



TORRES STRAIT MAPPING: SEAGRASS CONSOLIDATION 2002-2014

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To download this report and view the GIS layers go to the Torres Strait eAtlas:
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KEY FINDINGS

1. Torres Strait seagrass provides critical habitat for commercial and traditional fishery species, and an important food resource for dugong and green turtle populations.
2. This study consolidated seagrass spatial data collected between 2002 and 2014 by TropWATER and the TSRA into a Geographic Information System (GIS) database documenting the current state of knowledge of intertidal and subtidal meadows across the region.
3. The sampling methods applied were developed by the TropWATER Seagrass Group and CSIRO for seagrass habitat surveys of subtidal meadows; and TropWATER methods for port surveys and intertidal surveys in areas considered at high risk from shipping accidents in the Torres Strait. These included sampling by boat (free divers, underwater video camera, grabs, sled with net backing), helicopter, and walking.
4. Twelve seagrass species from 3 families were identified in intertidal and subtidal meadows between 2002 and 2014. Seagrass was present at 53% of intertidal sites, 53% of subtidal sites (TropWATER surveys), and 34% of subtidal sites from the 2005 CSIRO survey.
5. High seagrass biomass regions include the Warrior Reefs, the eastern edge of the Dugong Sanctuary subtidal meadow, and reef top meadows and surrounding islands between Prince of Wales Island and Orman Reefs.
6. Seagrass diversity hotspots were identified in meadows between Horn, Wednesday and Hammond Island, and between Badu and Moa Islands, and the eastern edge of the Dugong Sanctuary subtidal meadow.
7. Three Torres Strait regions were identified as data deficient, where basic knowledge of seagrass and benthic habitat is unknown or extremely limited (Map 23). These regions are (1) North of the Dugong Sanctuary, including the proposed Dugong Sanctuary extension area extending east to the Warrior Reefs, (2) Prince of Wales Island to western Cape York, and (3) Eastern Cape York and south east Torres Strait.
8. Future priorities for seagrass research in Torres Strait should focus on gathering information on seagrasses in data deficient regions identified in this report, extending the current data set to assess habitats at risk from shipping accidents across Torres Strait, and using this spatial data to model oil spill scenarios.

TABLE OF CONTENTS

KEY FINDINGS	iv
1 INTRODUCTION.....	6
2 METHODS	9
2.1 Sampling methods	9
2.2 Habitat characterisation sites.....	9
2.3 Geographic Information System (GIS)	10
3 RESULTS	15
3.1 Seagrass species.....	15
3.2 Key findings for each species.....	24
4 DISCUSSION	40
4.1 Data deficient regions	41
4.2 Recommendations	41
5 REFERENCES.....	44

1 INTRODUCTION

Seagrasses are one of the most productive marine habitats on earth and provide a variety of important ecosystem services with substantial economic value (Costanza et al. 2014; Costanza et al. 1997). Seagrass/ algae beds were found to be worth in excess of US\$28,000 per hectare per year (in 2007 dollar value) for the services they contribute (Costanza et al. 2014). These services include the provision of nursery habitat for economically-important fish and crustaceans (Heck et al. 2003; McKenzie et al. 1996; Coles et al. 1993) and food for herbivores like dugongs and sea turtles (Unsworth and Cullen 2010; Heck et al. 2008). Seagrasses play a major role in the cycling of nutrients (McMahon and Walker 1998), stabilisation of sediments (Madsen et al. 2001) and improving water quality (McGlathery et al. 2007). Recent studies also suggest seagrass meadows are one of the most efficient and powerful marine carbon sinks, storing nearly three times more organic carbon than the carbon stocks of the world's forests (Lavery et al. 2013; Fourqurean et al. 2012; Pendleton et al. 2012).

The Torres Strait region covers an area of more than 48,000 km² and is located on one of the world's most extensive continental shelves. Torres Strait comprises 247 islands, 18 of which are permanently inhabited. Local island communities in the Torres Strait are deeply connected to their sea country through their culture and economy. The health of marine resources is vital to Torres Strait Islanders from a subsistence, commercial and cultural point of view. Torres Strait is estimated to contain between 13,425km² (Coles et al. 2003) and 17,500km² (Poiner and Peterkin 1996) of seagrass habitat, providing critical habitat for commercial and traditional fishery species as well as important food resources for dugong and green turtle populations (Marsh and Kwan 2008; Coles et al. 2003). The largest population of dugongs in the world is in Torres Strait (Sheppard et al. 2008; Marsh and Lawler 2002; Marsh et al. 1997), where the long-standing importance of dugongs for subsistence by Torres Strait Islanders has been traced in archaeological deposits dating back 7000 years (Vanderwal 1973). Dugong remains the most significant and highest ranked marine food source in Torres Strait's traditional subsistence economy (Kwan 2002; Johannes and MacFarlane 1991; Raven 1990; Nietschmann 1984). A segment of the Torres Strait Protected Zone and adjacent area was designated as a Dugong Sanctuary, in which all hunting of dugong was banned from 1985; an extension of the Dugong Sanctuary is proposed to the north of the current sanctuary (Map 1).

Seagrasses are declining globally from natural disturbances such as storms, disease and overgrazing by herbivores, and from anthropogenic influences including disturbance from coastal development, dredging, trawling, and changes in water quality due to sedimentation, pollution and eutrophication (Waycott et al. 2009; Short and Wyllie-Echeverria 1996). In the tropical Indo-Pacific region a recent assessment of the relative impacts of anthropogenic activities identified industrial and urban run-off, port development, and dredging as the main threats to seagrass ecosystems (Grech et al. 2012). In Torres Strait, seagrasses may be strongly influenced by extremes in weather. Substantial seagrass dieback (up to 60%) has been documented on two occasions in central Torres Strait and linked to declines in the dugong population (Marsh et al. 2004; Long and Skewes 1996). The causes for these diebacks were initially proposed to be caused by flooding and runoff from land based mining activities in Papua New Guinea (Long and Skewes 1996), but recent investigations have found dispersal of terrigenous sediments appears to be restricted to within 5-10km of the Papua New Guinea coast (Heap and Scaffi 2008) and that movement of large sandbanks are unlikely to affect seagrass communities of Torres Strait on a regional scale (Daniell et al. 2006). The causes of such diebacks, therefore, remain unclear.

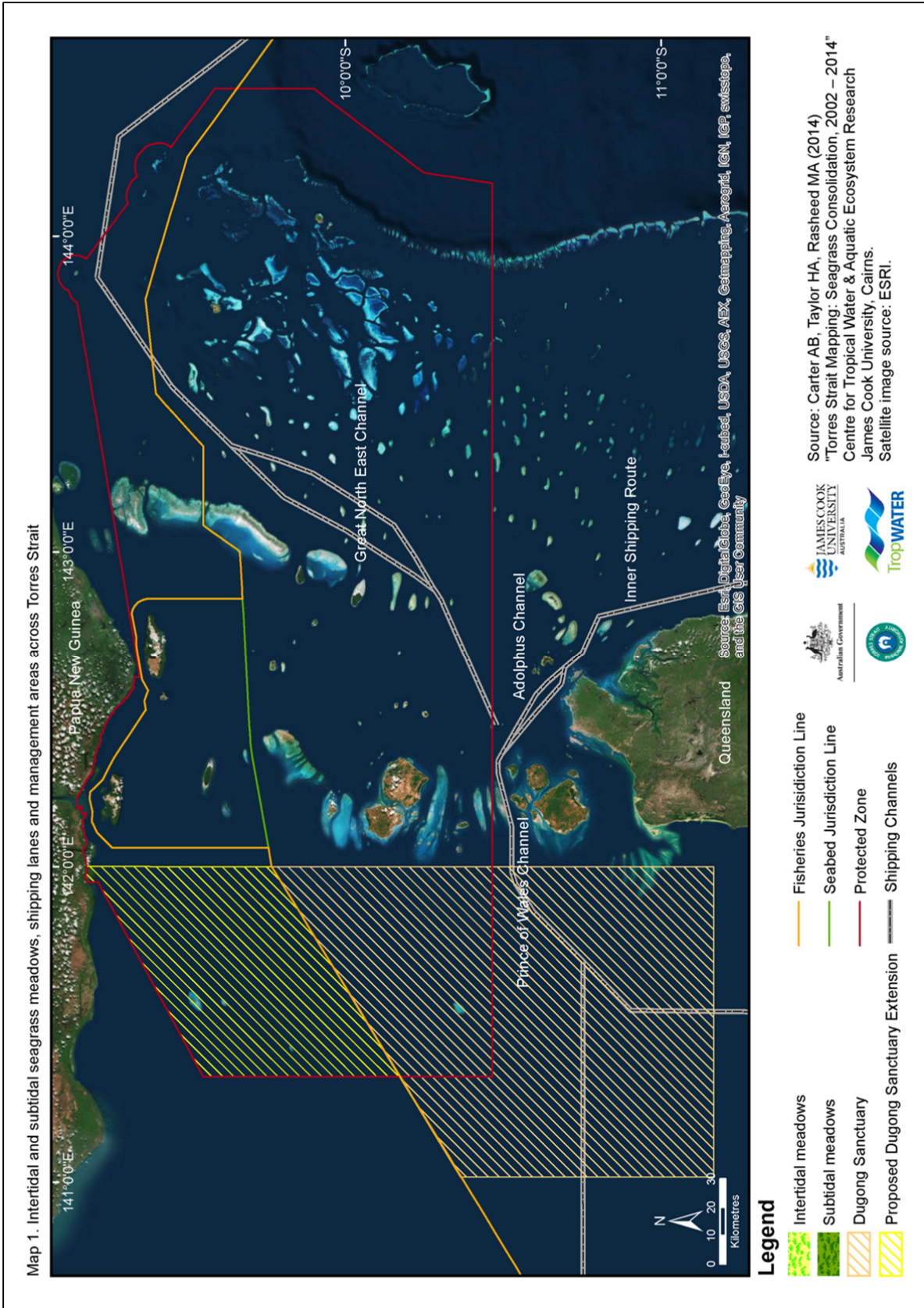
Shipping activity in Torres Strait also poses a threat for seagrasses in the region. Designated shipping lanes that traverse Torres Strait waters provide a means for large vessels to access ports. These shipping lanes often pass through economically and ecologically important natural habitats and often occur in areas that contain significant navigation hazards. In these areas there is a heightened risk of shipping accidents, including collisions and groundings of vessels that may result in oil, fuel and chemical spills. Many marine habitats such as seagrasses, algae, mangroves and coral reefs are vulnerable to oil and fuel spills, particularly when they occur in intertidal areas. Torres Strait contains three of six marine environments identified as high risk areas (MEHRAs) for Queensland's shipping lanes and ports, where there is a heightened risk of accidents as well as heightened consequences of an accident (Queensland Transport and GBRMPA 2000) (Map 1). The six MEHRAs identified in the risk assessment were:

1. Prince of Wales Channel (Torres Strait)
2. Great North East Channel (Torres Strait)
3. Inner Shipping Route between Cape Flattery and Torres Strait
4. Whitsunday Islands and Passages
5. Hydrographers Passage
6. Moreton Bay

Managing seagrass resources in Torres Strait requires adequate baseline information on the seagrass presence and absence, seagrass biomass, species composition, and meadow area. This baseline will be particularly important as a point of reference against which to compare seagrass losses should another dieback event occur in Torres Strait. 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 spatial data on intertidal and subtidal seagrass in Torres Strait since 2002. This spatial data comes from four research projects:

1. Intertidal surveys in areas considered at high risk from shipping accidents in the Torres Strait (2002, 2004-2006, 2008-2013).
2. Subtidal seagrass surveys in western Torres Strait and the Dugong Sanctuary (2009-2011).
3. CSIRO mapping and characterisation of benthic assemblages in Torres Strait (2005).
4. Port of Thursday Island intertidal and subtidal seagrass surveys (conducted biennially since 2002).

The objective of the present study was to consolidate the extensive seagrass spatial data collected between 2002 and 2014 by TropWATER into a Geographic Information System (GIS) database documenting the current state of knowledge of intertidal and subtidal meadows across the region.



2 METHODS

2.1 Sampling methods

The sampling methods applied were developed by the TropWATER Seagrass Group for seagrass habitat surveys previously used at subtidal meadows, e.g. Mabuia Island (Chartrand et al. 2009), Badu Island (Taylor and Rasheed 2010) and Moa Island (Taylor 2011); port surveys, e.g. Thursday Island (Carter et al. 2014); and intertidal surveys in areas considered at high risk from shipping accidents in the Torres Strait (Carter et al. 2013).

Methods used in the 2005 CSIRO subtidal survey employed a video camera that was towed for 500 m at each site, then towing of a 1.5 m wide epibenthic sled with a 10mm mesh net backing to collect seagrass specimens. The sled was towed for 200 m over the same site. Sediment type and depth below mean sea level (dbMSL) were also recorded. Samples were sorted into species and weighed (wet weight). Detailed descriptions of the sampling methods and seagrass collected on this trip are provided in Haywood et al. (2008) and Sheppard et al. (2008).

2.2 Habitat characterisation sites

Data recorded at each site included:

1. **Site details** – Latitude and longitude by GPS, depth below mean sea level (dbMSL) for subtidal meadows.
2. **Seagrass biomass** – Above-ground biomass was determined using a “visual estimates of biomass” technique (Mellors 1991) using trained observers. A linear regression was calculated for the relationship between the observer ranks and the harvested values. This regression was used to calculate above-ground biomass for all estimated ranks made from the survey sites. Biomass ranks were then converted into above-ground biomass estimates in grams dry weight per square metre (g DW m⁻²). Observers estimated biomass data using video transects, grabs, free diving, helicopter and walking:
 - (a) Video transect: commonly used for subtidal meadows. At each transect site an underwater CCTV camera system was lowered from the vessel to the bottom (Figure 1). For each transect the camera was towed at drift speed (less than one knot) and ten random “drops” of the camera were conducted approximately 5m apart. Footage was observed on a TV monitor and digitally recorded. The video was paused at each of the ten random time frames selected. From this frame, an observer recorded an estimated rank of seagrass biomass and species composition. On completion of the video analysis, the video observer ranked five additional quadrats that had been previously videoed for calibration. These quadrats were videoed in front of a stationary camera, and then harvested, dried and weighed.
 - (b) van Veen grab: commonly used for subtidal meadows. A sample of seagrass was collected using a van Veen grab (grab area 0.0625 m²) to identify species present at each site (Figure 1). Species identified from the grab sample were used to inform species composition assessments made from the recorded video transects (Kuo and McComb 1989).
 - (c) Free diving, helicopter and walking: At each site seagrass above-ground biomass and species composition were estimated from three 0.25 m² quadrats placed randomly within a 10m² circular area. Seagrass per cent cover and sediment type were recorded at each site. The “visual estimates of biomass” technique when applied to helicopter/walking surveys involves ranking while referring to a series of quadrat

photographs of similar seagrass habitats for which the above-ground biomass has previously been measured. Three separate biomass scales are used: low-biomass, high-biomass, and *Enhalus*-biomass. The relative proportion of the above-ground biomass (percentage) of each seagrass species within each survey quadrat is also recorded. Field biomass ranks are converted into above-ground biomass estimates in grams dry weight per square metre (g DW m⁻²). At the completion of sampling each observer ranks a series of calibration quadrats as with the video surveys.



Figure 1. Subtidal mapping of seagrass meadows using CCTV system and van Veen sediment grab.

2.3 Geographic Information System (GIS)

All survey data were entered into a Geographic Information System (GIS) developed for Torres Strait using ArcGIS software. Rectified colour satellite imagery of the region (Source: ESRI) and aerial photographs taken from the helicopter during surveys were used to identify geographical features, such as reef tops, channels, deep-water drop-offs, to assist in determining seagrass meadow boundaries. Several GIS layers were created in ArcMap® to describe intertidal and subtidal seagrass meadows.

Site information layers

This layer contains information on all data collected at habitat assessment sites, and includes seagrass percent cover and above-ground biomass (for each species), percent algal cover, Shannon-Weaver diversity index values, sediment type, time, latitude and longitude from GPS fixes, dbMSL for subtidal meadows, sampling method and any comments. Site information is presented several times in this report to represent the year of survey (Map 2), intertidal and subtidal sampling sites (Map 3), seagrass presence/absence (Map 4) and seagrass species composition from the CSIRO 2005 survey (Map 22).

Seagrass meadow layers

This includes area data for seagrass meadows with summary information on meadow characteristics. Information in the site layer was used to construct subsequent polygon (area) layers describing whether seagrass meadows were intertidal or subtidal (Map 20), seagrass meadow community type (Maps 21-22), and seagrass meadow cover (Maps 21-22). Seagrass community types were determined according to overall species composition within a meadow. A standard nomenclature system was used to categorize each seagrass meadow. This system was based on the percent composition of biomass contributed by each species within the meadow (Table 1). This nomenclature also included a measure of meadow density categories (light, moderate, dense) that was determined by the mean above-ground biomass of the dominant

species within the meadow (Table 2). Seagrass cover was categorized according to whether coverage consisted of isolated patches, aggregated patches, or continuous cover (Figure 2). Seagrass cover was not recorded for every meadow surveyed between 2002 and 2014, but where that data was available it has been included on the maps.

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.

Density	Mean above-ground biomass (g DW m ⁻²)					
	<i>H. uninervis</i> (narrow)	<i>H. ovalis</i> <i>H. decipiens</i> <i>H. capricorni</i>	<i>H. uninervis</i> (wide) <i>C. serrulata</i> <i>C. rotundata</i> <i>S. isoetifolium</i> <i>T. hemprichii</i>	<i>H. spinulosa</i>	<i>Z. muelleri</i> subsp. <i>capricorni</i>	<i>E. acoroides</i> <i>T. ciliatum</i>
Light	< 1	< 1	< 5	< 15	< 20	< 40
Moderate	1 - 4	1 - 5	5 - 25	15 - 35	20 - 60	40 - 100
Dense	> 4	> 5	> 25	> 35	> 60	> 100

Each seagrass meadow was assigned a mapping precision estimate ($\pm m$) based on the mapping method used for that meadow (Table 3). Mapping precision estimates ranged from <5m for isolated intertidal seagrass meadows to 10 - 100m for larger patchy intertidal/ subtidal meadows. The mapping precision estimate was used to calculate a range of meadow area for each meadow and was expressed as a meadow reliability estimate (R) in hectares. The reliability estimate for subtidal habitat is based on the distance between sites with and without seagrass when determining the habitat boundary. Additional sources of mapping error associated with digitising aerial photographs into base maps and with GPS fixes for survey sites were embedded within the meadow reliability estimates.

Seagrass biomass and diversity

An inverse distance weighted interpolation (IDW) was applied to seagrass biomass at habitat characterisation sites to describe spatial variation in biomass across each meadow and throughout the region (Maps 5-6). IDW interpolations were also applied to biomass of each seagrass species (Maps 9-19). The Shannon-Weaver (or Shannon-Weiner) index was used as a measure of seagrass species diversity and is presented in Maps 7-8. This index is a mathematical measure of species richness (the number of species present) and the relative abundance of different species (Spellerberg and Fedor 2003).

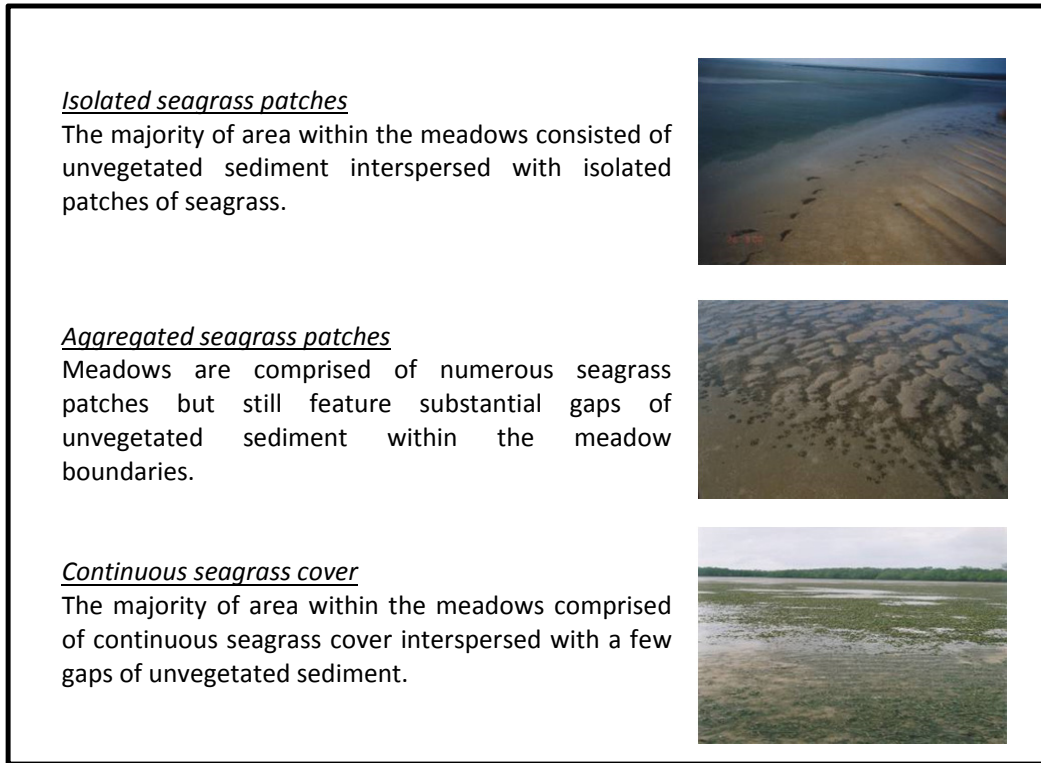
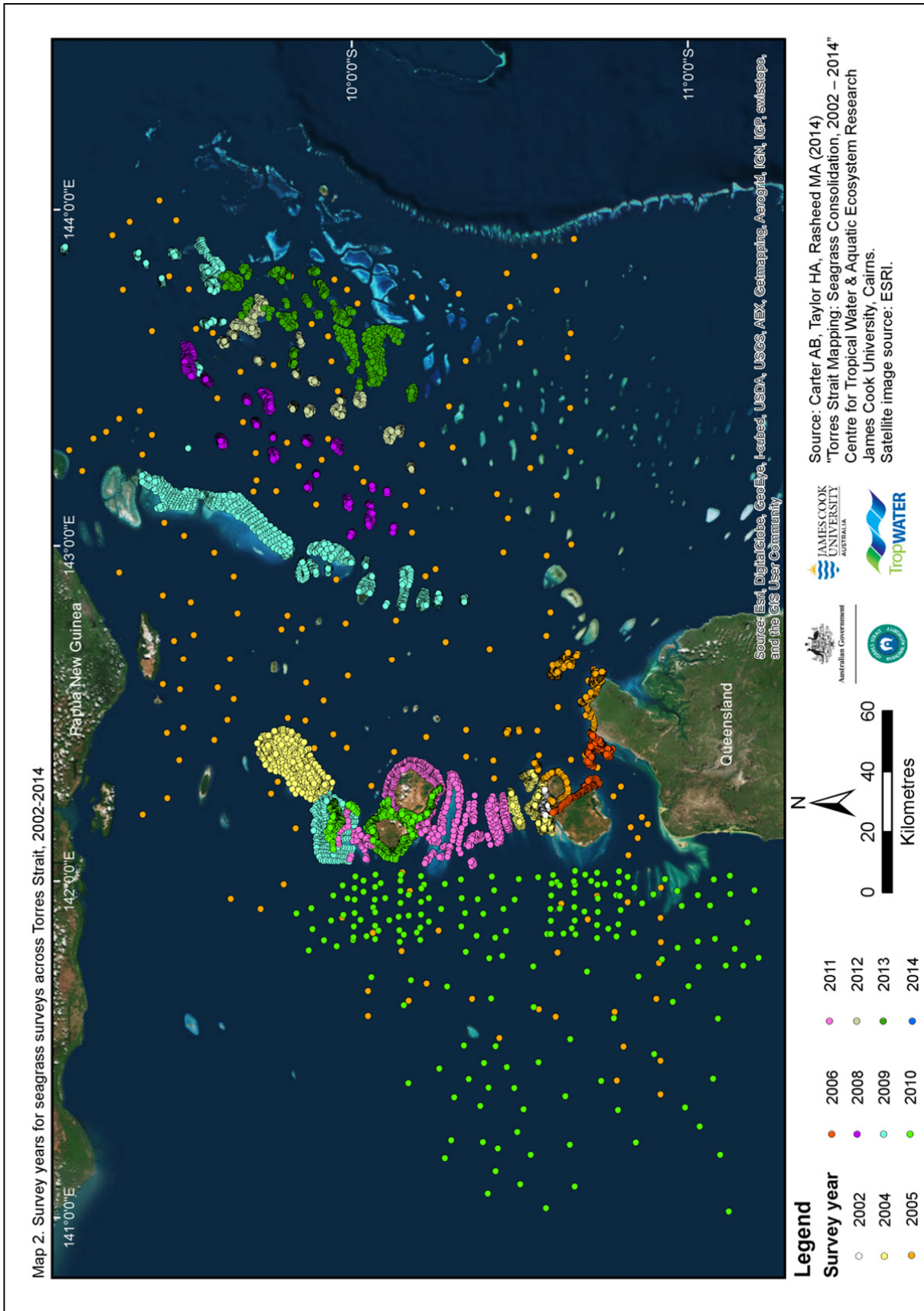
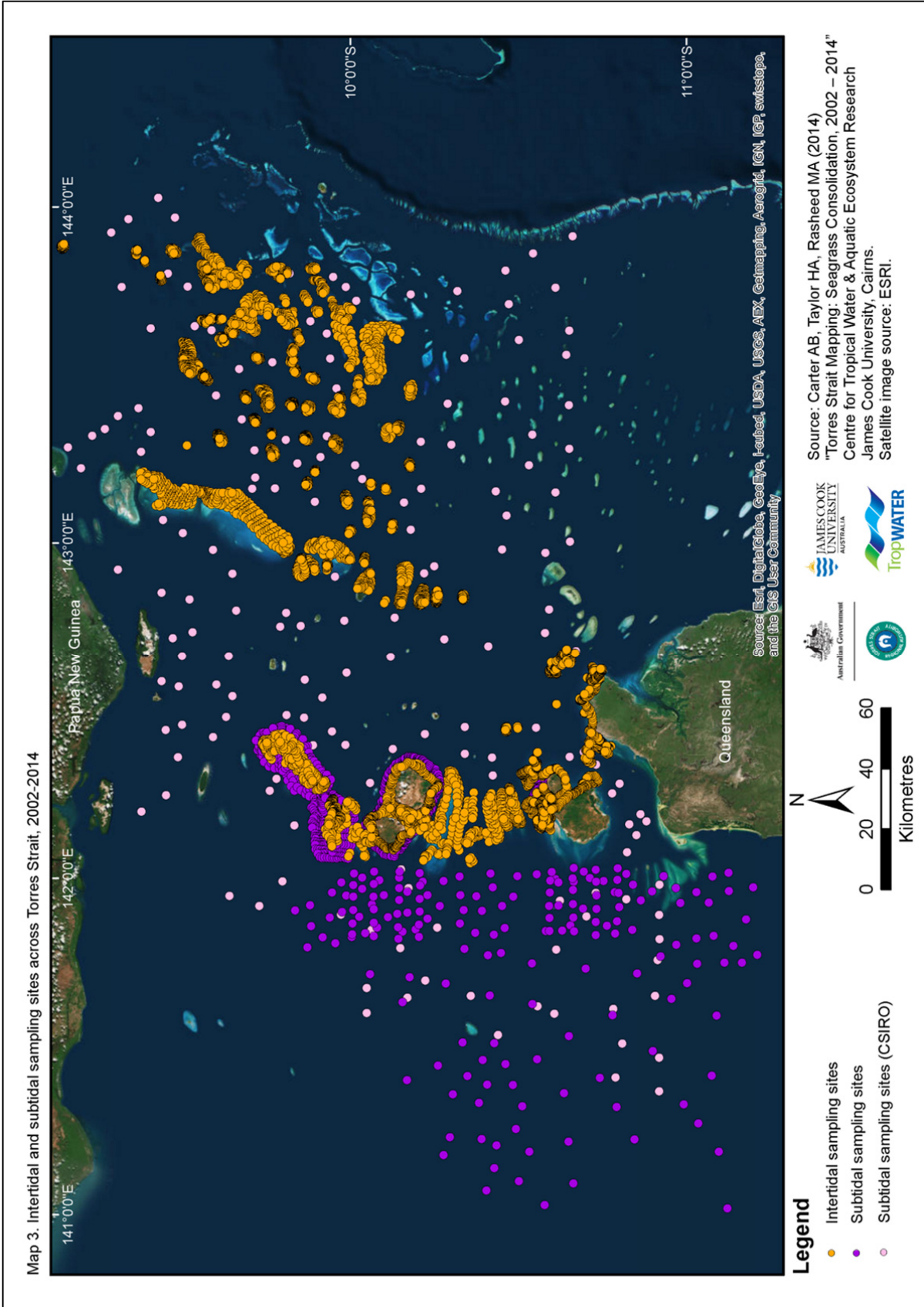


Figure 2. Seagrass cover categories used to describe Torres Strait meadows.

Table 3. Mapping precision and methods for seagrass meadows.

Mapping precision	Mapping method
1-10 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 aided in mapping.
10-50 m	Meadow boundaries determined from helicopter and camera/grab surveys; Inshore boundaries mapped from helicopter; Offshore boundaries interpreted from survey sites and aerial photography; Relatively high density of mapping and survey sites.
100 m	Sites generally 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





3 RESULTS

3.1 Seagrass species

Twelve seagrass species from three families were identified in intertidal and subtidal meadows between 2002 and 2014 (Figure 3). Seagrass was present at 53% of 7149 intertidal sites, 53% of 1901 subtidal sites (TropWATER surveys), and 34% of 168 subtidal sites from the 2005 CSIRO survey (Map 4).

In terms of the average contribution to biomass across all sites, *E. acoroides* followed by *T. hemprichii* were the dominant species at intertidal sites (Figure 4a); *E. acoroides*, *C. serrulata* and *T. ciliatum* were the three equally dominant species at subtidal sites (each contributing approximately 20% of biomass, Figure 4b); and *C. serrulata* and *H. spinulosa* combined accounted for 77% of biomass at the subtidal CSIRO sites (Figure 4c). The dominance of *E. acoroides* and *T. ciliatum* occurred because these species, when present, have relatively high biomass compared to other seagrass species. For example, *E. acoroides* contributed an average 46% of biomass across intertidal sites, but was only present in 17% of sites (Figures 4a, 5a); *T. ciliatum* contributed an average 20% of biomass across subtidal sites, but was only present in 3% of sites (Figures 4b, 5b). The most frequently recorded species were *T. hemprichii* (29%) and *H. uninervis* (19%) at intertidal sites (Figure 5a); *C. serrulata* (22%) and *H. ovalis* (21%) at subtidal sites (Figure 5b); and *C. serrulata* (23%) and *H. spinulosa* (22%) at the subtidal CSIRO sites (Figure 5c).

Seagrass biomass was generally less than 10 g DW m⁻² in meadows (Map 5). Regions of high seagrass biomass include the Warrior Reefs, the eastern edge of the Dugong Sanctuary subtidal meadow, and reef top meadows and surrounding islands between Prince of Wales Island and Orman Reefs (Map 6). Seagrass diversity was lowest in the central and eastern Torres Strait (Map 7). Seagrass diversity hotspots were identified in meadows between Horn, Wednesday and Hammond Island, and between Badu and Moa Islands, and the eastern edge of the Dugong Sanctuary subtidal meadow (Map 8).












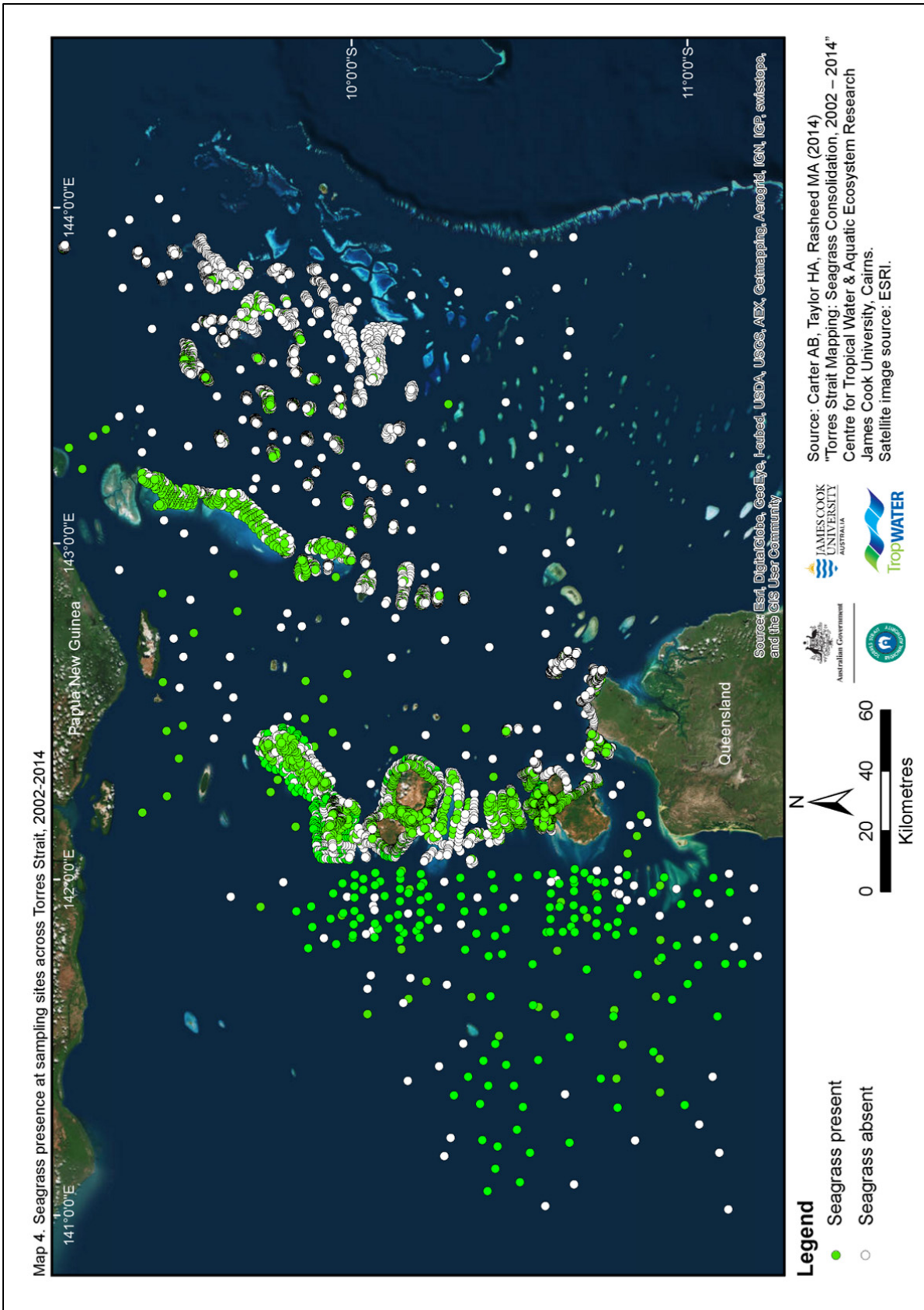
FAMILY	SPECIES		
CYMODOCACEAE E Taylor	 <p data-bbox="544 304 782 367"><i>Cymodocea serrulata</i> (R.Br.) Aschers and Magnus</p>	 <p data-bbox="1031 304 1351 388"><i>Halodule uninervis</i> (thin and wide leaf morphology) (Forssk.) Boiss.</p>	
	 <p data-bbox="544 514 782 577"><i>Cymodocea rotundata</i> Asch. & Schweinf.</p>	 <p data-bbox="1031 525 1351 588"><i>Syringodium isoetifolium</i> (Ashcers.) Dandy</p>	
	ZOSTERACEAE Drummondier	 <p data-bbox="544 766 782 829"><i>Zostera muelleri</i> subsp. <i>Capricorni</i> (Aschers.)</p>	 <p data-bbox="1031 787 1351 850"><i>Thalassodendron ciliatum</i> (Forssk.) Hartog</p>
		HYDROCHARITACEAE Jussieu	 <p data-bbox="544 1102 782 1165"><i>Thalassia hemprichii</i> (Ehrenb. ex Solms) Asch.</p>
 <p data-bbox="544 1375 782 1407"><i>Enhalus acoroides</i> (L.F.) Royle</p>	 <p data-bbox="1096 1375 1351 1428"><i>Halophila ovalis</i> (R. Br.) Hook. F.</p>		
 <p data-bbox="544 1575 782 1627"><i>Halophila spinulosa</i> (R. Br.) Aschers.</p>	 <p data-bbox="1096 1575 1351 1627"><i>Halophila decipiens</i> (Ostenfeld)</p>		

Figure 3. Seagrass species present across Torres Strait intertidal and subtidal meadows, 2002-2014.



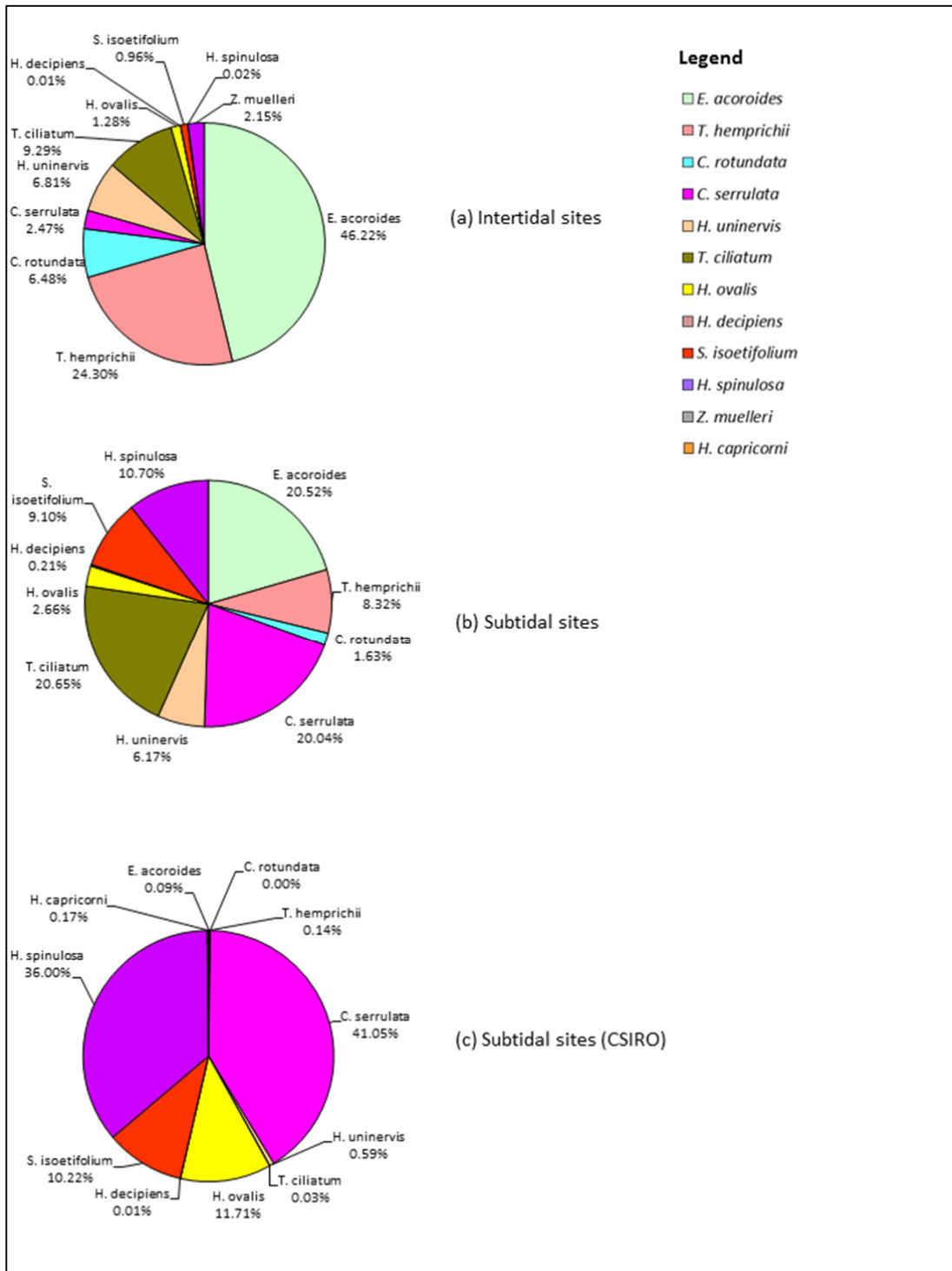


Figure 4. Average seagrass species composition at sites with seagrass across Torres Strait (a) intertidal and (b) subtidal meadows (2002-2014), and (c) subtidal meadows surveyed during CSIRO cruise (2005).

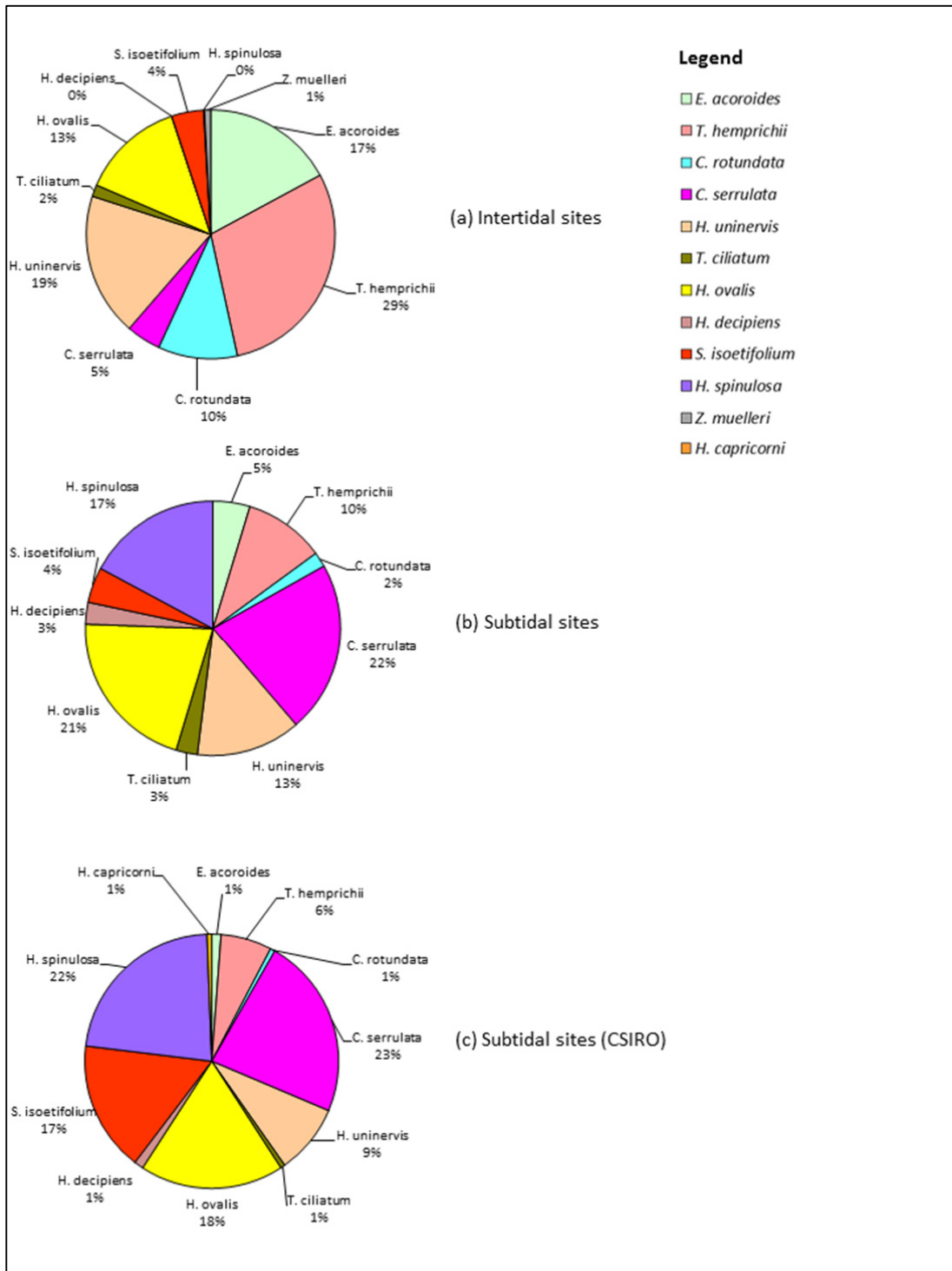
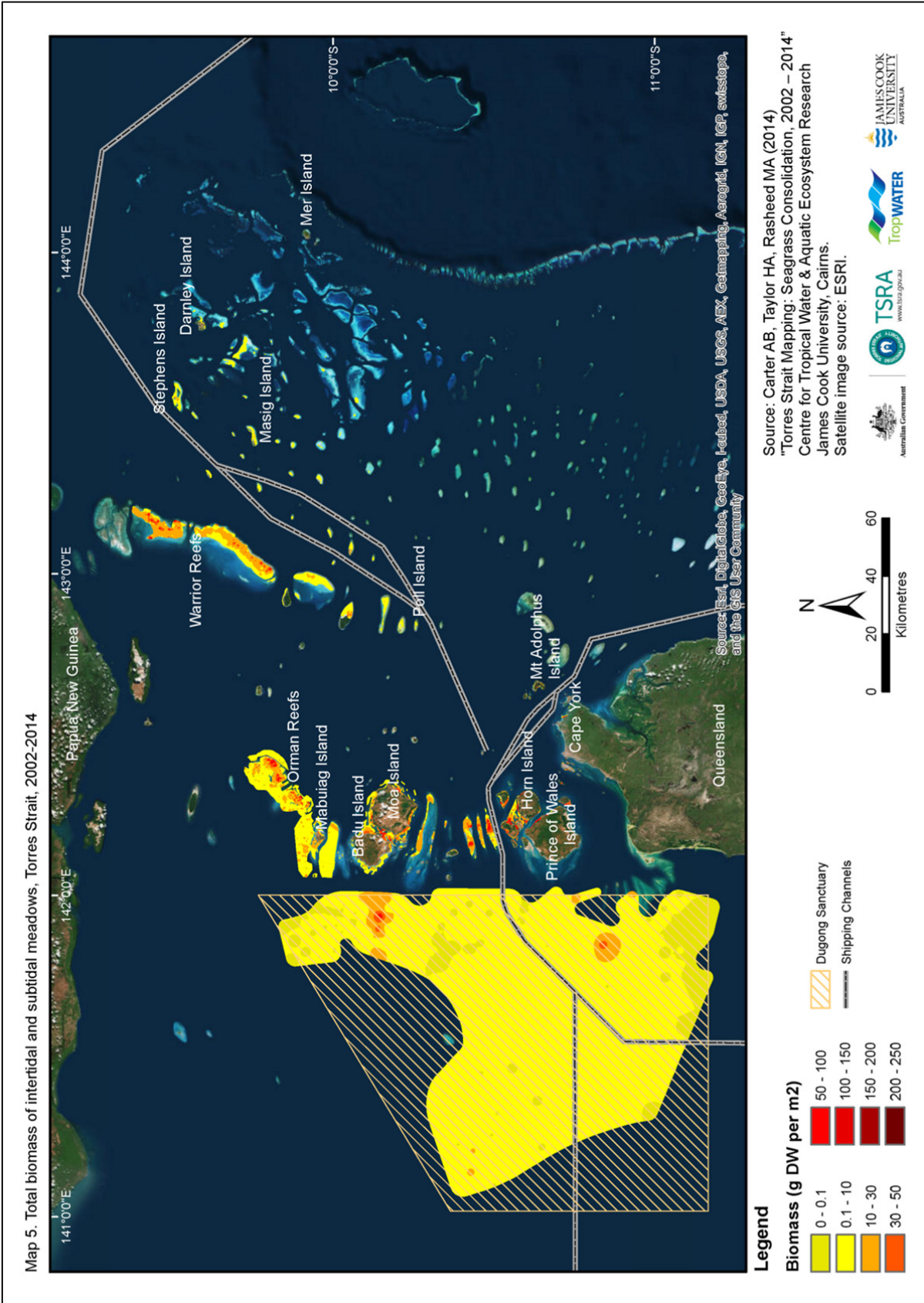
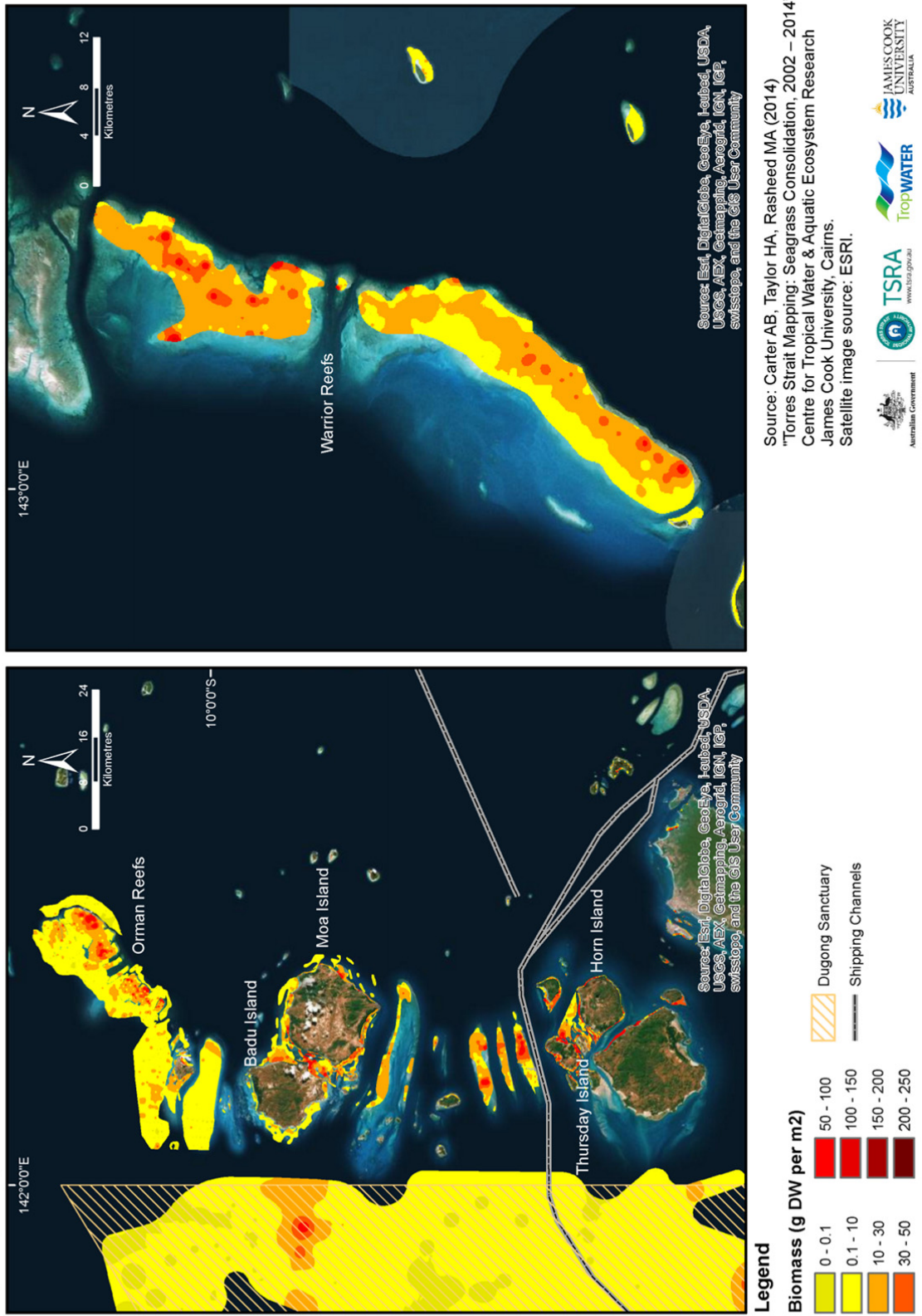
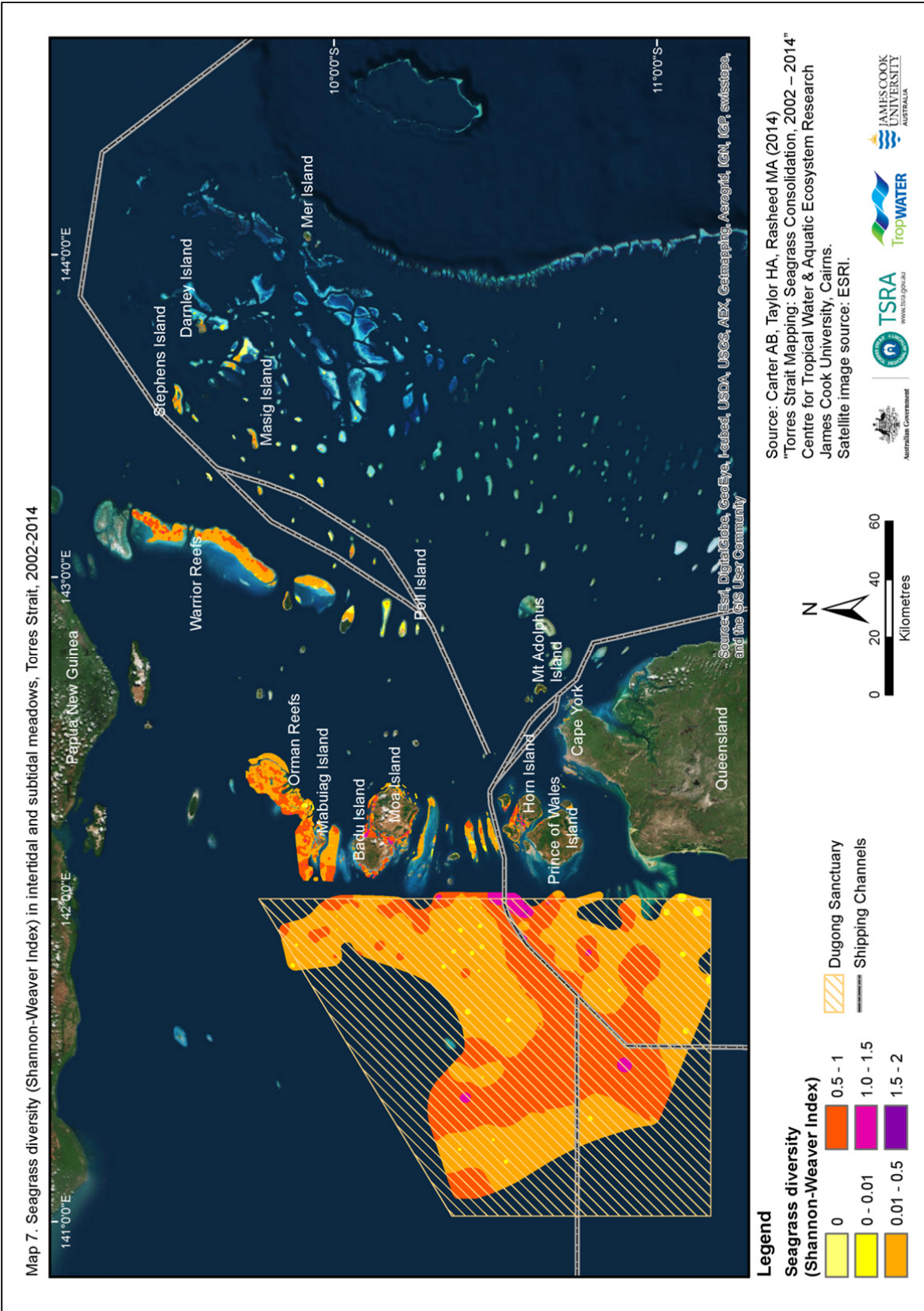


Figure 5. Presence of seagrass species at sites with seagrass across Torres Strait (a) intertidal and (b) subtidal meadows (2002-2014), and (c) subtidal meadows surveyed during CSIRO cruise (2005).

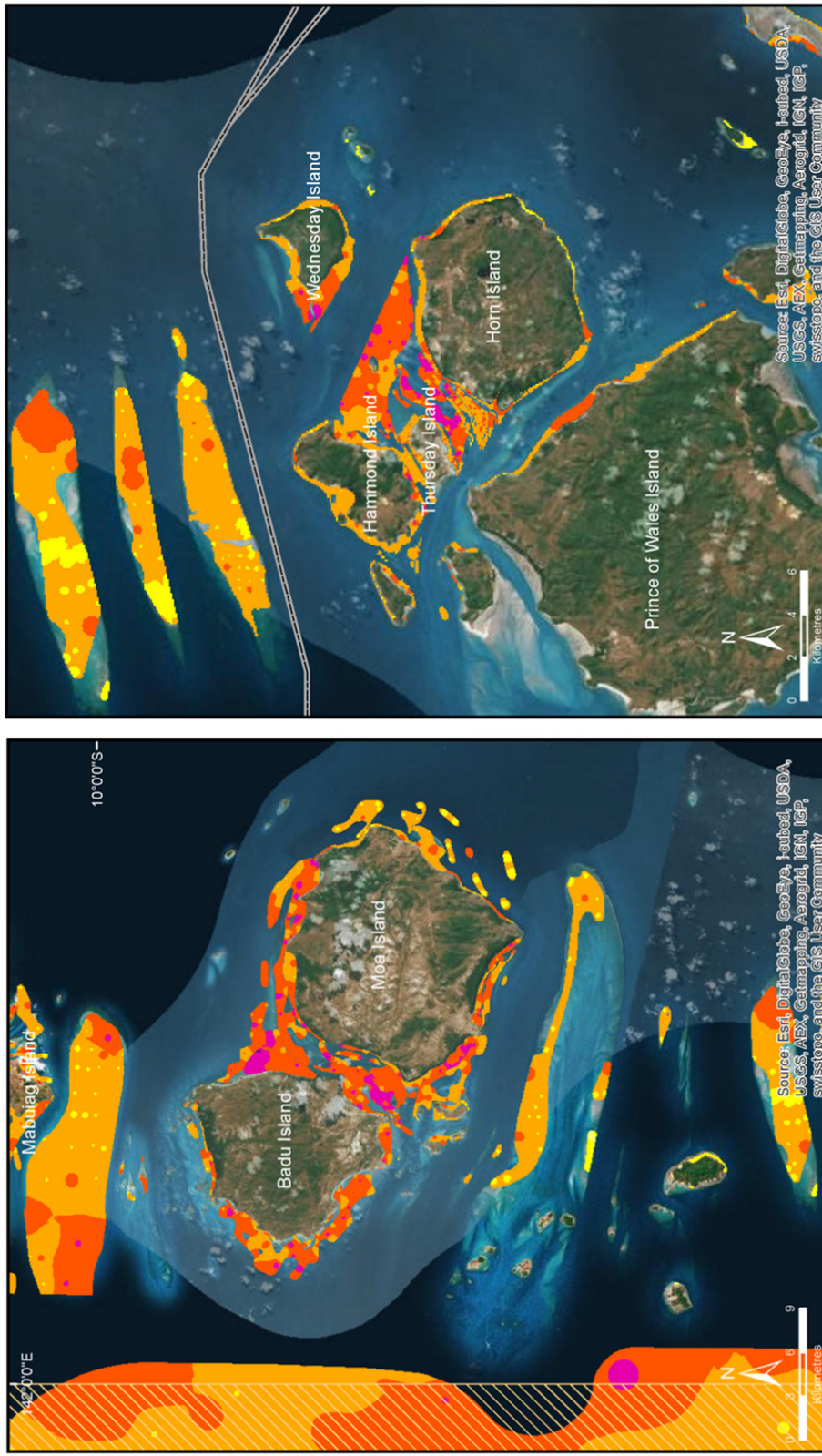


Map 6. Regions of peak biomass for intertidal and subtidal meadows, Torres Strait, 2002-2014





Map 8. Seagrass diversity (Shannon-Weaver Index) hotspots in intertidal and subtidal meadows, Torres Strait, 2002-2014



Source: Carter AB, Taylor HA, Rasheed MA (2014)
 "Torres Strait Mapping: Seagrass Consolidation, 2002 – 2014"
 Centre for Tropical Water & Aquatic Ecosystem Research
 James Cook University, Cairns.
 Satellite image source: ESRI.



3.2 Key findings for each species

H. spinulosa was recorded throughout most of the Dugong Sanctuary meadow, subtidal areas around Orman Reefs to Mabuiag Island, and small patches between Horn and Hammond Island (Maps 9, 20-22).

H. ovalis was recorded throughout most of the Dugong Sanctuary meadow, intertidal and subtidal areas around Orman Reefs to Prince of Wales Island, Warrior Reefs intertidal reef tops, and intertidal areas in north east Torres Strait (Maps 10, 21-22). *H. ovalis* is a low biomass species so meadows were rarely classed as *H. ovalis* dominant; a few exceptions were small meadows near Moa and Badu Island and in the Horn Island region (Map 21).

H. decipiens was mainly recorded in patches on the eastern side of the Dugong Sanctuary meadow, subtidal areas around Orman Reefs, and small patches from Mabuiag Island to Thursday Island (Maps 11, 22). *H. decipiens* is a low biomass species and only one meadow was classed as *H. decipiens* dominant, at Orman Reefs (Map 21).

S. isoetifolium was recorded in patches throughout most of the Dugong Sanctuary meadow, and intertidal and subtidal areas following the island chain from western Cape York to Boigu Island near Papua New Guinea (Maps 12, 22). *S. isoetifolium* was the dominant species in the large subtidal meadow between Mabuiag Island and Orman Reefs (Map 21).

H. uninervis was mainly recorded in patches on the eastern side of the Dugong Sanctuary meadow, and reef top meadows and surrounding islands between Prince of Wales Island and Orman Reefs (Maps 13, 22). *H. uninervis* is a low biomass species and meadows were rarely classed as *H. uninervis* dominant; several exceptions include small meadows in the Moa and Badu Island region (Map 21).

C. serrulata was recorded throughout the Dugong Sanctuary meadow, intertidal and subtidal areas between Prince of Wales Island and Boigu Island, and patches in the Warrior Reef/ Sassie Island region (Maps 14, 20-22). High biomass *C. serrulata* sites ($> 30 \text{ g DW m}^{-2}$) occurred in the areas between Horn and Hammond Islands, where *C. serrulata* was the dominant species (Maps 14, 21). *C. serrulata* was also the dominant species in meadows in the Moa and Badu Island region (Map 21).

C. rotundata was recorded in intertidal meadows from Orman Reefs to Prince of Wales Island, the Warrior Reef/ Sassie Island region, and intertidal areas in north east Torres Strait (Map 15). High biomass *C. rotundata* sites occurred in meadows in the Prince of Wales, Wednesday and Horn Island region, and the Badu and Moa Island regions where a few small meadows were classed as *C. rotundata* dominated (Maps 15, 21).

T. hemprichii was recorded in intertidal and subtidal meadows from Orman Reefs to Prince of Wales Island, and the Warrior Reef/ Sassie Island and north east Torres Strait regions (Maps 16, 22). Very high biomass *T. hemprichii* sites ($> 50 \text{ g DW m}^{-2}$) occurred on reef tops at the south Warrior Reefs and north Orman Reefs (Map 16). *T. hemprichii* was the dominant species in the Warrior Reef/ Sassie Island and north east Torres Strait region in all but one meadow (northern Warrior Reefs, Map 20). *T. hemprichii* was also the dominant species in many of the intertidal and shallow subtidal meadows between Orman Reefs and Horn Island (Map 21).

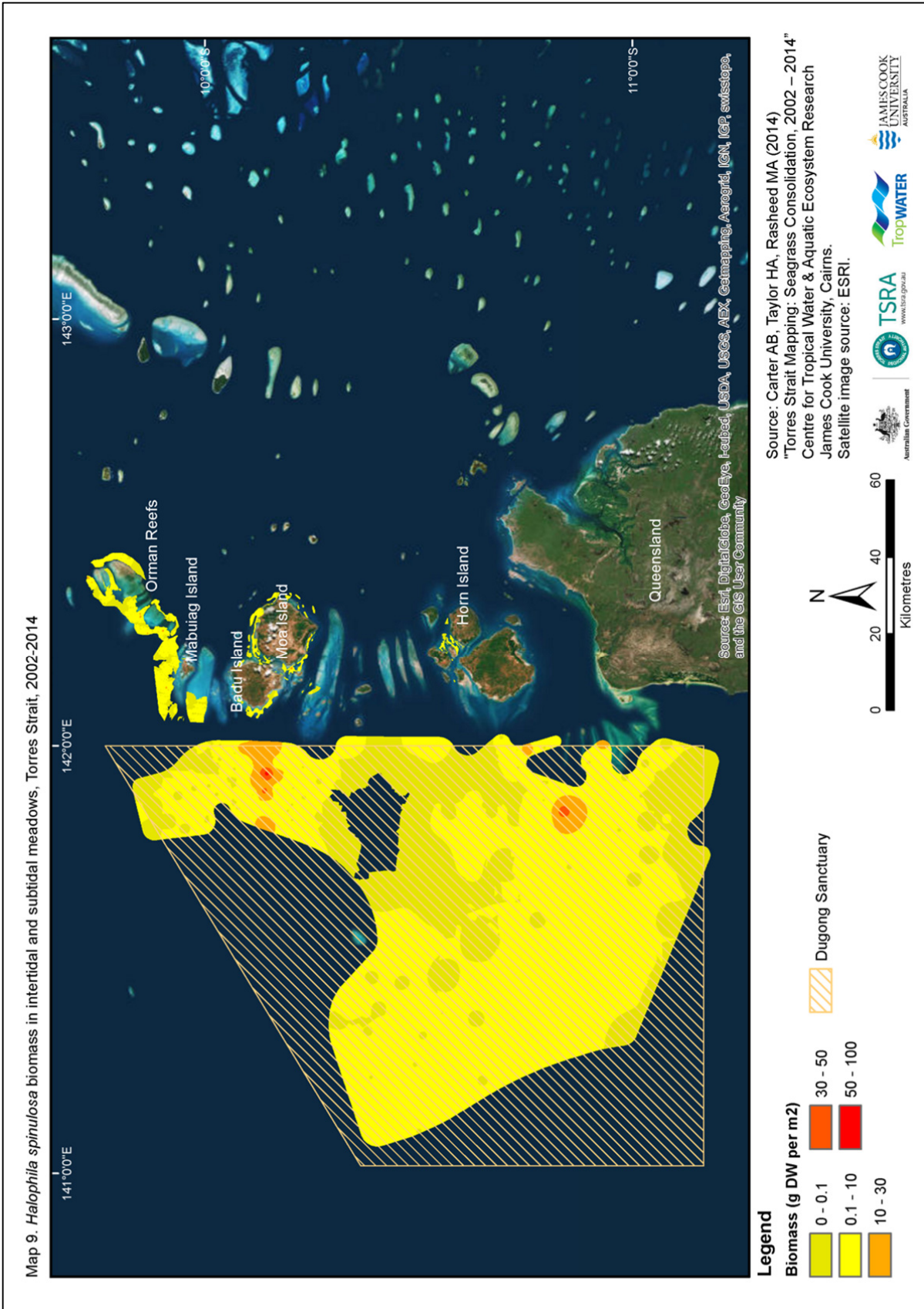
E. acoroides was recorded in intertidal and shallow subtidal areas following the island chain from western Cape York to Saibai Island near Papua New Guinea, intertidal areas in the Warrior Reef/ Sassie Island region, and small patches around Stephens and Darnley Islands in north east Torres Strait (Maps 17, 22). Very high biomass *E. acoroides* sites ($> 50 \text{ g DW m}^{-2}$) occurred on

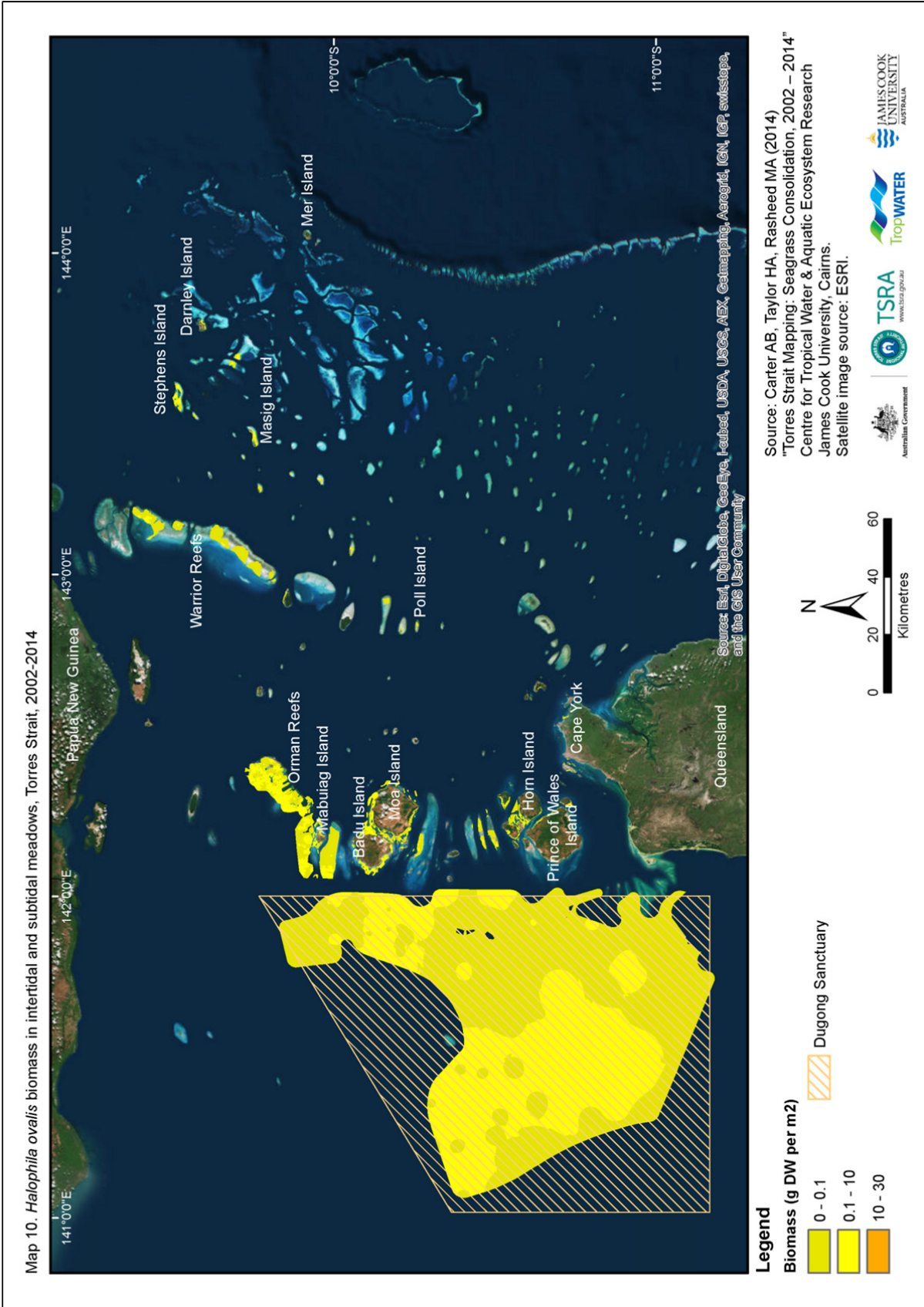
reef tops at the Orman Reefs and the Prince of Wales, Hammond and Horn Island region (Map 17). *E. acoroides* was the dominant species in the intertidal meadow on north Warrior Reef and in many of the intertidal meadows between Orman Reefs and western Cape York peninsula (Maps 20-21).

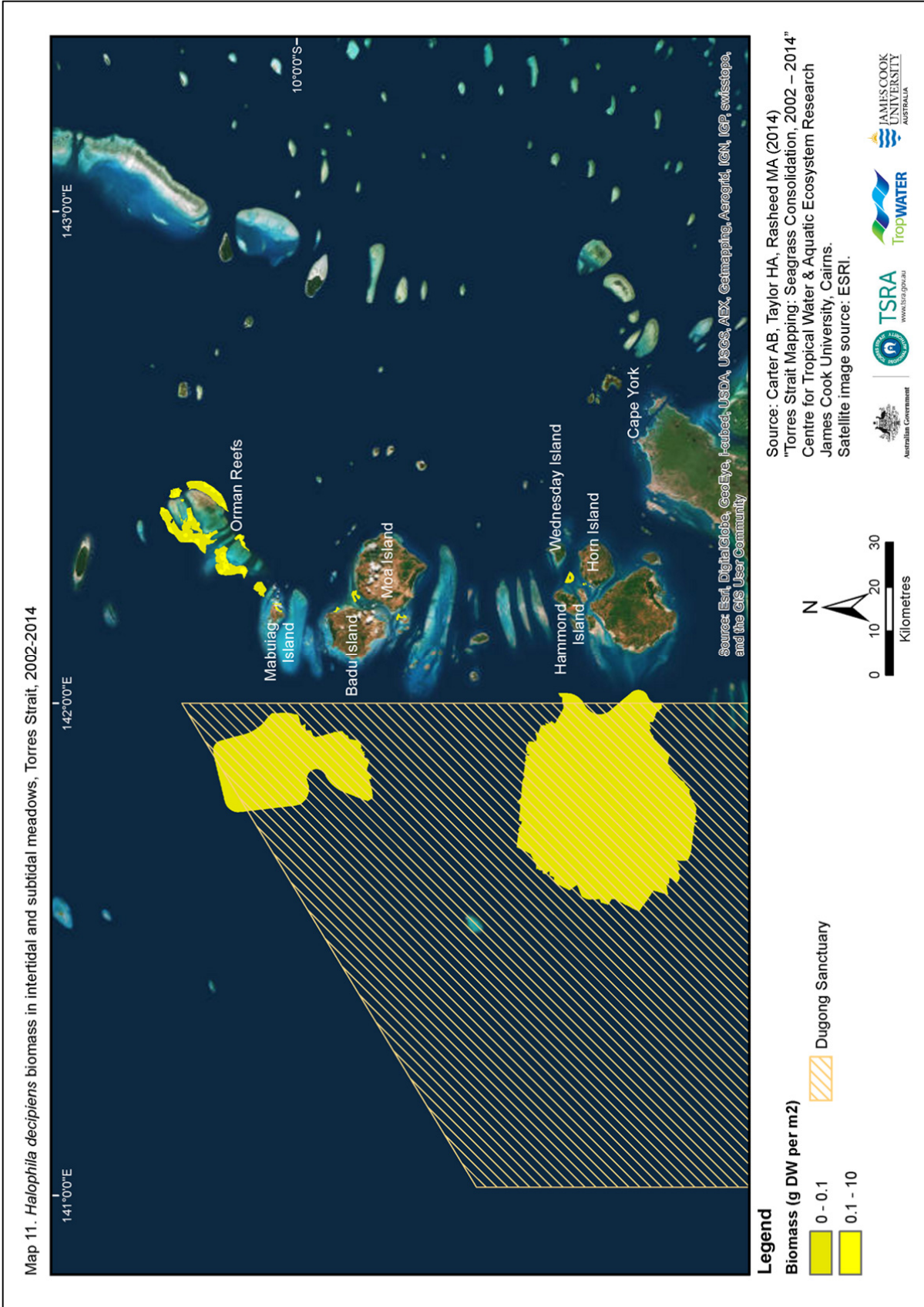
T. ciliatum was recorded in intertidal and subtidal areas following the island chain from Prince of Wales to Orman Reefs, intertidal areas on the Warrior Reefs, and several small patches in the north east section of the Dugong Sanctuary meadow (Map 18). Sites with very high biomass ($> 50 \text{ g DW m}^{-2}$) were recorded throughout the intertidal regions where *T. ciliatum* was found (Map 18). *T. ciliatum* was the dominant species in several meadows, including south Orman Reefs, between Badu and Moa Islands, between Hammond and Thursday Islands, and northern Wednesday Island (Map 21).

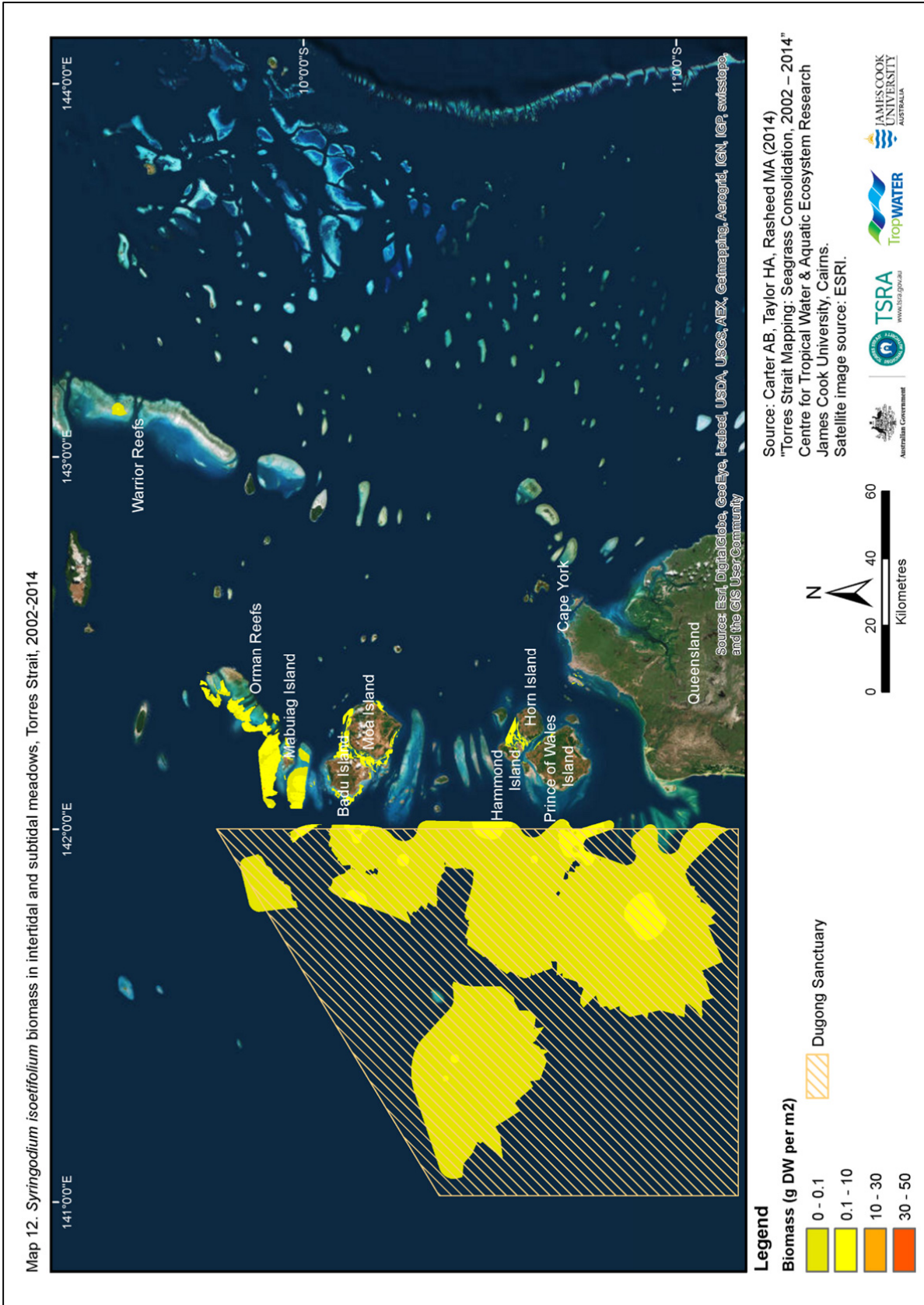
Z. muelleri subsp. *capricorni* had the smallest distribution of intertidal species recorded in Torres Strait, with small patches recorded on the northern tip of Cape York, Adolphus Island, and in the area between Prince of Wales, Horn and Hammond Islands (Map 19). Sites with very high biomass ($> 50 \text{ g DW m}^{-2}$) of *Z. muelleri* subsp. *capricorni* sites were recorded at Cape York, Prince of Wales Island and Horn Island (where it was also the dominant species in one meadow (Maps 19, 21). *Z. muelleri* subsp. *capricorni* was not present at any of the subtidal sites surveyed during the 2005 CSIRO cruise (Map 22).

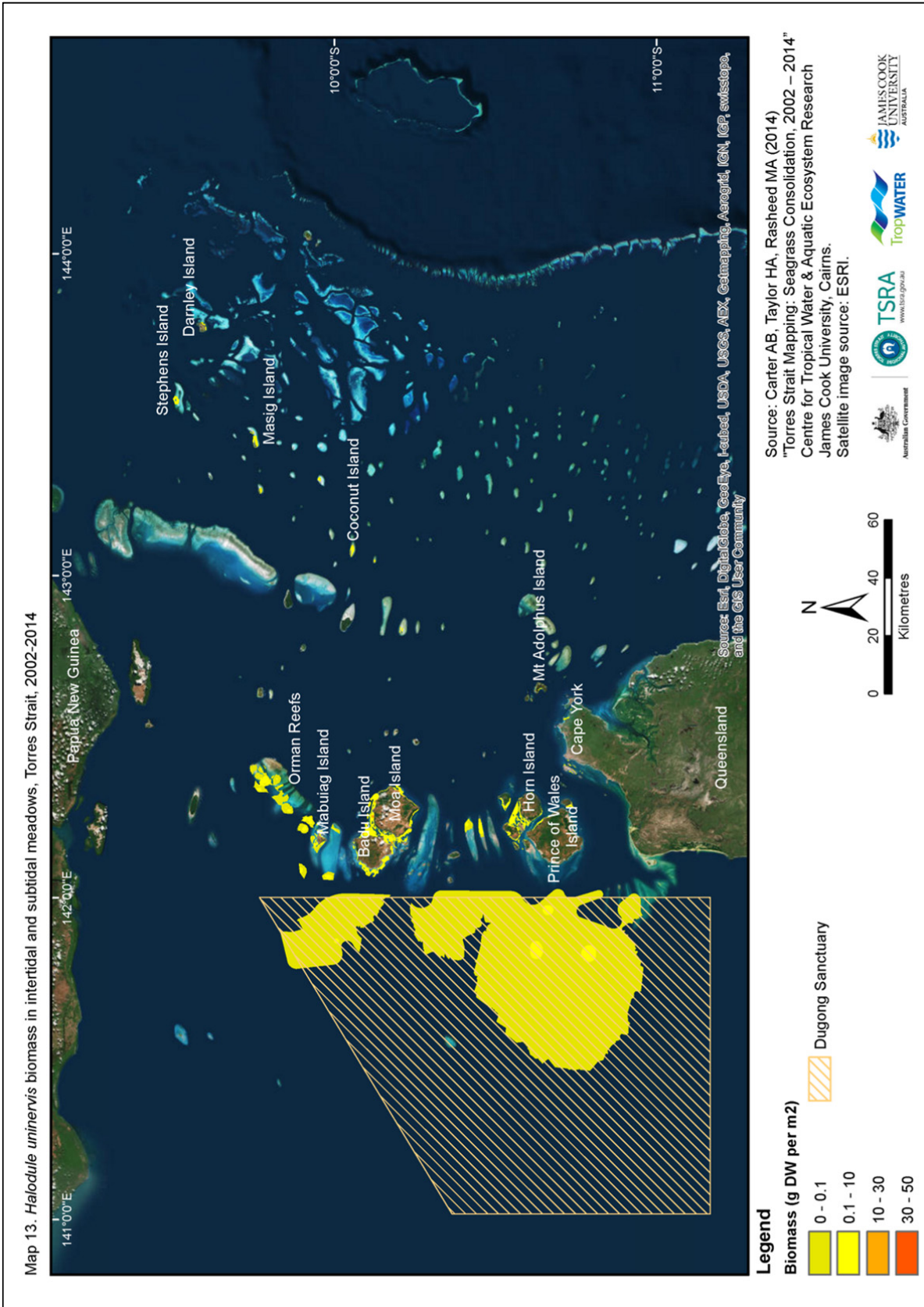
H. capricorni was recorded at only one subtidal site, just west of Orman Reefs, as one of six species at a site dominated by *S. isoetifolium* and *H. spinulosa* (Map 22).

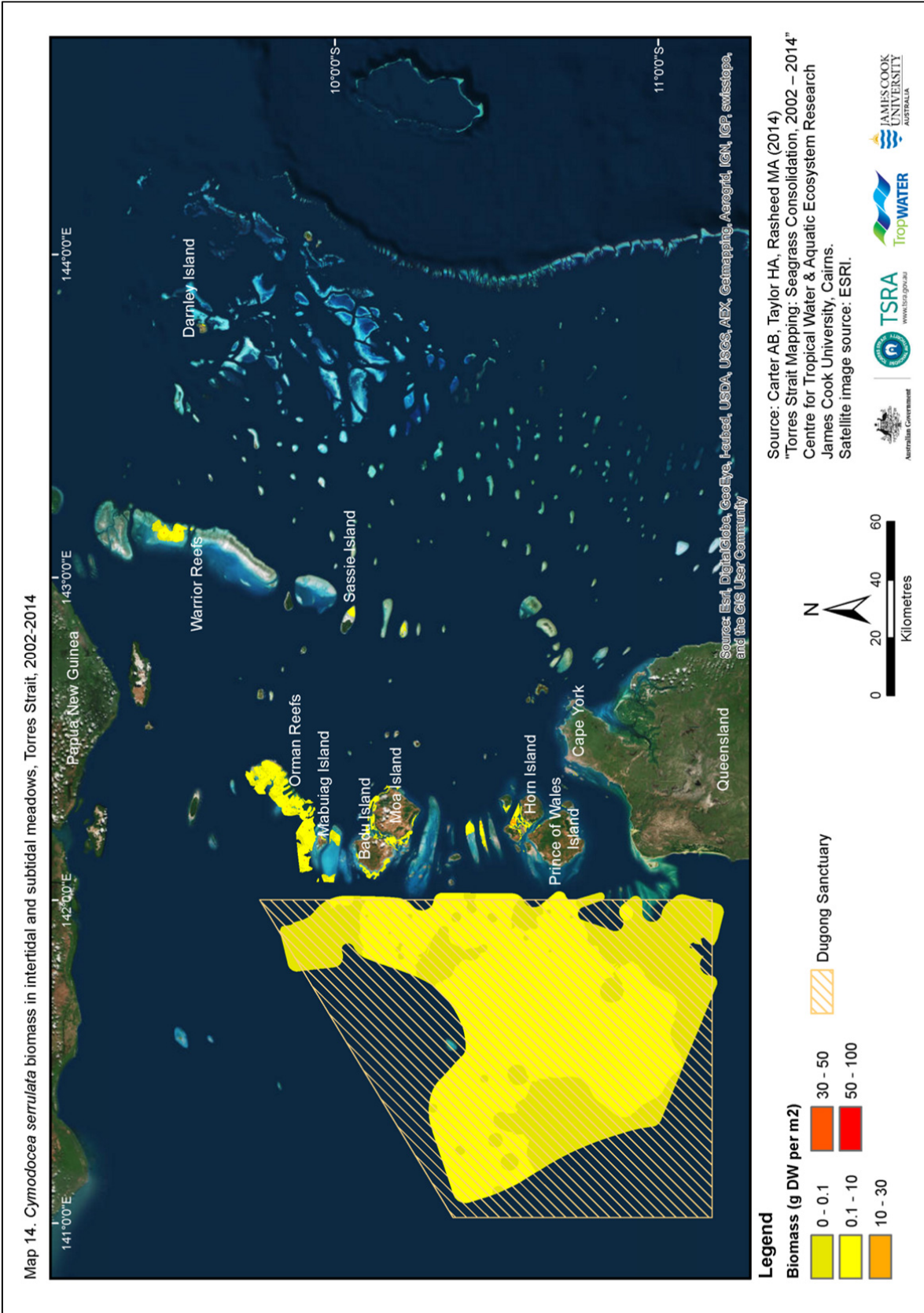


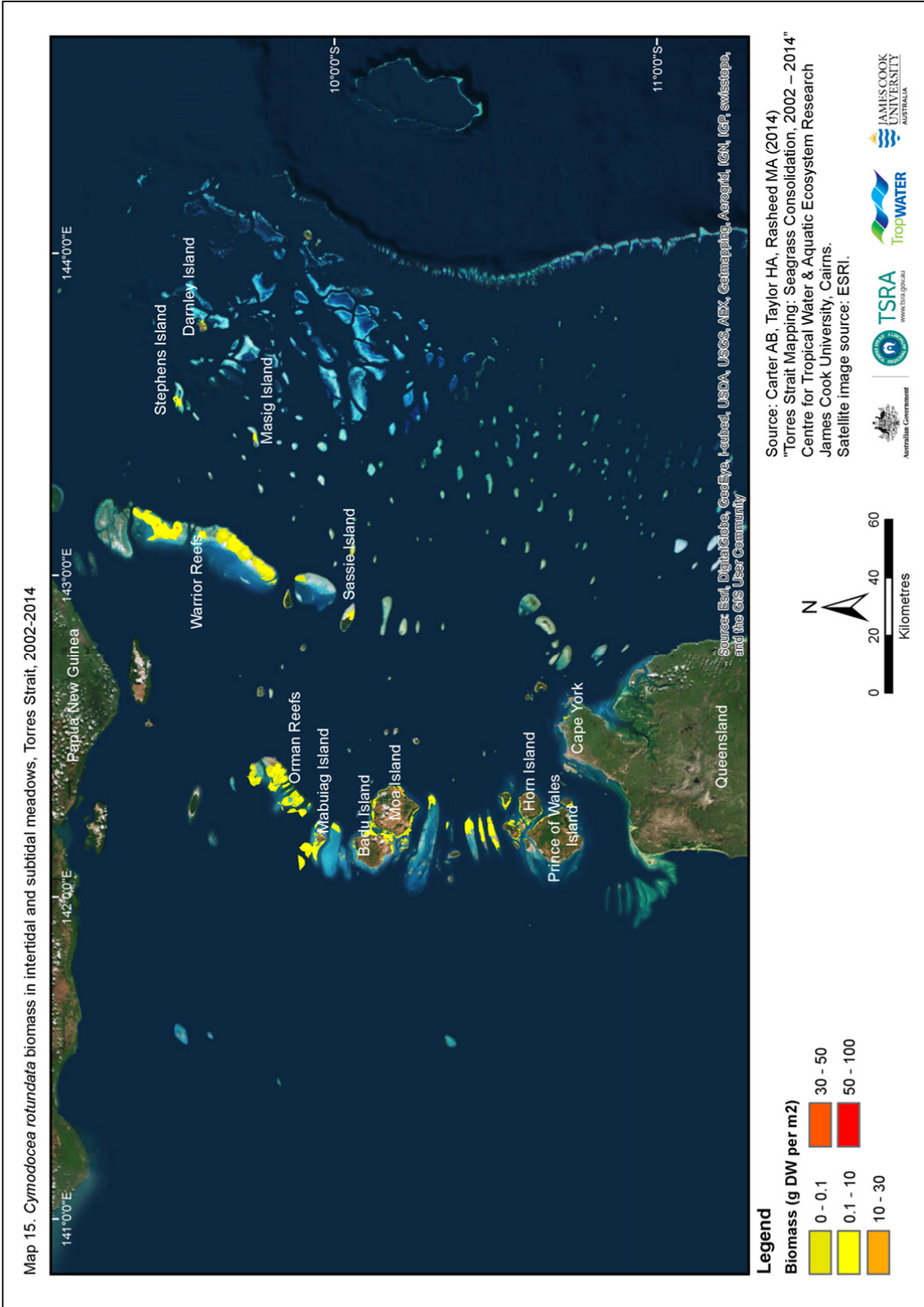


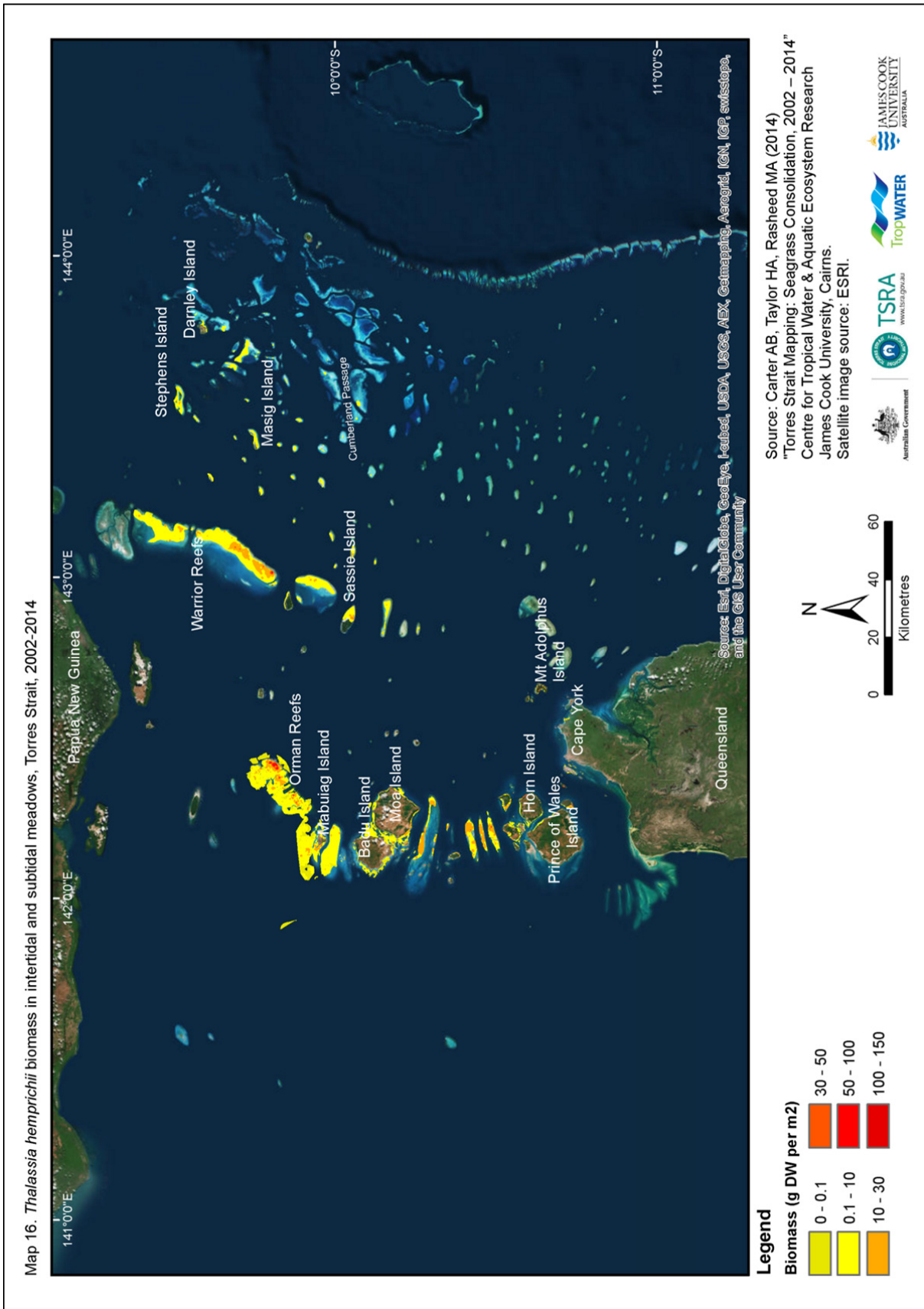


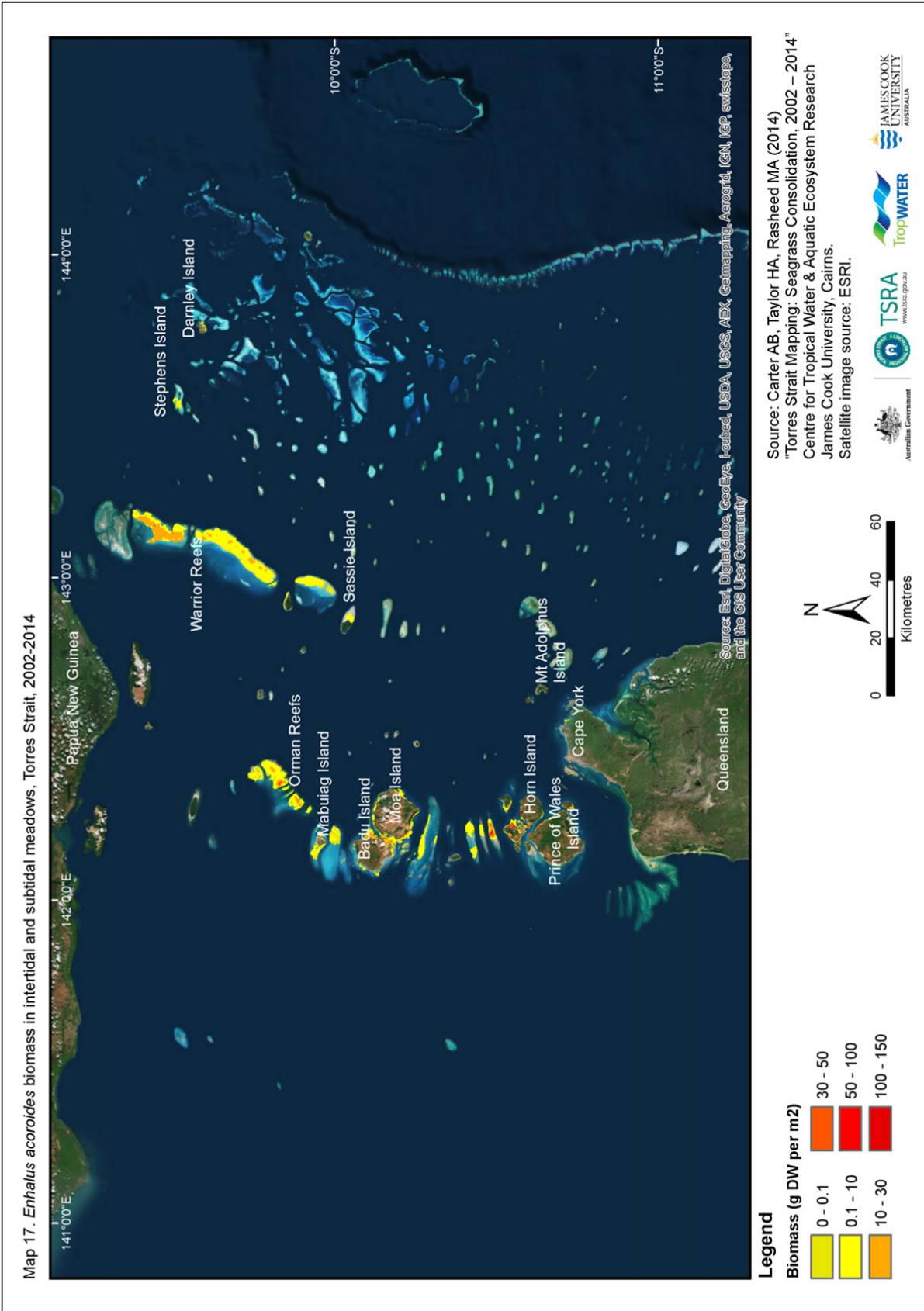


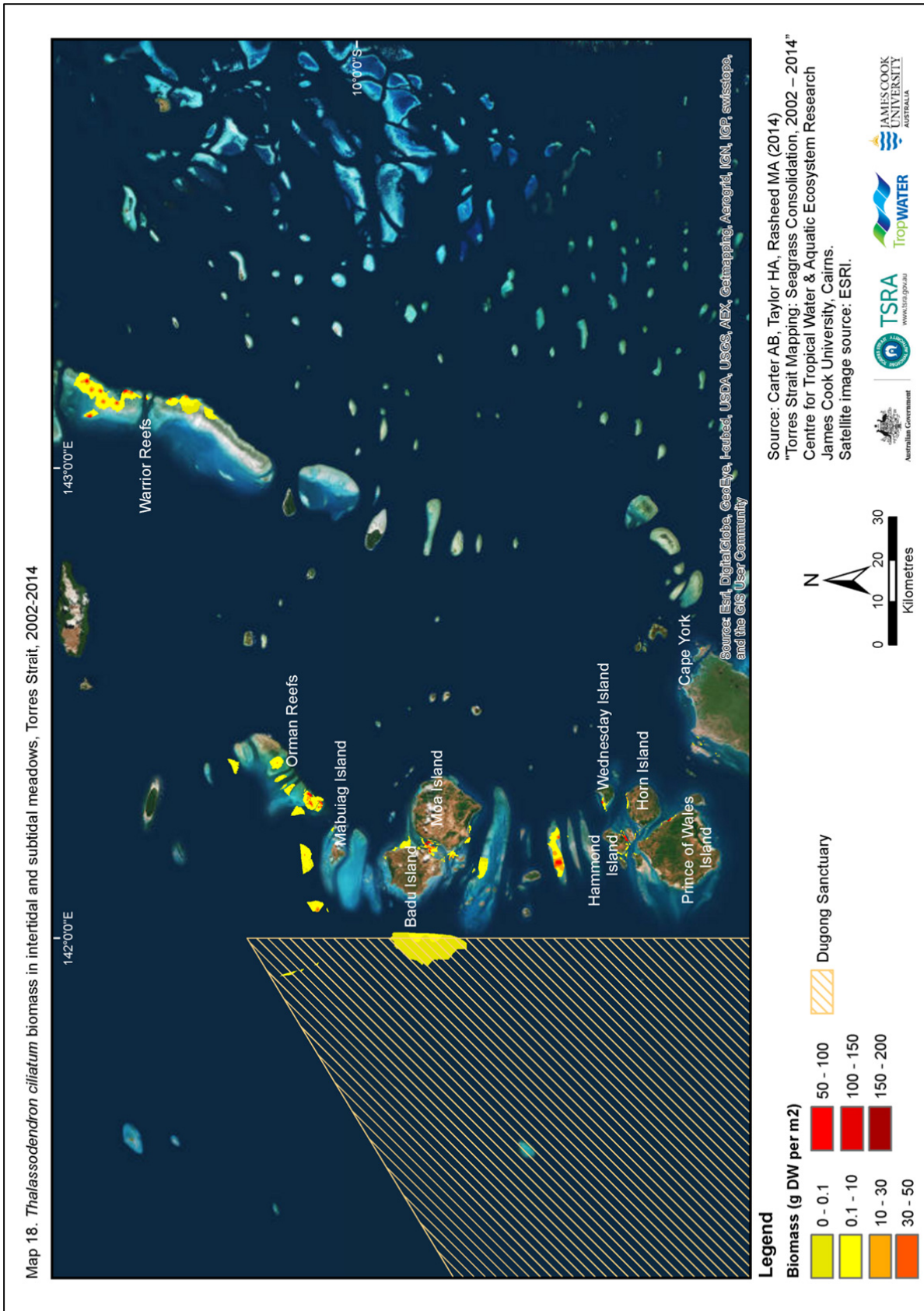


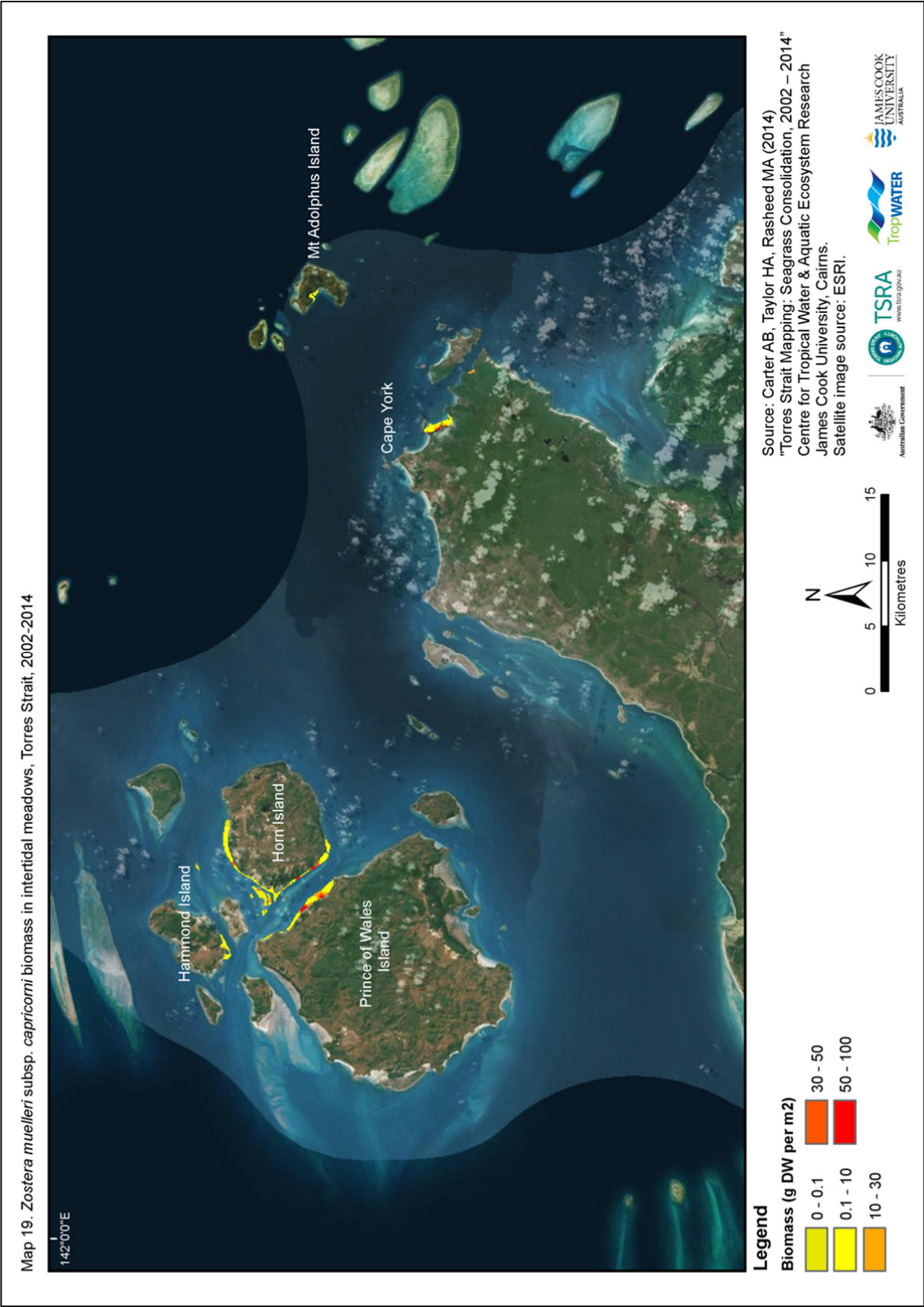


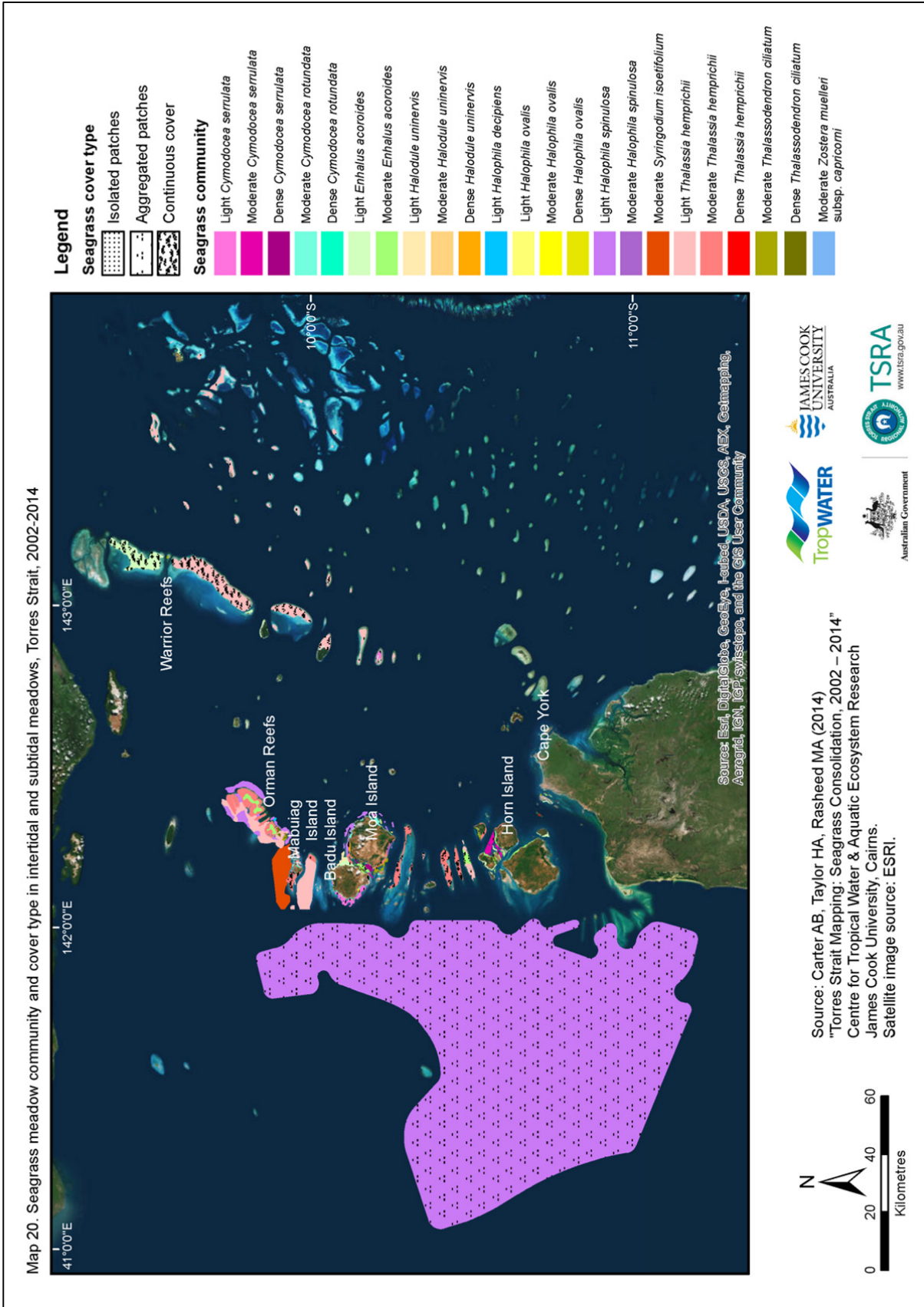




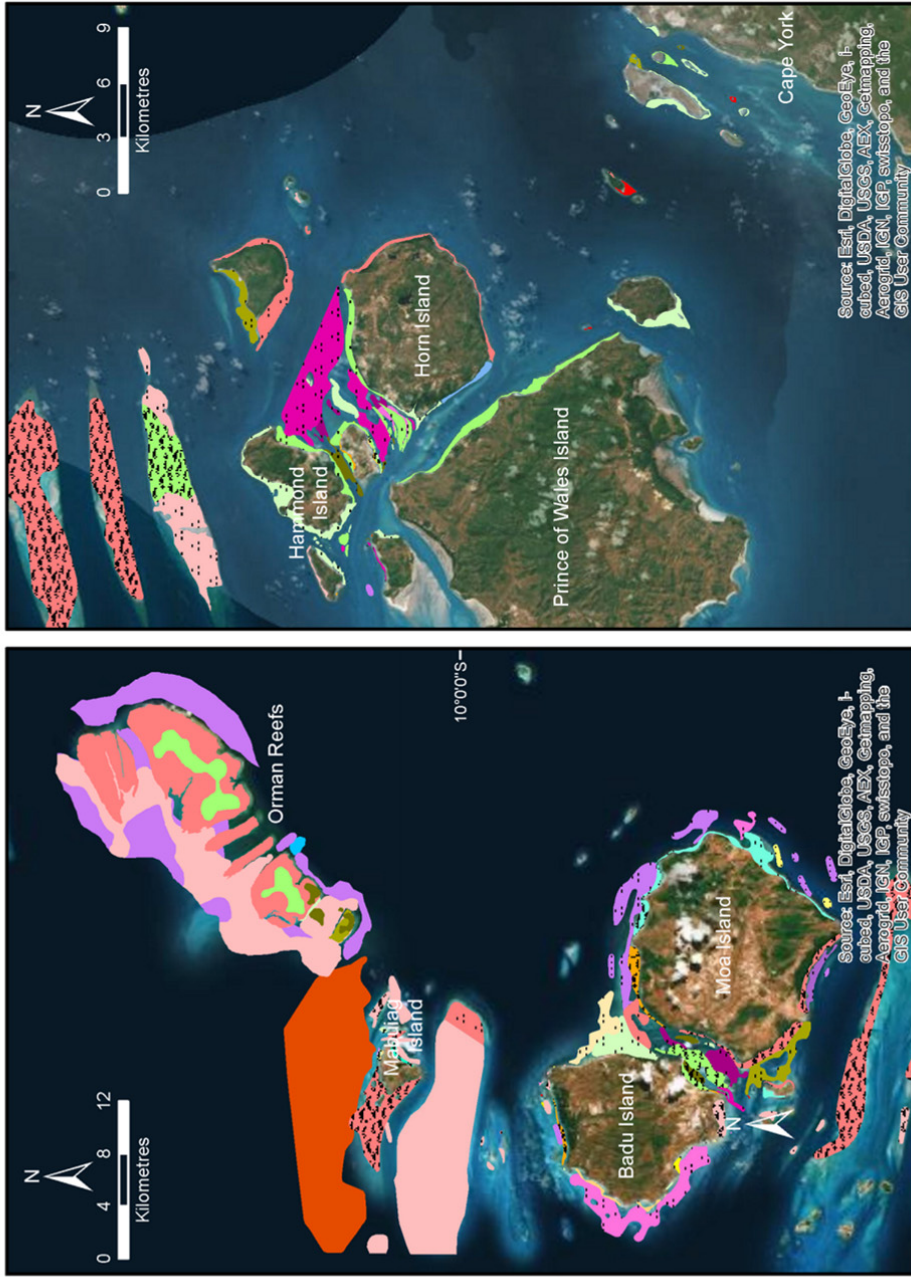








Map 21. Seagrass meadow community and cover type in intertidal and subtidal meadows, Torres Strait, 2002-2014



Legend

Seagrass cover type

- Isolated patches
- Aggregated patches
- Continuous cover

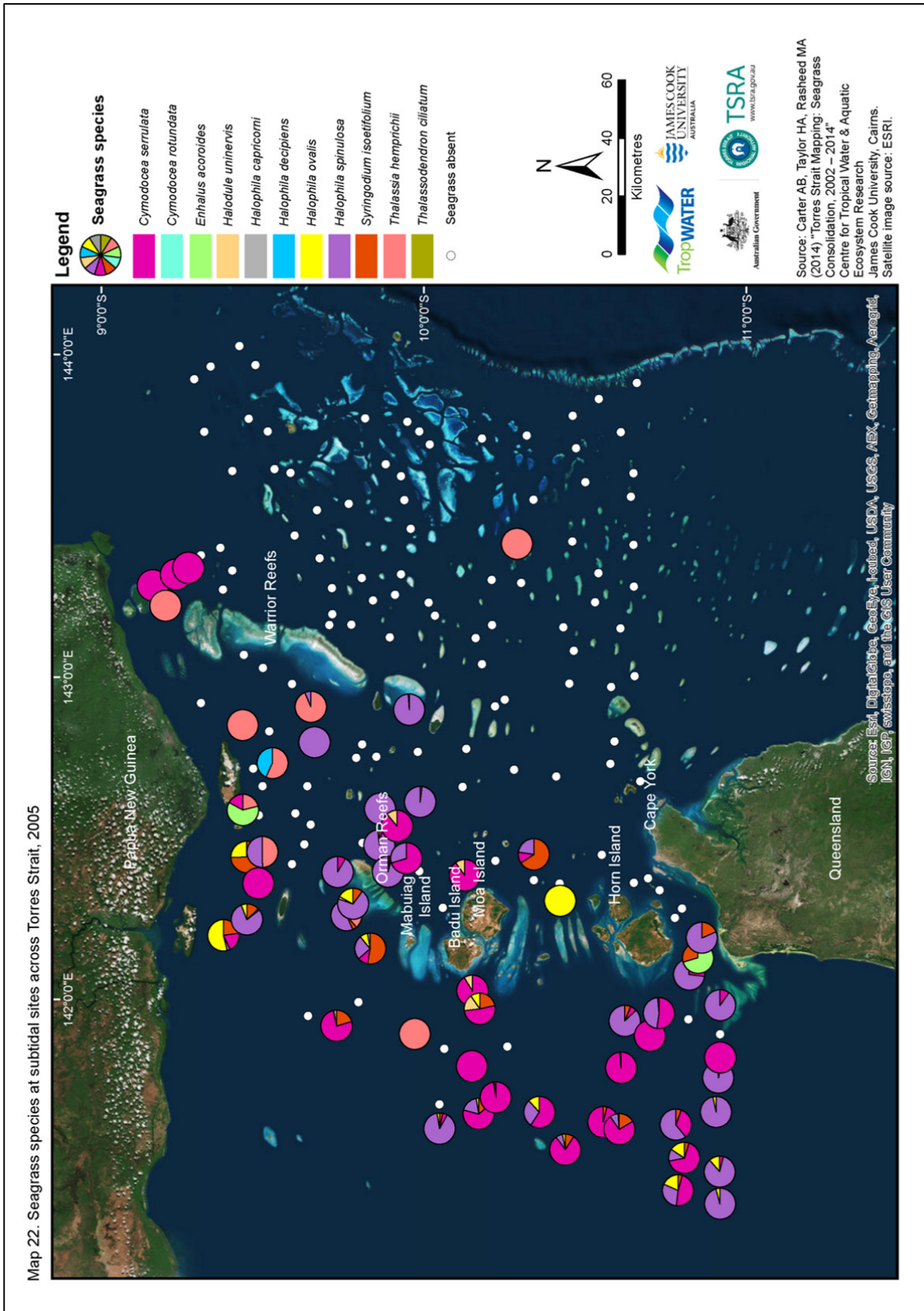
Seagrass community

- Light *Cymodocea serrulata*
- Moderate *Cymodocea serrulata*
- Dense *Cymodocea serrulata*
- Moderate *Cymodocea rotundata*
- Dense *Cymodocea rotundata*
- Light *Enhalus acoroides*
- Moderate *Enhalus acoroides*
- Light *Halodule uninervis*
- Moderate *Halodule uninervis*
- Dense *Halodule uninervis*
- Light *Halophila decipiens*
- Light *Halophila ovalis*
- Moderate *Halophila ovalis*
- Dense *Halophila ovalis*
- Light *Halophila spinulosa*
- Moderate *Halophila spinulosa*
- Moderate *Syringodium isoetifolium*
- Light *Thalassia hemprichii*
- Moderate *Thalassia hemprichii*
- Dense *Thalassia hemprichii*
- Moderate *Thalassodendron ciliatum*
- Dense *Thalassodendron ciliatum*
- Moderate *Zostera muelleri* subsp. *capricorni*

Source: Esri, DigitalGlobe, GeoEye, I-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Source: Esri, DigitalGlobe, GeoEye, I-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Source: Carter AB, Taylor HA, Rasheed MA (2014) "Torres Strait Mapping: Seagrass Consolidation, 2002 – 2014" Centre for Tropical Water & Aquatic Ecosystem Research James Cook University, Cairns. Satellite image source: ESRI.



4 DISCUSSION

This study provides a comprehensive spatial description of intertidal and subtidal seagrass resources across Torres Strait, incorporating data collected over 12 years. Species diversity and biomass hotspots were primarily found on reeftops and surrounding continental islands between Prince of Wales Island and Orman Reefs. Subtidal seagrasses showed a clear distributional pattern and were almost exclusively located west of the Warrior Reefs. Intertidal seagrass was present east of the Warrior Reefs but was almost exclusively restricted to *T. hemprichii*.

The Dugong Sanctuary in western Torres Strait contains the largest recorded single continuous seagrass meadow in Australia and, along with extensive intertidal and subtidal meadows extending from Prince of Wales Island to the Orman Reefs, is likely to play a vital role for local dugong and turtle populations as an important food resource. Seagrass species found included those known to be important for dugong and turtles (Aragones et al. 2006; Bjorndal 1995) as well as nursery grounds for commercial fisheries species (Coles et al. 1993; Watson et al. 1993). An analysis of the data collated during this study indicates that seagrass remains in the area throughout the year, providing an important and consistent food source for dugong and turtle.

Torres Strait contains a high diversity of seagrass species. Species rich seagrass assemblages in the Indo-Pacific Ocean may be a product of past grazing activities of large herbivores, particularly dugong (Heck and Valentine 2006). When feeding, dugong often remove the entire plant (including roots and rhizomes) which tends to prevent the development of a climax community dominated by a single species, and allows their preferred forage species to persist (Aragones et al. 2006). The vast area of highly diverse seagrasses provides a consistent source of primary production supporting the region's marine ecosystems. Studies at the nearby Orman Reefs and Mabuiag Island have shown Torres Strait seagrass meadows are extremely productive, completely turning over their above-ground biomass in as little as 9 and 12 days respectively (Taylor et al. 2013; Rasheed et al. 2008).

Future changes in the distribution and structure of Torres Strait seagrass communities may have profound implications for local and regional biota, particularly dugong, turtle and economically important fisheries. The spatial distribution of quality food strongly influences the movement patterns and foraging behaviours of dugong (Sheppard et al. 2007). Seagrass areas in Torres Strait have undergone 'diebacks', or large-scale episodic losses and changes in distribution on temporal scales of up to decades (Williams 1994). Torres Strait Islanders widely reported such a dieback event in the mid-1970s and in the early 1980s (Williams 1994; Johannes and MacFarlane 1991). Although the reasons behind these diebacks remain unclear, local dugong mortality rates increased dramatically following these events (Marsh et al. 2004). A similar pattern of large-scale seagrass loss across the east coast of Queensland in 2011 resulted in a 215% and 176% increase in dugong and turtle deaths respectively (compared to 2010), primarily as a result of starvation (DERM 2011). These statistics are alarming in the face of predicted climate change scenarios and the potential negative effect on seagrasses. The management of seagrass resources should be focused on reducing any anthropogenic impacts and risks to ensure resilience levels of local seagrass populations remain high.

4.1 Data deficient regions

Three Torres Strait regions were identified where basic knowledge of seagrass and benthic habitat is unknown or extremely limited (Map 23). These regions are:

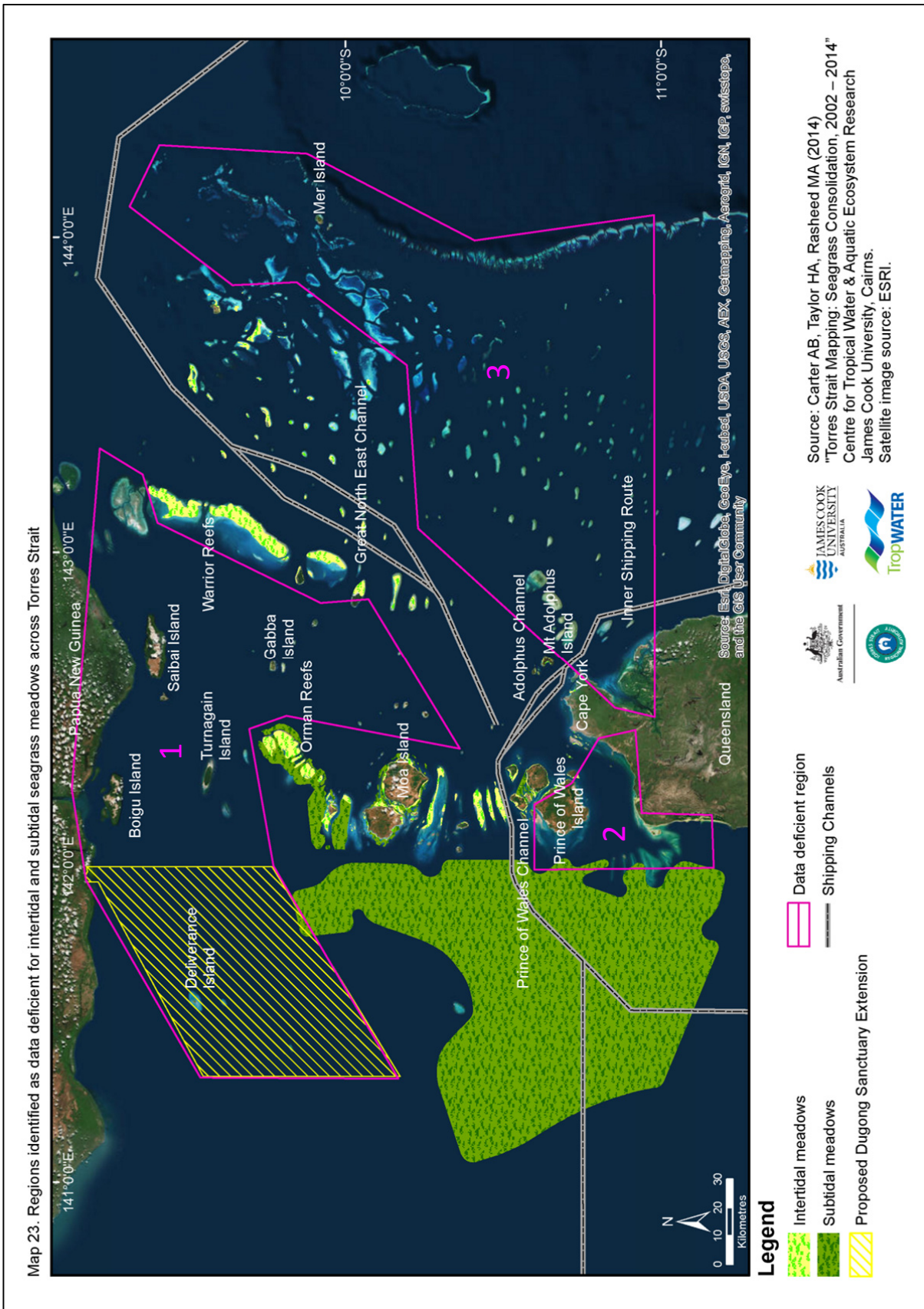
1. Data deficient region 1 - North of the Dugong Sanctuary, including the proposed Dugong Sanctuary extension area extending east to the Warrior Reefs. This region includes all subtidal areas and Deliverance, Boigu, Turnagain, Saibai and Gabba Islands. This region has been identified as containing large dugong and turtle populations, and is an important hunting and fishing ground for Traditional Owners, in particular people from Boigu Island (Map 23). A spatial model of dugong distribution based on aerial survey results (1987 - 2011) indicated the most important dugong habitat in Torres Strait is the ~10 500 km² area that extends from Badu/Moa Islands to Boigu Island, east to Gabba Island and west to Deliverance Island. This region contains 56% of the high and very high density dugong habitat in Torres Strait (Marsh et al. 2012).
2. Data deficient region 2 - Prince of Wales and western Cape York. Seagrass meadows already mapped adjacent to this region have high biomass and diversity. This data deficient region is adjacent to the Prince of Wales Shipping Channel so seagrasses in this region are particularly at risk from shipping accidents and oil and chemical spills (Map 23).
3. Data deficient region 3 - Eastern Cape York and south east Torres Strait. This data deficient region is adjacent to the Adolphus Shipping Channel and Inner Shipping Route, and includes reefs and islands to the south of the Great Northeast Shipping Channel, so seagrasses in this region are also particularly at risk from shipping accidents and oil and chemical spills (Map 23).

4.2 Recommendations

This study provides a valuable spatial assessment of the current state of knowledge of intertidal and subtidal seagrass biomass, meadow area, species composition and species diversity across Torres Strait. Future priorities for seagrass research in Torres Strait should focus on gathering information on seagrasses in data deficient regions identified in this report, extending the current data set to assess habitats at risk from shipping accidents across Torres Strait, and using this spatial data to model oil spill scenarios. We recommend:

1. Conduct subtidal and intertidal seagrass surveys in data deficient regions 1-3. This would provide Torres Strait Islanders with detailed maps of intertidal and subtidal seagrass habitats in regions where there is currently no data available. This is particularly important in data deficient region 1 (northern Torres Strait) where dugong occur in the highest densities (Marsh et al. 2012). Gathering information on seagrass habitat in all data deficient regions are particularly important, however, considering the Torres Strait community's dependence on fisheries from an economic and subsistence perspective, and the importance of seagrass meadows as fisheries habitat. Data collected during intertidal surveys would also continue the 2002 - 2013 mapping of marine habitats at risk from shipping in Torres Strait (see Recommendation 2, below). Information on the biomass, distribution and species composition of seagrass can be used to inform future decision making on spatial management of marine resources and could be incorporated into the e-Atlas.

2. Extend the current data set to assess habitats at risk from shipping accidents across Torres Strait. This project would involve the consolidation of all habitat vulnerability to shipping accidents and oil spill spatial data collected in Torres Strait by the TropWATER Seagrass Group and Torres Strait CRC between 2002 and 2013, plus any additional data collected from Recommendation 1. The spatial data would incorporate seagrass, coral, algae and other benthic information at intertidal sites and incorporate a habitat sensitivity matrix. This spatial data would allow for an assessment of regions in Torres Strait that have high habitat sensitivity to shipping accidents and oil spills that should be priority areas for protection in the event of a spill, and would provide the basis for identifying candidate areas in Torres Strait where oil spill scenarios should be modelled with hydrodynamic information (Recommendation 3). This spatial data would be incorporated into the National Oil Spill Response Atlas and e-Atlas.
3. Oil spill scenario modelling in Torres Strait. This would incorporate the consolidated habitats at risk from shipping accidents and oil spills spatial data with hydrodynamic modelling to assess different oil spill scenarios in Torres Strait. This information is particularly important considering the Torres Strait community's dependence on fisheries from an economic and subsistence perspective, and the proximity of key fisheries habitat to shipping channels.



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