 5	> 25	> 35	> 100

Table 3. Mapping precision and methods for subtidal seagrass meadows.

Mapping precision	Mapping method
50 - 100 m	Sites surveyed by boat. Seagrass meadow boundary determined from distance between sites. Distinct topographic features from satellite imagery aided in mapping (reefs, islands). Medium density of survey sites.
100 - 200 m	Sites surveyed by boat. Seagrass meadow boundary determined from distance between sites. No distinct topographic features from satellite imagery aided in mapping Relatively low density of survey sites.

2.2.3 Seagrass biomass interpolation layer

An inverse distance weighted (IDW) interpolation was applied to seagrass site data to describe spatial variation in seagrass biomass across seagrass meadows. The interpolation was conducted in ArcMap 10.8©.

2.3 Collaboration with TSRA, Rangers and Traditional Owners

The collaboration between TropWATER researchers and TSRA LSMU staff, Rangers from Mabuyag, Badu and Moa Islands, Traditional Owners, and use of the ranger vessel *Sager* were essential to the success of this survey. TropWATER researchers relied heavily on the Traditional Owners and Ranger's local knowledge of the survey area, logistical support prior to the surveys, and all aspects of sampling including data collection, seagrass identification, and operation of field equipment (Figure 6).

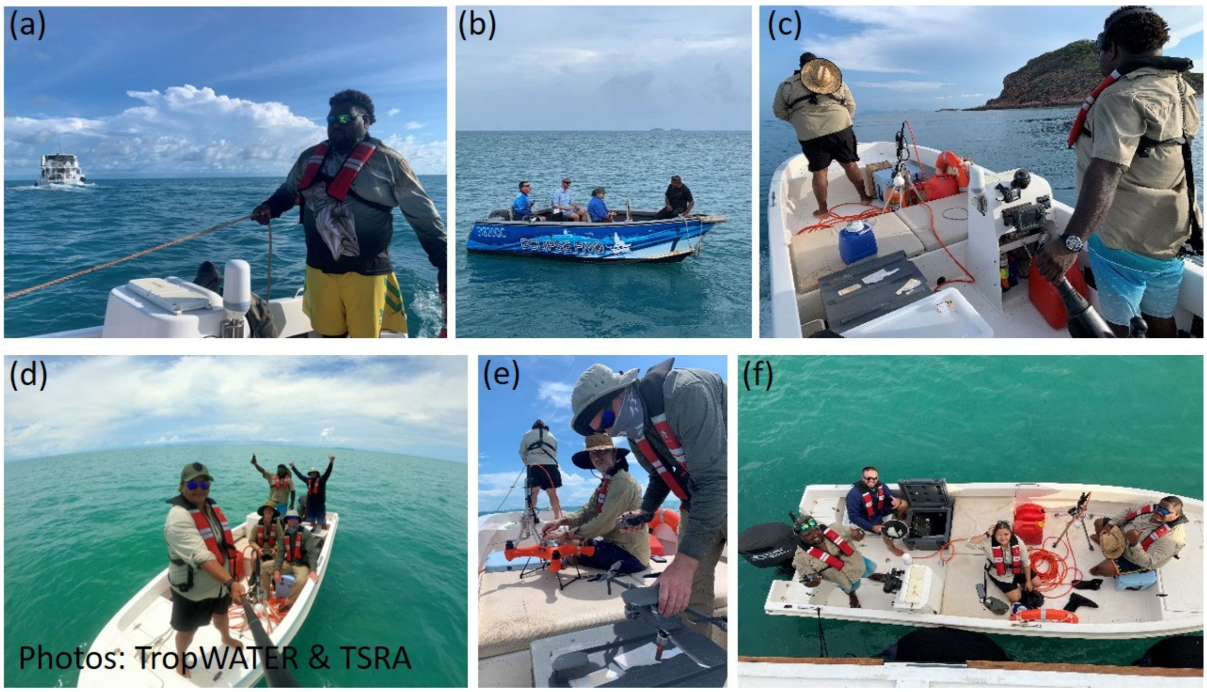

Figure 6. Traditional Owners, TSRA LSMU staff and Rangers from Badu, Mabuyag and Moa Islands collaborated with TropWATER researchers to conduct this survey.

3 RESULTS

3.1 Seagrass

Benthic habitat was surveyed December 3-12, 2020. Seagrass was present at 43% of the 495 subtidal sites surveyed (Figure 7). The maximum depth recorded during the survey was 18.2 m dbMSL, and seagrass was found growing to a depth of 16.9 m dbMSL. Seagrass biomass varied greatly, ranging from 0.001 gDW m^{-2} in the large subtidal meadows in the Dugong Sanctuary, to biomass hotspots reaching up to 23 gDW m^{-2} in the meadow between Badu and Moa Islands and the Orman Reefs area (Figure 8).

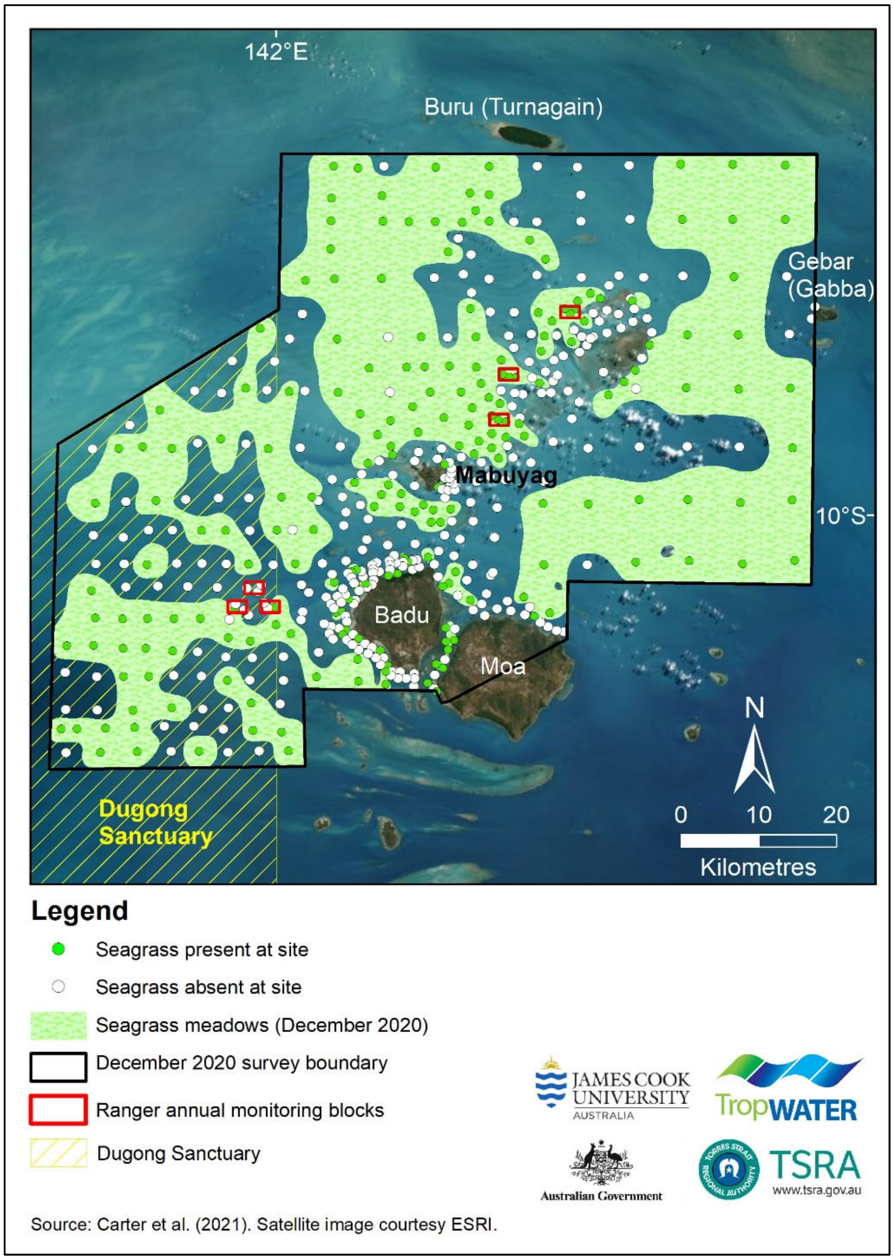

Figure 7. Seagrass subtidal meadows and seagrass presence/absence at sites within the survey area, December 2020.

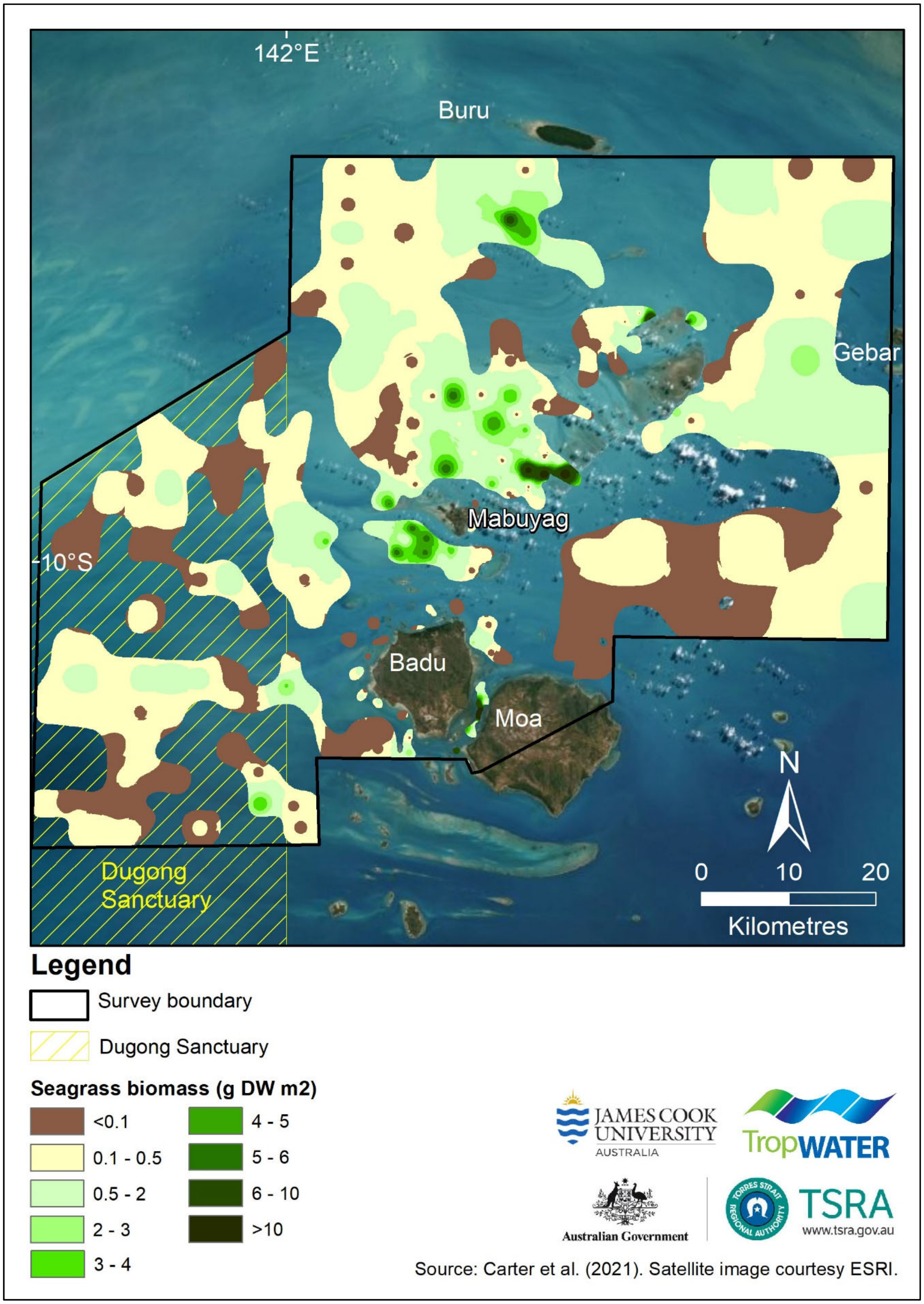

Figure 8. Variation in seagrass biomass across subtidal meadows in western Torres Strait, December 2020.

Nine seagrass species from two families were identified in the subtidal survey area (Figure 9). Seagrass diversity and biomass hotspots were greatest in the large subtidal meadow between Mabuyag and Buru Islands where eight species were present in the meadow and biomass reached 13 gDW m^{-2} (Figure 8, Figure 12). *Halophila* species tended to be the dominant species in the regions of meadows that were greater than 9m dbMSL. *Thalassodendron ciliatum* was only recorded in the meadow between Moa and Badu Islands (Figure 11).

A total of 300,535 ha of seagrass was mapped across 27 subtidal meadows (Table 4). The majority of seagrass area came from two extensive meadows north of Mabuyag Island, and between Moa Island, Gebar Island and the Orman Reefs (Figure 8). The two largest seagrass meadows in the Dugong Sanctuary contributed 77,202 ha to the total area of seagrass mapped.

Table 4. Western Torres Strait subtidal seagrass meadows, December 2020. Meadow numbers correspond to Meadow ID numbers on seagrass maps (Figure 10 - Figure 13).

Meadow	Density	Community type	Depth range (m)	Area (ha ± R)	Biomass (mean ± SE)
0	Light	*C. serrulata*/*H. uninervis* with mixed species	2.4 – 10.5	86949 ± 4166	1.57 ± 0.34
1	Light	*T. hemprichii* with *C. rotundata* with mixed species	2.8 – 4.3	4995 ± 182	2.55 ± 0.65
2	Light	*C. serrulata*/*H. ovalis*	3.6	108 ± 19	0.09 ± 0
3	Light	*H. ovalis* with *H. uninervis* (thin)	5.2	92 ± 18	0.86 ± 0
4	Light	*H. ovalis*	5.4 – 7.4	109 ± 20	0.41 ± 0.37
5	Light	*H. ovalis* with *H. decipiens*	7.4 – 8.3	185 ± 26	0.75 ± 0.29
6	Light	*H. ovalis* with *H. uninervis* (thin)	5.4 – 10.3	1321 ± 85	0.77 ± 0.46
7	Light	*H. ovalis* with *H. decipiens* with mixed species	10.6 – 16.7	113409 ± 5165	0.48 ± 0.12
8	Light	*H. uninervis* (wide) with *H. ovalis* with mixed species	7.7 – 13.3	39285 ± 3905	0.52 ± 0.18
9	Light	*H. uninervis* (wide) with *H. ovalis* with mixed species	11.5 – 13.2	6082 ± 802	0.79 ± 0.76
10	Light	*H. ovalis*	4.9	37 ± 12	0.04 ± 0
11	Moderate	*T. ciliatum* with *T. hemprichii* with mixed species	4.7 – 6.1	519 ± 80	6.12 ± 3.59
12	Light	*H. decipiens*	7.5	58 ± 18	0.24 ± 0.21
13	Moderate	*C. serrulata*	4.9	368 ± 36	8.89 ± 0
14	Light	*H. ovalis* with *H. decipiens* with mixed species	8.5 – 14.8	37917 ± 3301	0.46 ± 0.13
15	Light	*C. rotundata*/*H. uninervis* (thin) with mixed species	2.6 – 8.5	4932 ± 423	1.23 ± 0.83
16	Light	*H. uninervis* (thin)	4.1	18 ± 11	1.53 ± 0
17	Light	*H. decipiens*	16.9	236 ± 58	0.003 ± 0
18	Light	*H. decipiens* with *H. ovalis*	15.4 – 16.4	155 ± 47	0.01 ± 0.003
19	Light	*H. decipiens* with *H. ovalis*	4.4 – 16.7	140 ± 25	0.03 ± 0.01
20	Light	*H. ovalis* with *T. hemprichii*	8.4 – 11.8	92 ± 20	0.34 ± 0.1
21	Light	*H. ovalis*	14.5	230 ± 28	0.09 ± 0
22	Light	*T. hemprichii* with mixed species	2.3 – 7.8	76 ± 18	0.7 ± 0.26

23	Light	*H. spinulosa*	8.7	52 ± 14	0.01 ± 0
24	Moderate	*T. hemprichii* with mixed species	6.6	45 ± 13	8.35 ± 0
25	Light	*H. ovalis*	12.4	1509 ± 291	0.13 ± 0
26	Light	*H. ovalis*	13.3	1616 ± 301	0.29 ± 0

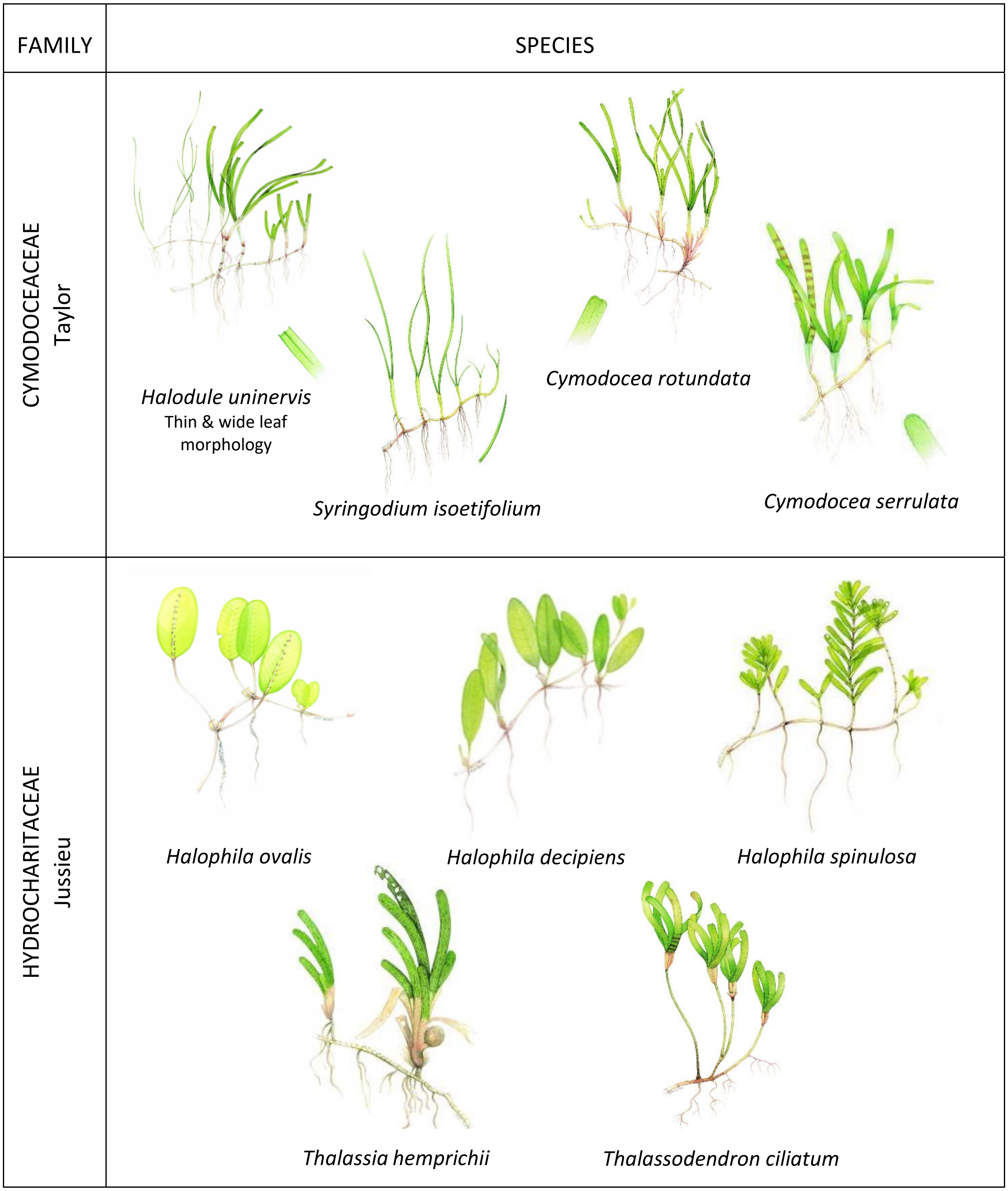

Figure 9. Seagrass species present in western Torres Strait, December 2020.

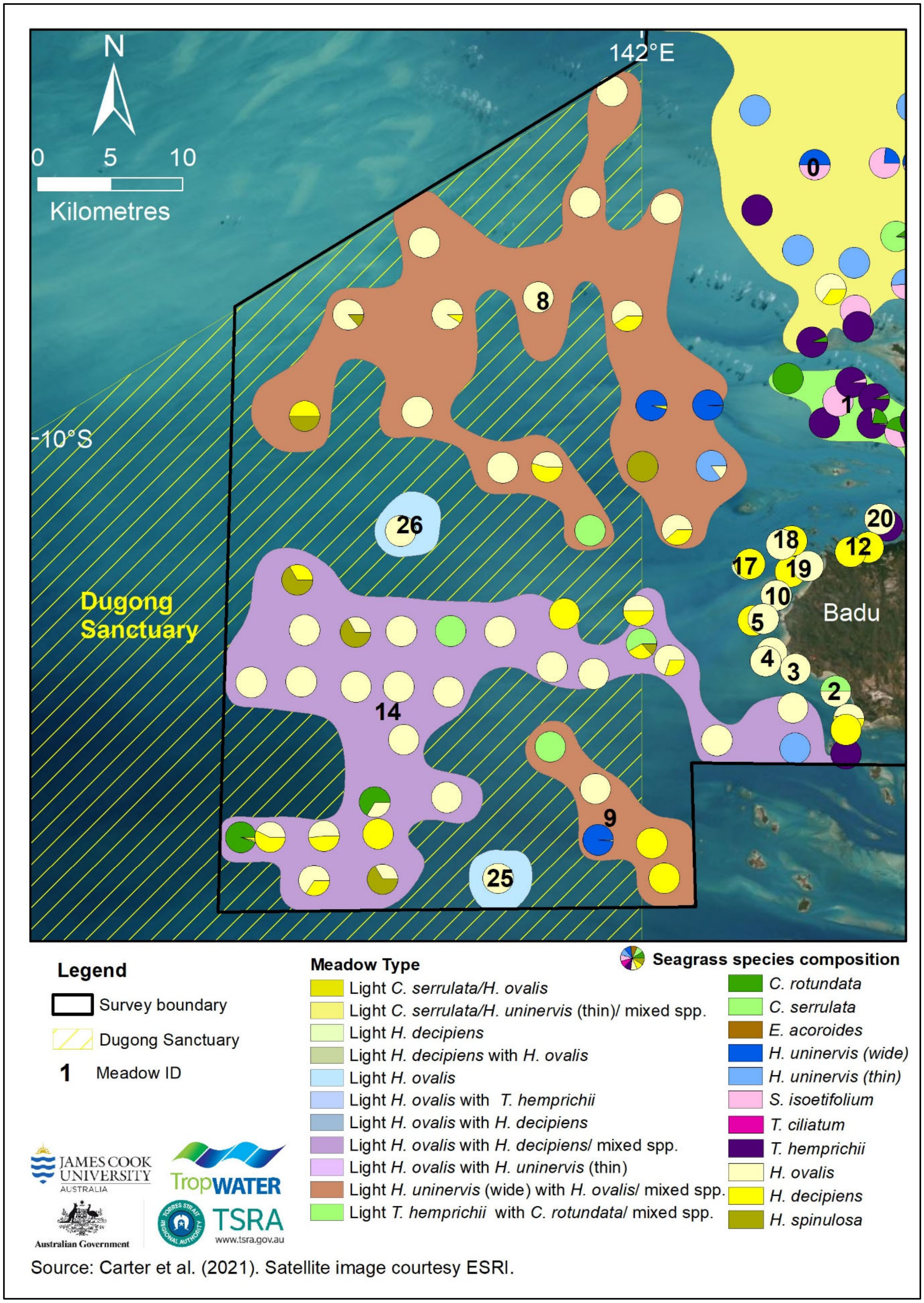

Figure 10. Species composition of survey sites and meadow community type for subtidal meadows in the Dugong Sanctuary and adjacent areas, western Torres Strait, December 2020.

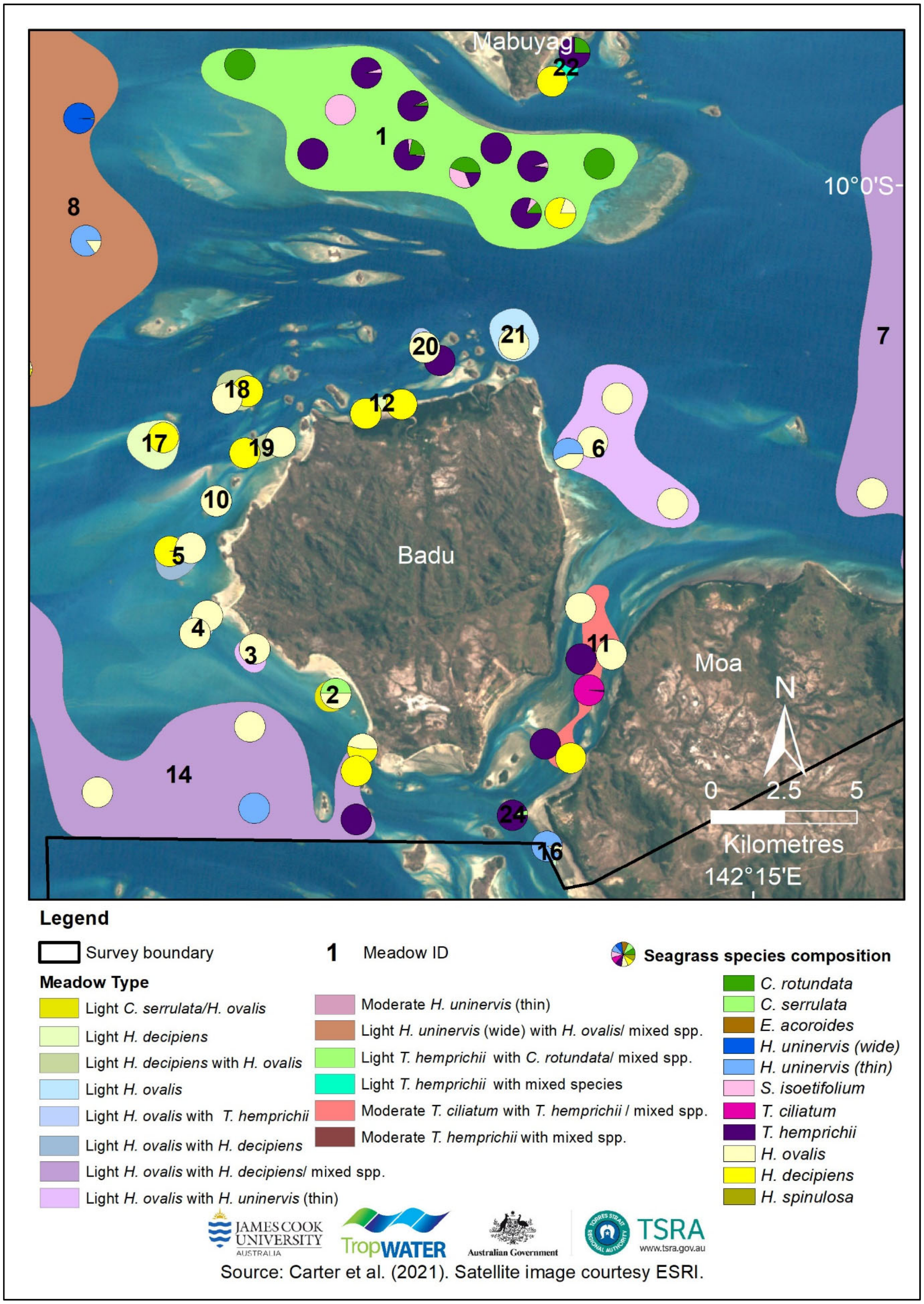

Figure 11. Species composition of survey sites and meadow community type for subtidal meadows between Mabuyag and Moa Islands, western Torres Strait, December 2020.

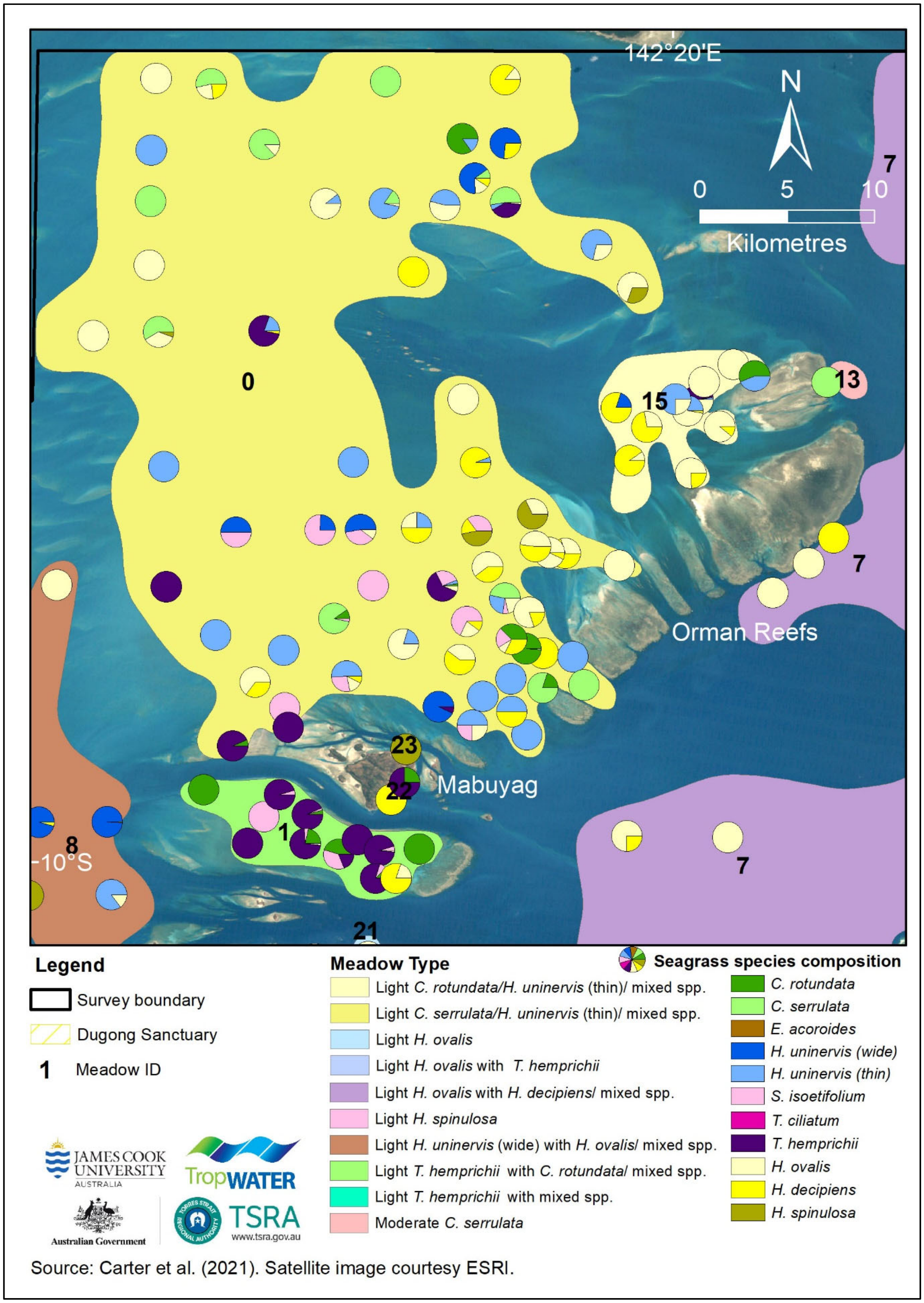

Figure 12. Species composition of survey sites and meadow community type for subtidal meadows north of Mabuyag Island and Orman Reefs, western Torres Strait, December 2020.

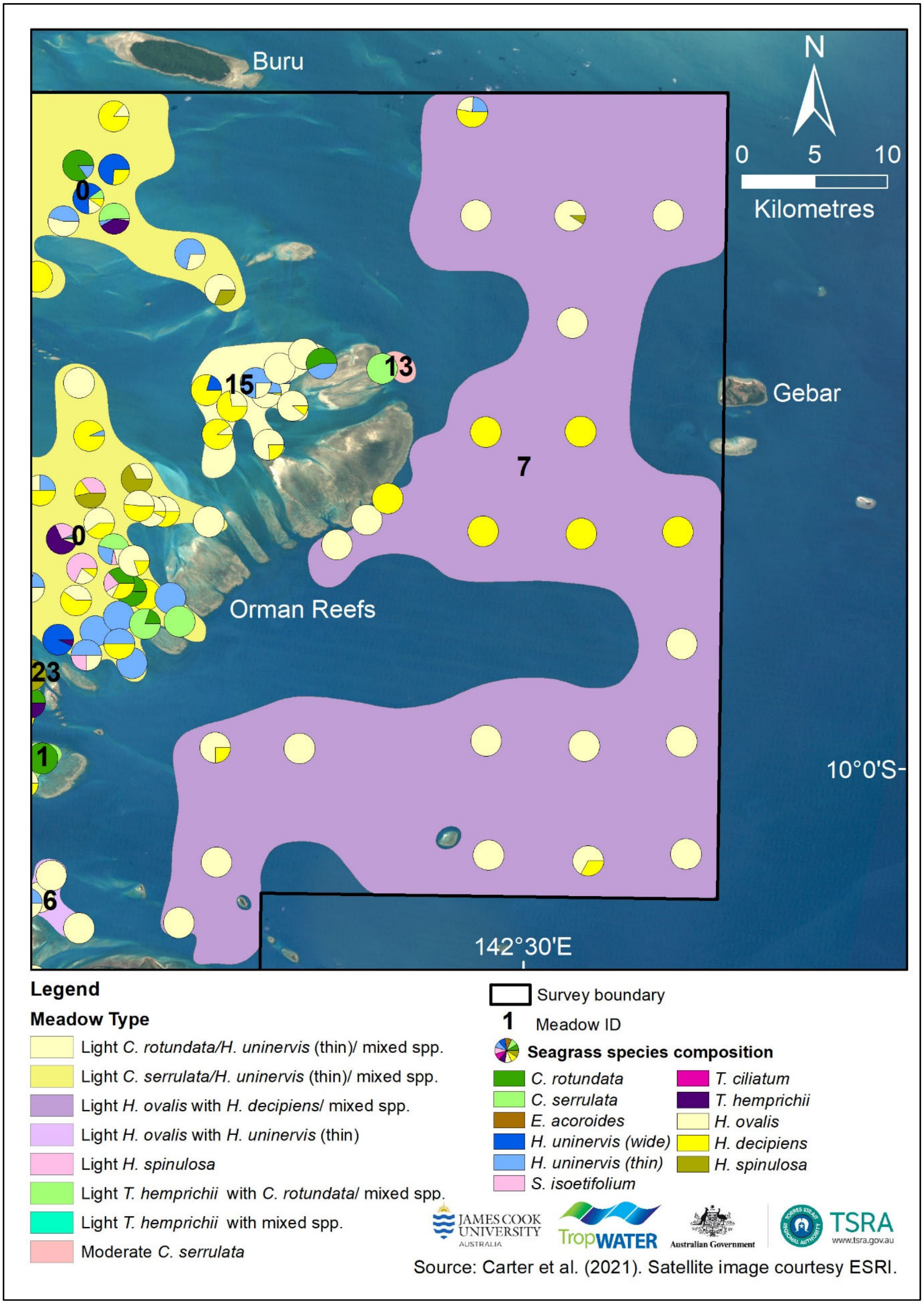

Figure 13. Species composition of survey sites and meadow community type for subtidal meadows east of the Orman Reefs, western Torres Strait, December 2020.

3.1.1 Comparison with previous seagrass surveys

An extensive survey of seagrass in the Dugong Sanctuary was last conducted was in 2010 (Taylor and Rasheed 2010b). Since then, the seagrass meadow has become patchier and a notable loss of *H. spinulosa* has occurred in the meadow (Figure 14). There was also an overall decline in the maximum seagrass biomass at survey sites. In 2020, the maximum biomass at a site was 4 gDW m^{-2}; in 2010 it was 63 gDW m^{-2}. The species present had only minor changes between surveys; *C. rotundata* was present in the comparable section of the meadow in 2020 but not in 2010, and *S. isoetifolium* was present in 2010 and not 2020.

Subtidal seagrass meadows around Badu and Moa Islands were last surveyed in 2010 - 2011 (Taylor 2011; Taylor and Rasheed 2010a). These surveys mapped extensive and continuous seagrass meadows around the islands, with high species diversity. In 2020, the same meadows were fragmented and patchy (Figure 14). As with the Dugong Sanctuary meadow, seagrass biomass had also declined. The range of seagrass biomass at sites in 2010 - 2011 was <1 - 108 gDW m^{-2}; at comparable sites in 2020 the biomass range was <1 - 23 gDW m^{-2}. Most of the meadows in 2020 were dominated by *H. ovalis* and *H. decipiens*, with no *H. spinulosa* present, compared to 2010 - 2011 when a relatively large *H. spinulosa* meadow was mapped on the northern side of Moa Island (Figure 14).

Mabuyag Island's subtidal waters were last surveyed in 2009. The footprint and species composition of the two large meadows immediately north and south of Mabuyag, as well as the smaller meadows at the north and south end of the airstrip, remained relatively unchanged in 2020 compared to 2009 (Figure 14). Three relatively small meadows to the east and west of Mabuyag were present in 2009 but not 2020. *H. spinulosa* was frequently found in the 2009 survey, but in 2020 was recorded at only one site on the northern shore of Mabuyag Island.

The Orman Reefs' subtidal waters were last extensively surveyed in 2004-2005. Since then the Mabuygiw and Mura Badhulgau Rangers have conducted annual monitoring of three subtidal monitoring blocks along the western side of the Orman Reefs since 2018 (Carter et al. 2021). *H. spinulosa* was a common species on the western side of the reef system in the 2004-2005 surveys, but found at only one survey site in the Orman Reefs area in 2020 (Figure 14).

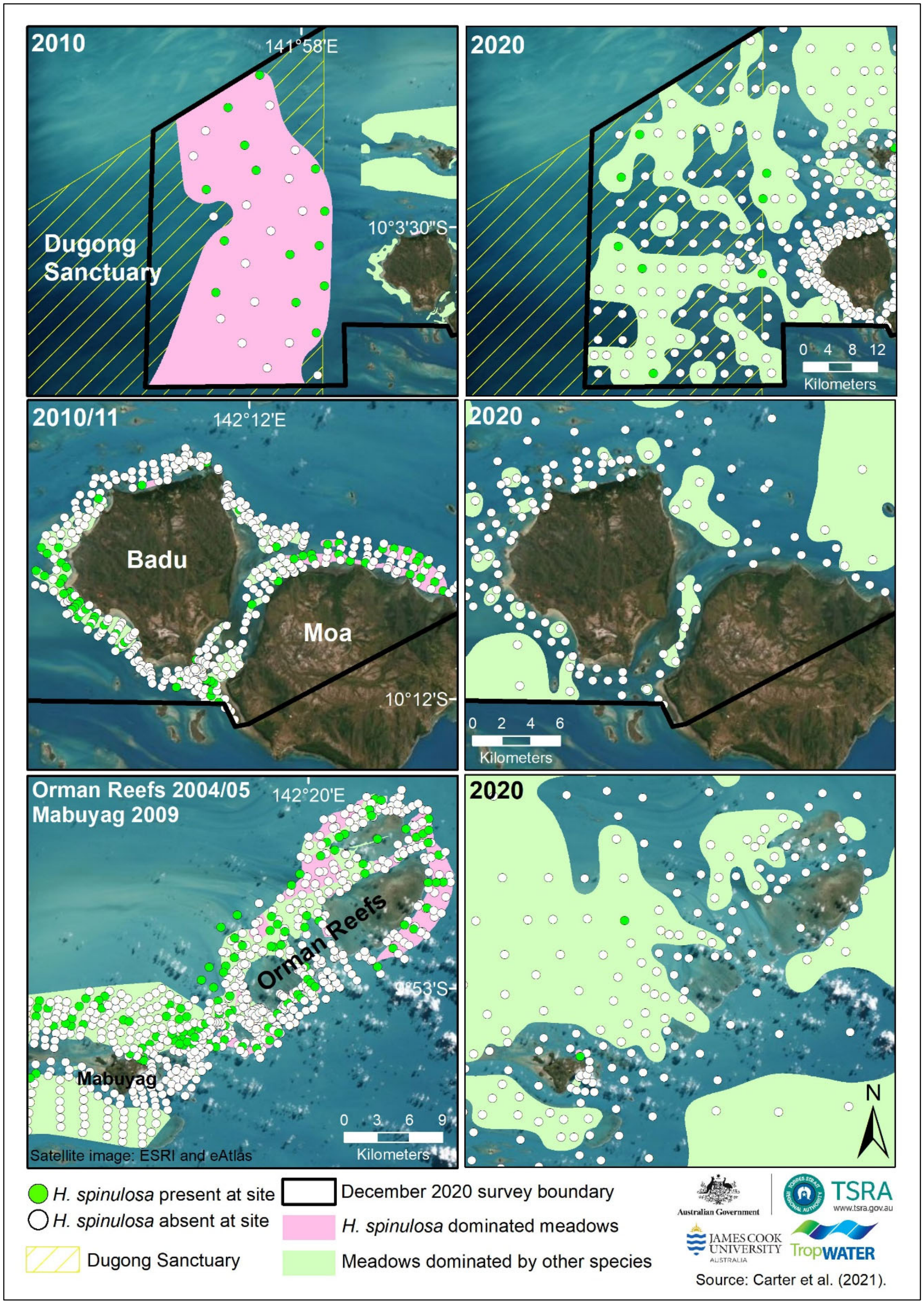

Figure 14. Comparison of historical and recent distribution of subtidal survey sites and seagrass meadows dominated by *H. spinulosa* in (a) the Dugong Sanctuary, (b) at Moa and Badu Islands, and (c) Mabuyag Island and the Orman Reefs.

3.2 Algae

Algae cover in the survey area was extensive (Figure 15 - Figure 18). Algae was present at 68% of the survey sites and accounted for up to 85% of benthic cover at some sites. All five functional algal groups were recorded, with most communities featuring a mixture of groups. Erect macrophyte algae was the dominant type throughout the survey area.

Regions of greatest algae cover tended to be associated with the islands and reefs, or where reefs were nearby (Figure 15 - Figure 18). These sites were dominated by erect macrophyte and erect calcareous algae. Algae contributed less to total benthic cover in the more sandy open regions of the survey area. For example, algae cover at was low (<10%) and mainly consisted of erect macrophyte algae at sites in the Dugong Sanctuary (Figure 15) and east of the Orman Reefs (Figure 18).

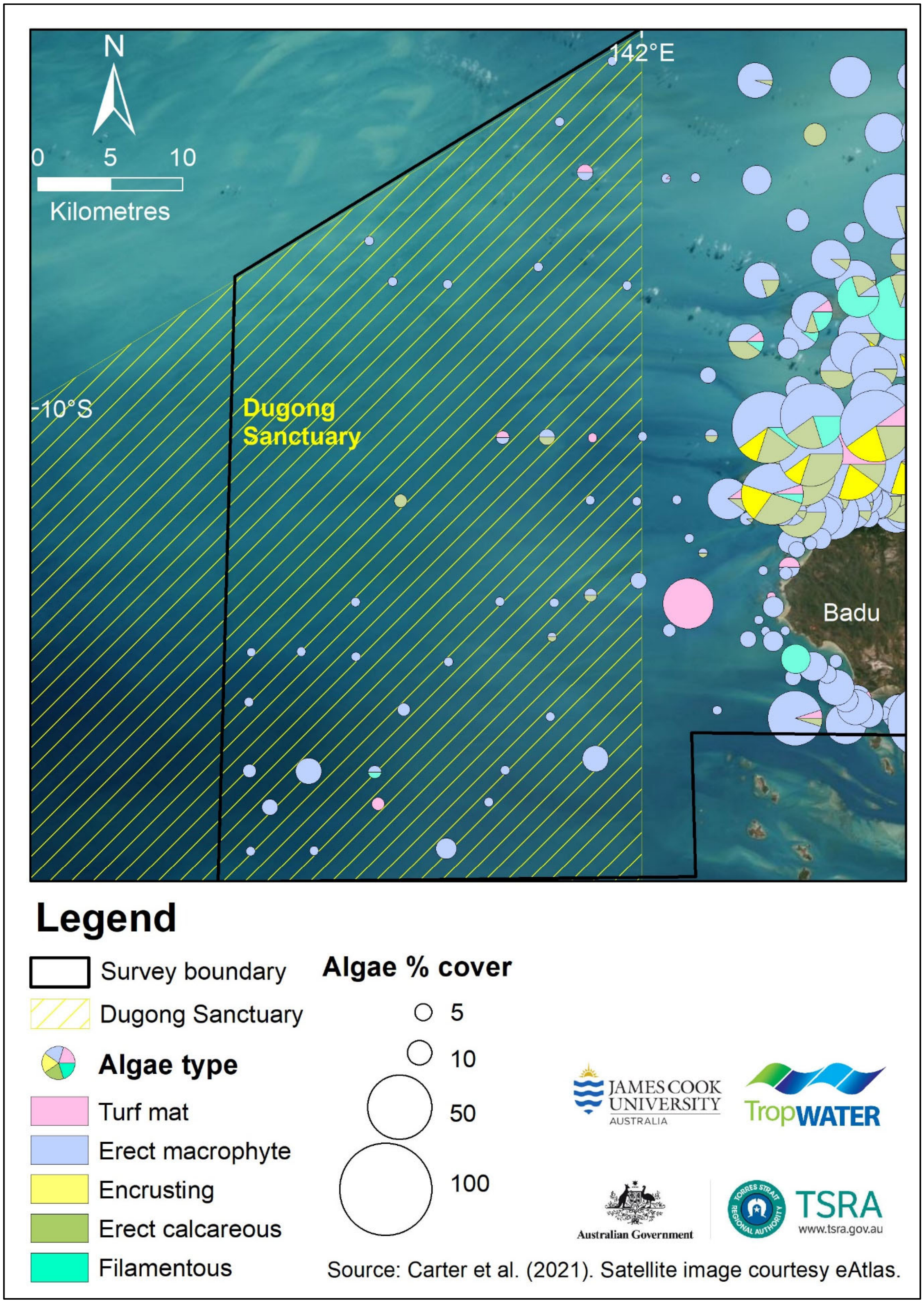

Figure 15. Algae cover and composition at subtidal sites in the Dugong Sanctuary and adjacent areas, western Torres Strait, December 2020.

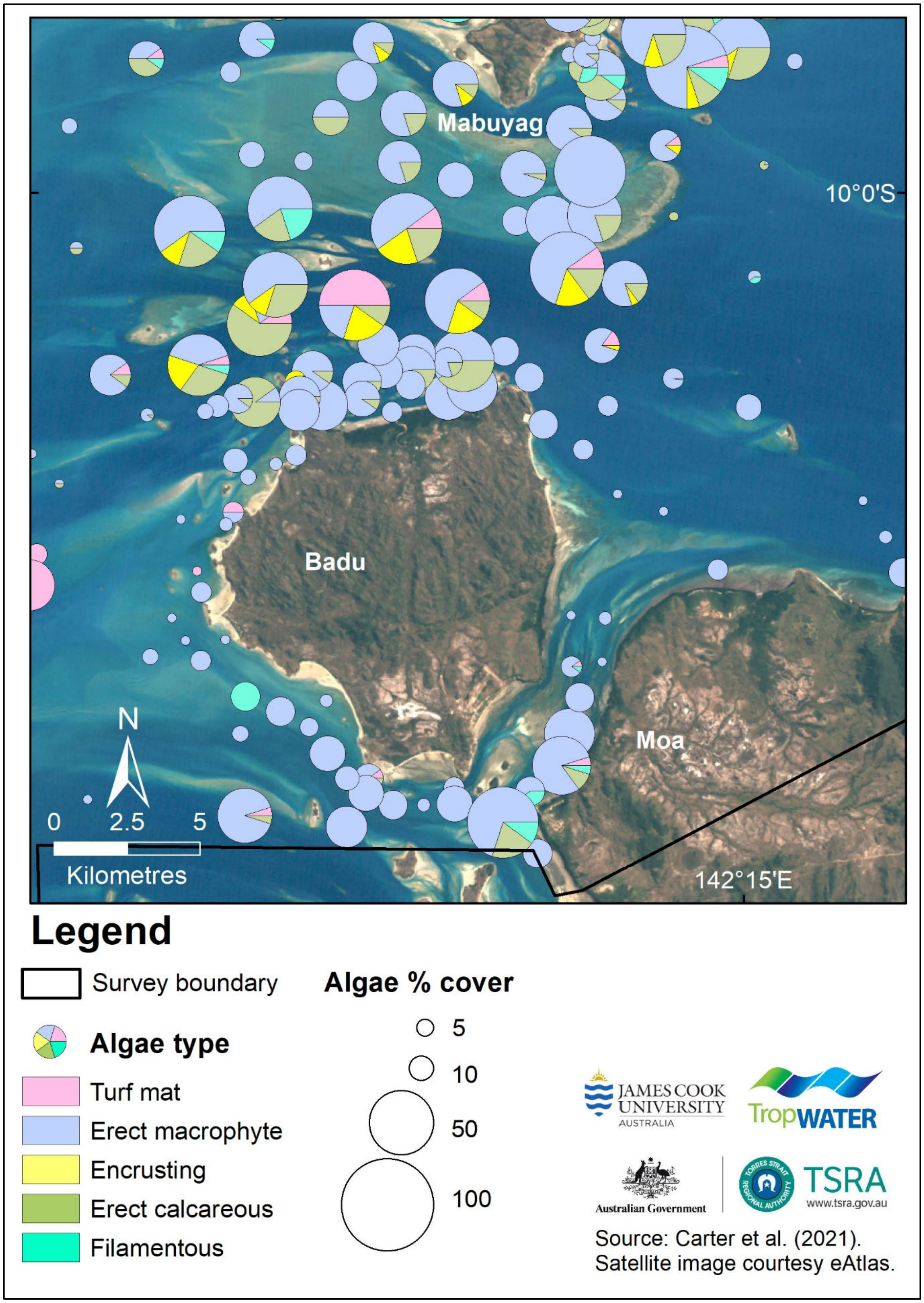

Figure 16. Algae cover and composition at subtidal sites between Mabuyag and Moa Islands, western Torres Strait, December 2020.

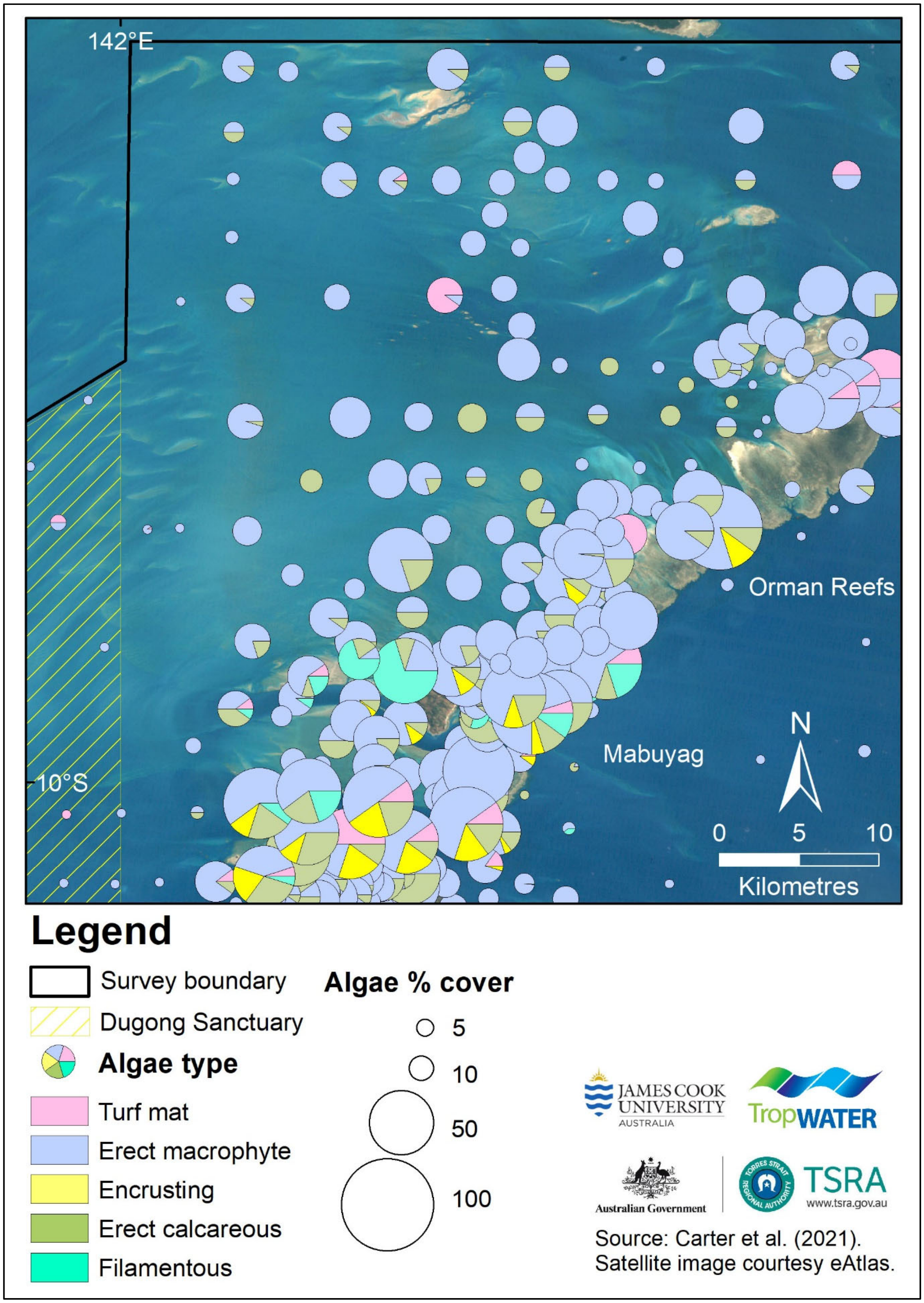

Figure 17. Algae cover and composition at subtidal sites north of Mabuyag Island and Orman Reefs, western Torres Strait, December 2020.

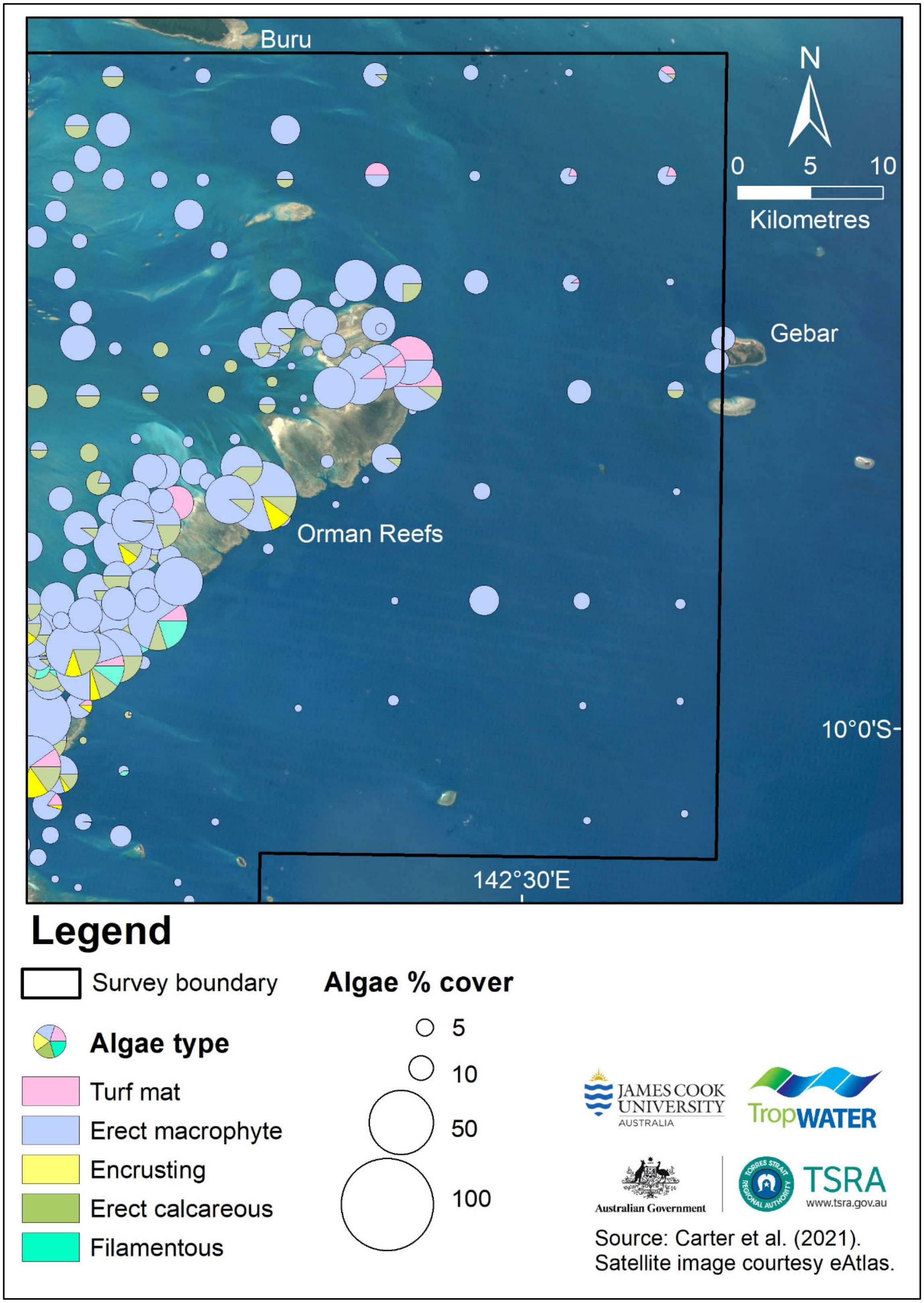

Figure 18. Algae cover and composition at subtidal sites east of the Orman Reefs, western Torres Strait, December 2020.

3.3 Benthic macro-invertebrates

Most of the survey area had very low or no cover of benthic macro-invertebrates (Figure 19 - Figure 22). Sponges were the most common benthic macro-invertebrate type and recorded at 22% of sites. Sponge coverage at a site was relatively low, generally 1-10% cover. Benthic macro-invertebrate cover increased closer to islands and reefs, particularly between the northern coast of Badu Island and Buru Island. In these areas of higher coverage, hard and soft corals tended to dominate, with up to 50% hard coral cover and 20% soft coral cover recorded at individual sites (Figure 20 - Figure 21).

No hard or soft corals were found in the Dugong Sanctuary (Figure 19). The only benthic macro-invertebrates recorded the Dugong Sanctuary was a low cover of sponges, hydroids and bryozoans (classed as “other BMI” in spatial data set). Very few benthic macro-invertebrates were found east of the Orman Reefs to Gebar Island (Figure 22). This included an absence of hard coral and, when benthic macro-invertebrates were present, <5% cover.

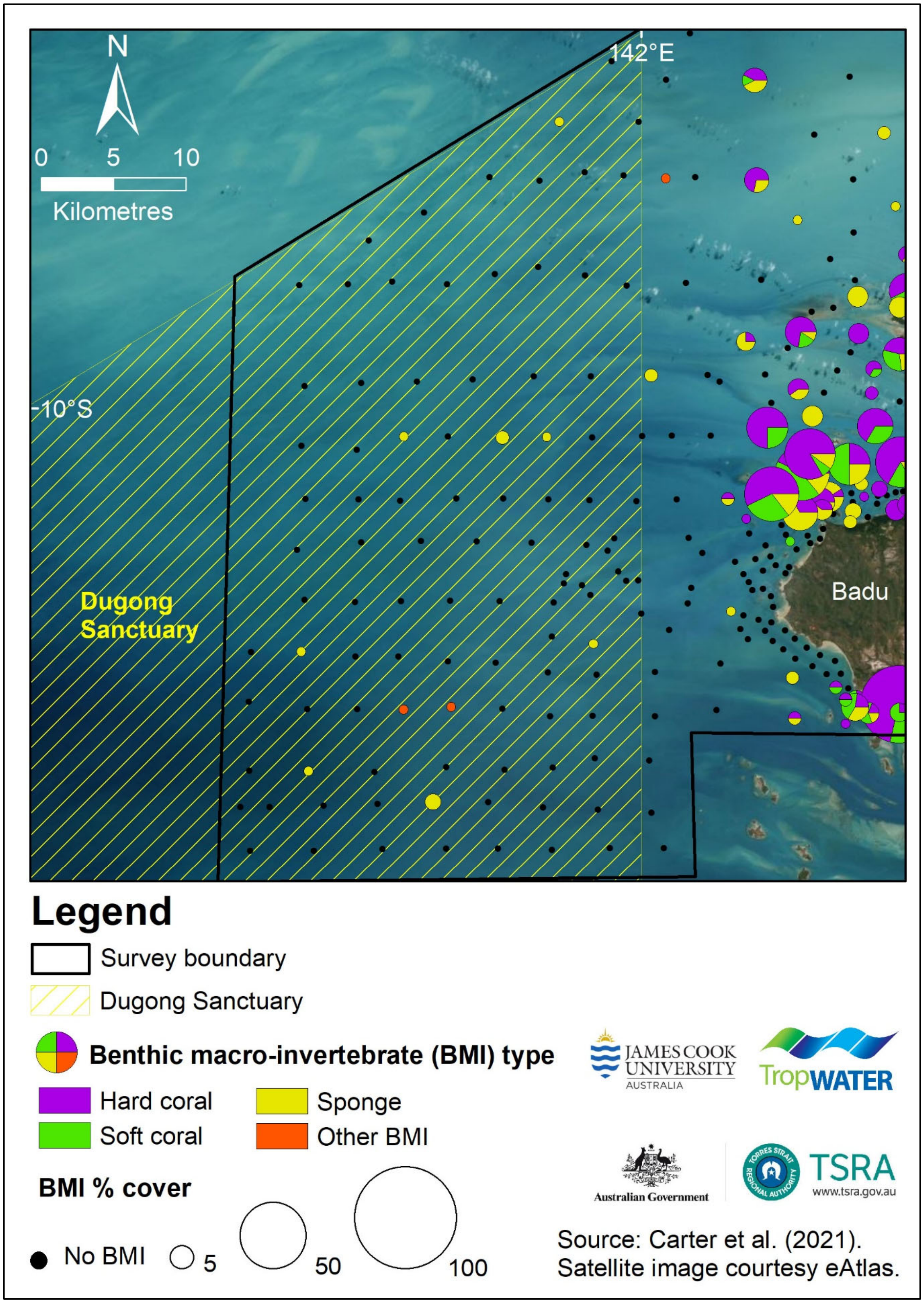

Figure 19. Benthic macroinvertebrate cover and composition at subtidal sites in the Dugong Sanctuary and adjacent areas, western Torres Strait, December 2020.

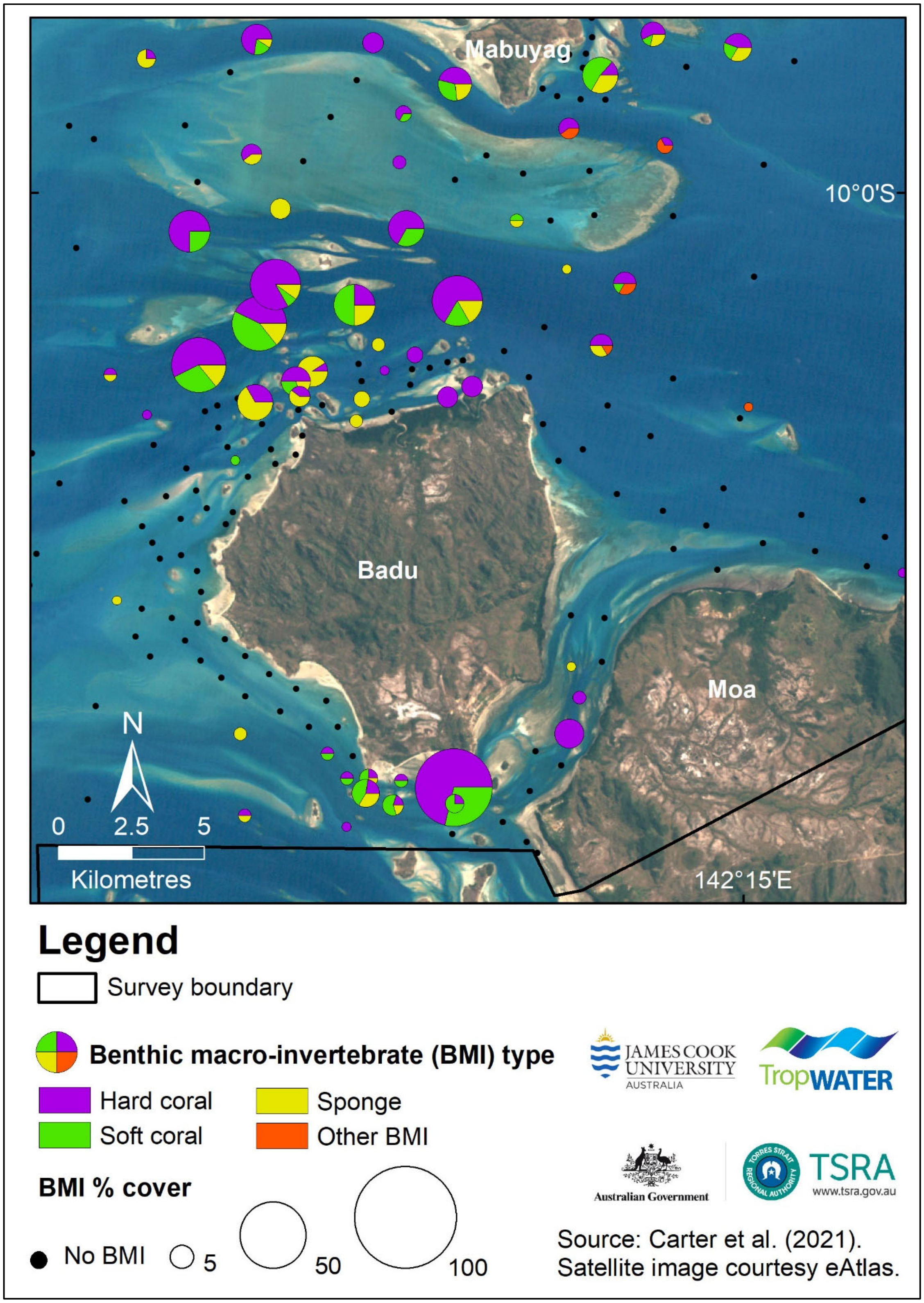

Figure 20. Benthic macroinvertebrate cover and composition at subtidal sites between Mabuyag and Moa Islands, western Torres Strait, December 2020.

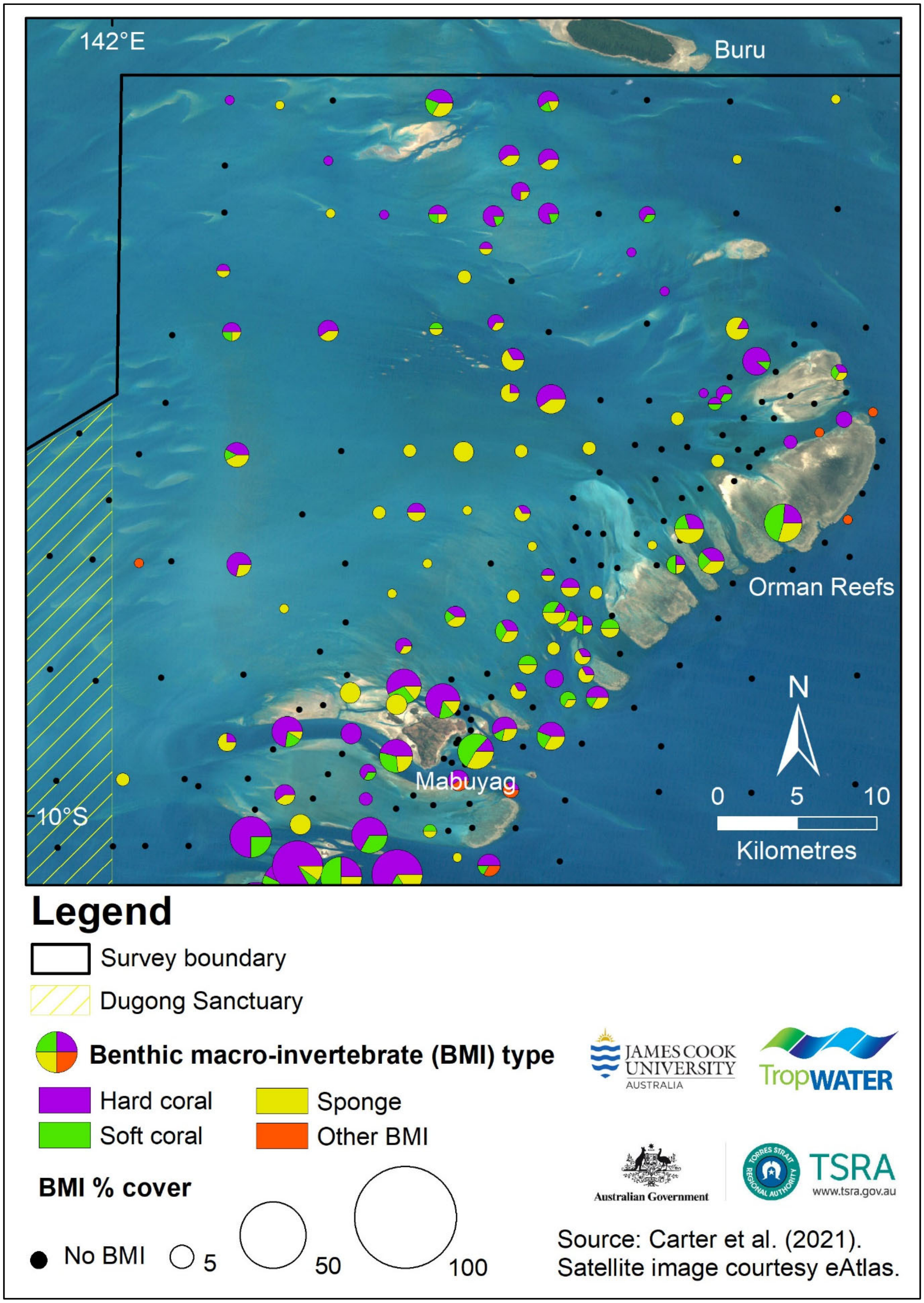

Figure 21. Benthic macroinvertebrate cover and composition at subtidal sites north of Mabuyag Island and Orman Reefs, western Torres Strait, December 2020.

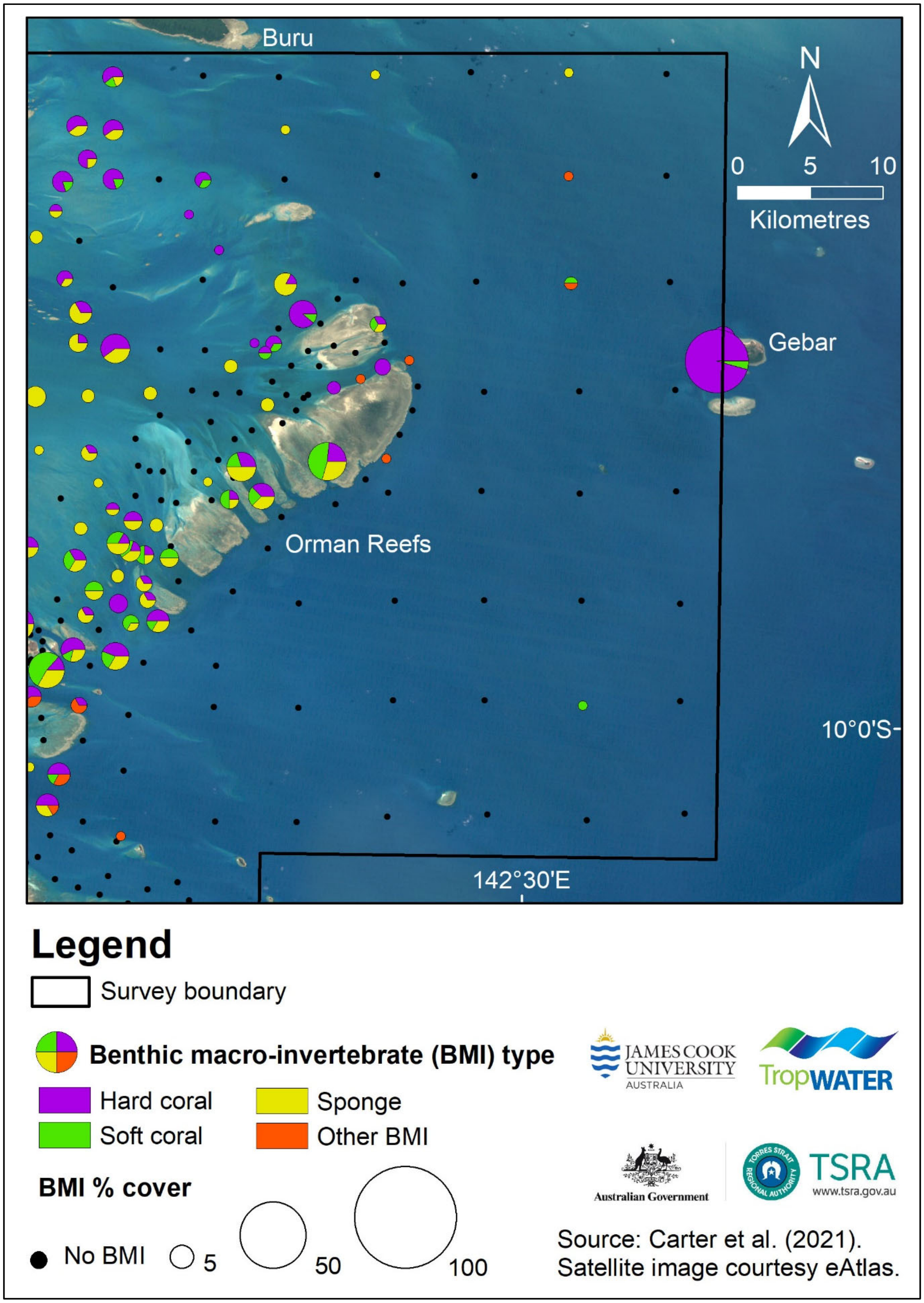

Figure 22. Benthic macroinvertebrate cover and composition at subtidal sites east of Orman Reefs, western Torres Strait, December 2020.

4 DISCUSSION

4.1 Subtidal seagrass in the Western Cluster

Extensive subtidal seagrass meadows were mapped throughout Torres Strait's Western Cluster in December 2020. These included large, continuous meadows north of Mabuyag Island to Buru Island, and east of the Orman Reefs to Gebar Island, and a large but patchy meadow in the north-east section of the Dugong Sanctuary. These vast subtidal meadows are likely to be regionally important as the area they cover is several orders of magnitude greater than the smaller subtidal seagrass meadows that grow around islands such as Badu and Moa, and the intertidal seagrass meadows in the region (Figure 23). These large subtidal meadows are likely to provide an important source of primary production that supports the region's marine ecosystems.

The Western Cluster is located within a large area of Torres Strait characterised by shallow waters (<20 m) that extend west of the Warrior Reefs and into the Dugong Sanctuary (Figure 23). Light availability is an important positive predictor of seagrass growth and distribution in Torres Strait (Carter et al. 2014a; Taylor et al. 2013), and extensive subtidal seagrass habitat extends throughout these shallow waters. We found seagrass growing down to 17 m during this survey, and no survey sites exceeded 20 m depth. The geographic extent of this seagrass habitat is likely driven by light limitations for subtidal seagrass. For example, seagrass does not grow in waters >30 m along the western edge of the Dugong Sanctuary (Carter et al. 2014c), in very shallow but turbid waters along the Papua New Guinea coast in north-west Torres Strait (Carter and Rasheed 2016), or in the deep inter-reef waters of eastern Torres Strait where depths often exceed 40 m (Haywood et al. 2008).

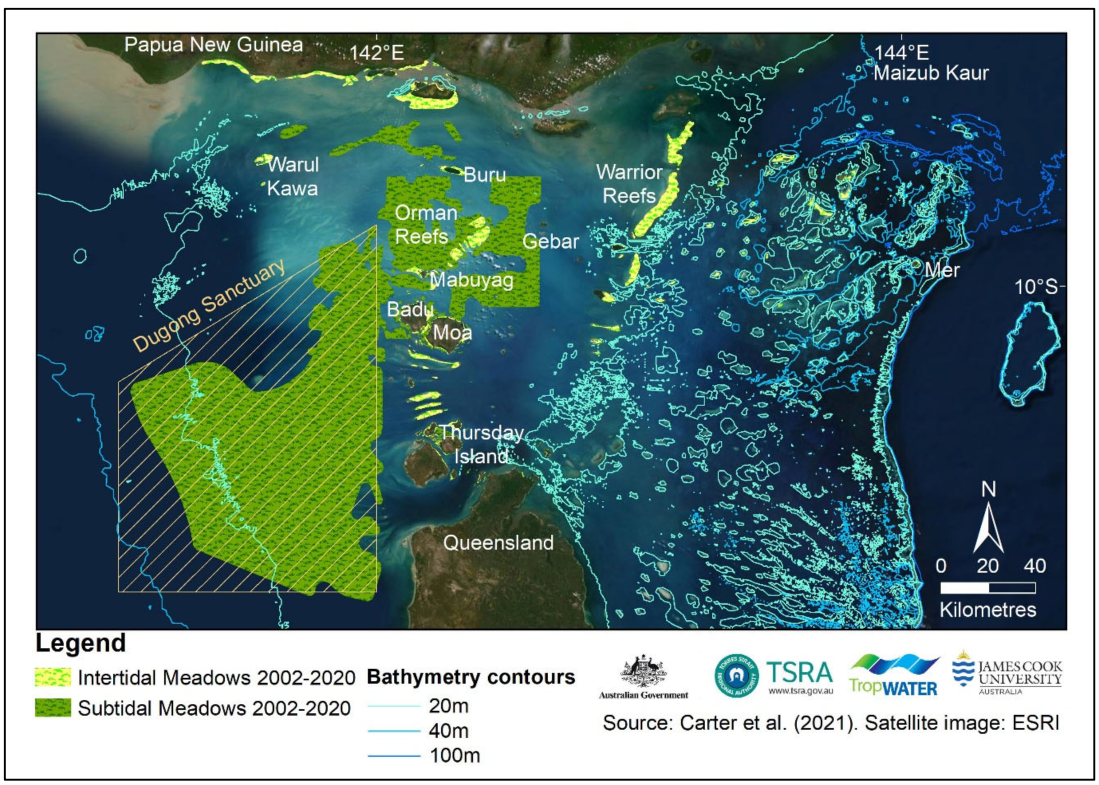

Figure 23. Distribution of mapped seagrass meadows in relation to depth contours across Torres Strait.

Seagrass species diversity in the Western Cluster is high. Twelve species have been recorded historically in Torres Strait (Carter et al. 2014c), and nine of those species were present during this survey. Each seagrass species has different minimum light requirements to maintain a stable state or to achieve positive growth (Chartrand et al. 2016; Collier et al. 2016; Collier et al. 2012). Species most commonly found in subtidal waters are characterised by their low light requirements, such as *Halophila* species that require only 10 - 30% surface light intensity (Freeman et al. 2008). As expected, *Halophila* was the dominant genera in many of the subtidal meadows mapped during this survey, including the large meadow between Orman Reefs and Gebar Island and meadow 14 in the Dugong Sanctuary. Several of the large meadows were characterised by greater mean biomass of other species, including *C. serrulata* communities north of Mabuyag Island and the Orman Reefs, and *H. uninervis* communities in the Dugong Sanctuary. However, this dominance was largely driven by relatively high biomass of non-*Halophila* species in sites closest to islands and reefs, while the low biomass *Halophila* species remained the most common species throughout these meadows.

A key reason for this survey was in response to significant declines in seagrass condition recorded in the Mabuyag-Orman Reefs area of the Western Cluster (Carter et al. 2020). In particular, subtidal seagrass biomass declines and loss of the dominant species *H. spinulosa* at Orman Reefs detected by the Ranger-led Subtidal Monitoring Program. The survey provided an opportunity to compare the extent and species composition of subtidal seagrass at several locations not surveyed in over a decade as well as capturing seagrass condition more broadly in the regions where smaller scale annual monitoring is conducted. The 2020 survey confirmed that subtidal seagrass declines extend far beyond the Orman Reef monitoring blocks. This includes the larger north-east section of the Dugong Sanctuary (Taylor and Rasheed 2010b), the Dugong Sanctuary long-term monitoring blocks last surveyed in 2018 (Carter et al. 2021), the broader Orman Reefs area (Rasheed et al. 2006), and around Mabuyag, Moa and Badu Islands (Taylor 2011; Taylor and Rasheed 2010a; Chartrand et al. 2009). Seagrass meadows in 2020 were generally patchier, smaller, and the previously dominant subtidal species *H. spinulosa* was gone from most sites. The assessment of biomass in the Orman Reefs and Dugong Sanctuary monitoring blocks using December 2020 survey data for the annual report card concluded that seagrass condition in both meadows was very poor (Carter et al. 2021).

Seagrass species vary in their sensitivity and resilience to impacts including those associated with shipping activities, storm events and shifting sediments. Seagrass species can be classed as colonising, opportunistic, or persistent (Kilminster et al. 2015). Persistent genera common to subtidal meadows in Torres Strait include *Cymodocea*, which form enduring meadows in stable habitats. Colonising species such as *Halophila* tend to be transitory – they are quick to succumb to disturbances but are often the first species to recolonise (Kilminster et al. 2015). As the Western Cluster contains a wide range of species it follows there would be a corresponding range of tolerances and capacity to recover from impacts. The shift from subtidal sites dominated by *H. spinulosa* in earlier surveys, to sites dominated by more marginal species like *H. ovalis* and *H. decipiens*, is ecologically relevant and indicative of a decline in growing conditions or recent impact (Carter et al. 2016).

Several substantial seagrass diebacks have been documented in Torres Strait and the direct cause of these are still debated. These include a widely reported dieback in the early 1970s (Johannes and MacFarlane 1991), and less widespread diebacks in north-western Torres Strait in the early 1990s (Poiner and Peterkin 1996), and in the Orman Reefs area in 1999-2000 (Marsh et al. 2004). Potential reasons for the recent declines in the Western Cluster include increased herbivory from green turtles and dugong, altered environmental conditions, and shifting sediment (Carter et al. 2021). Testing for seagrass disease in 2020 found no evidence this was the cause of the declines (Richard Davis, Department of Agriculture, Water and Environment, pers. comm.).

Burial by shifting sediments is a common occurrence in Torres Strait, and the capacity of seagrass species to withstand this is size-dependant. Small species such as *H. decipiens* are less tolerant, but also often dominate regularly used spoil grounds (Chartrand et al. 2008) due to their ability to rapidly colonise following disturbance through high reproductive output and the generation of large seed banks (Kenworthy 2000). A study on seed reserves in a mixed species subtidal seagrass meadow near Mabuiag Island found high densities of *Halophila* spp. seeds and low densities of *S. isoetifolium* and *C. serrulata,* despite the meadow consisting of six different species (Taylor et al. 2013). Larger growing species such as *C. serrulata* may have a greater capacity to withstand burial, but once they are lost take substantially longer to recover (Taylor et al. 2013; Cabaço et al. 2008). The presence of nine species in the survey area and prevalence of *H. ovalis* and *H. decipiens* throughout indicates these meadows have the potential for relatively fast biomass recovery, particularly *H. spinulosa* biomass, if seed reserves are not limited.

4.2 Importance for dugong and green turtle

Effective management and planning requires recent and spatially relevant seagrass information. This survey addressed a critical knowledge gap in Torres Strait seagrass. For the first time, seagrass was mapped in subtidal waters north of the Orman Reefs to Buru Island, and east of the Orman Reefs to Gebar Island. Knowledge on seagrass in areas previously surveyed more than a decade ago has also been updated for Orman Reefs, the Dugong Sanctuary, and waters around Mabuyag, Badu and Moa Islands.

Seagrass meadows in the Western Cluster and adjacent waters provide an important foraging ground for dugong and green turtle. Aerial surveys indicate the greatest dugong densities in Torres Strait include the area between Badu/Moa Islands and Boigu Island, and the eastern side of the Dugong Sanctuary (Hagihara et al. 2016). Turtle densities are greatest between Horn Island and Buru Island, east to Gebar Island, and include the eastern side of the Dugong Sanctuary (Hagihara et al. 2016). Despite the overlap in spatial distribution of dugong and green turtle in Torres Strait, these herbivores use common areas differently. Dugong in Torres Strait preferentially inhabit subtidal waters (>5-20 m) so presumably target subtidal meadows, while green turtles often are reef-associated and use the 0-5 m zone (Cleguer et al. 2016; Hagihara et al. 2016; Gredzens et al. 2014). Stomach content analysis indicates dugong feed exclusively on seagrass while green turtles consume seagrass and macroalgae (André et al. 2005). The extensive macroalgae in shallow subtidal waters at Orman Reefs and around Badu, Moa and Mabuyag Island described in this report are also potentially important foraging grounds for green turtles.

The spatial distribution of quality food strongly influences movement patterns, foraging behaviours and reproductive capacity of dugong (Marsh and Kwan 2008; Sheppard et al. 2007; Marsh et al. 2004) and turtle (Limpus and Nicholls 2000). Previous seagrass diebacks in Torres Strait have had significant impacts on local herbivore populations, and were linked to increases in dugong mortality and declines in dugong health (Marsh et al. 2004; Long and Skewes 1996). More recently on Queensland's east coast, dugong and turtle deaths increased significantly due to starvation following wide-spread seagrass loss during a series of floods and cyclones in 2009-2011 (DERM 2011). The recent decline in seagrass biomass in the Western Cluster is not as dramatic as that, but these declines may still have implications for dugong and turtle. Regular monitoring of turtle and dugong distribution and health would provide important information on how these herbivores respond to the current seagrass decline.

Our assessment of Western Cluster seagrass provides essential habitat information to the TSRA, Traditional Owners, and the Australian and Queensland governments. This information is also at scales useful to community-based Dugong and Turtle Management Plans. The 2020 survey area included subtidal waters that overlapped six Dugong and Turtle Management Areas: Mabuiag, Badu-Mabuiag, Badu, Maulgal, Wugalgal, and Saibai-Dauan. The surveys built research skills and capacity of Rangers and Traditional Owners from Moa, Badu and Mabuiag Islands. The survey outcomes provide a baseline against which future seagrass change can be assessed, and complements dugong and turtle research in the region.

4.3 Recommendations

Baseline surveys collect broad scale information on seagrass presence/absence, seagrass biomass, species composition and meadow area, plus other benthic information on algae, benthic macro-invertebrates, and sediment type. However, seagrass meadows respond to changes in water quality and this makes them ideal for detecting environmental change and understanding the health of marine environments (Orth et al. 2006; Abal and Dennison 1996; Dennison et al. 1993). Ongoing monitoring at targeted areas is therefore required to understand the condition of seagrass meadows over time, including detecting declines and understanding recovery. We recommend the following:

1. Maintain the Western Cluster's existing Ranger-led subtidal seagrass monitoring on the western side of Orman Reefs and the north-eastern part of the Dugong Sanctuary (Carter et al. 2021).
2. Expand the Ranger-led subtidal monitoring program to include meadows east of the Orman Reefs and/or close to Badu Island. This would increase our understanding of subtidal seagrass condition in the Western Cluster.
3. Continue collaboration with TSRA and Rangers to undertake baseline subtidal surveys in areas adjacent to the December 2020 survey. Priority areas include where seagrass data is lacking such as the region between Saibai and Iama Islands and the Warrior Reefs, and the region south of Badu/Moa Islands to Cape York. A priority area where data is more than a decade old is the southern section of the Dugong Sanctuary.

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