TORRES STRAIT DUGONG SANCTUARY DEEPWATER SEAGRASS MONITORING 2010-2014

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Carter, A.B., Taylor, H.A., Rasheed, M.A.

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AUSTRALIA

TORRES STRAIT DUGONG SANCTUARY
Deepwater Seagrass Monitoring
2010 – 2014

Prepared by Alex Carter, Helen Taylor & Michael Rasheed

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Centre for Tropical Water & Aquatic Ecosystem Research
(TropWATER)
James Cook University
PO Box 6811
Cairns Qld 4870
Phone: (07) 4781 4262
Email: seagrass@jcu.edu.au
Web: www.jcu.edu.au/tropwater/

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For further information contact:
Alex Carter
Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER)
James Cook University
seagrass@jcu.edu.au
PO Box 6811
Cairns QLD 4870

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KEY FINDINGS

1. The Torres Strait Dugong Sanctaury contains the largest recorded single continuous seagrass meadow in Australia and is likely to play a vital role for local dugong and turtle populations as an important food resource.
2. Seagrasses in the Dugong Sanctuary appear to be in a healthy and productive state.
3. Seagrass meadow biomass followed a distinct seasonal fluctuation with biomass peaks in late spring/ early summer, and biomass reductions in autumn/ winter.
4. *Halophila spinulosa* was the dominant species during all surveys (2010 – 2014). Seagrass species found included those known to be favoured by dugong and turtles, and act as nursery grounds for commercial fisheries species.

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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).

Torres Strait comprises 247 islands, eighteen 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 13,425km^2 (Coles et al. 2003) and 17,500km^2 (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; Sheppard et al. 2008; Coles et al. 2003). The largest population of dugongs in the world is in Torres Strait (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. The Dugong Sanctuary covers an area in excess of 1.3 million hectares in the western Torres Strait region (Figure 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 Sbaffi 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.

Prior to 2010 there was relatively little data available on seagrass within the Dugong Sanctuary. The Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER; formerly Department of Agriculture, Fisheries and Forestry), in collaboration with the Torres Strait Regional Authority (TSRA) Land and Sea Management Unit (LSMU) launched a research program to increase understanding of subtidal seagrass dynamics within the Dugong Sanctuary. The most comprehensive assessment of subtidal seagrass distribution, abundance and species composition in the Dugong Sanctuary was undertaken in March 2010 where the largest single continuous seagrass meadow in Australia was recorded (Taylor and Rasheed 2010b) (Figure 1). Further monitoring of subtidal seagrass in the Dugong Sanctuary was undertaken in November 2010 (Taylor and Rasheed 2011), December 2011 (Taylor and Rasheed 2012), April 2012, December 2013 and June 2014 to compare seasonal and inter-annual variation in seagrass within the Dugong Sanctuary. Long-term monitoring of seagrass in the Dugong Sanctuary provides important information on natural fluctuations in seagrass biomass, and a baseline that potential seagrass losses can be compared against should another seagrass dieback event occur in the region. The objective of the present study was to analyse changes in seagrass biomass and species composition over time using additional data collected in April 2012, December 2013 and June 2014.

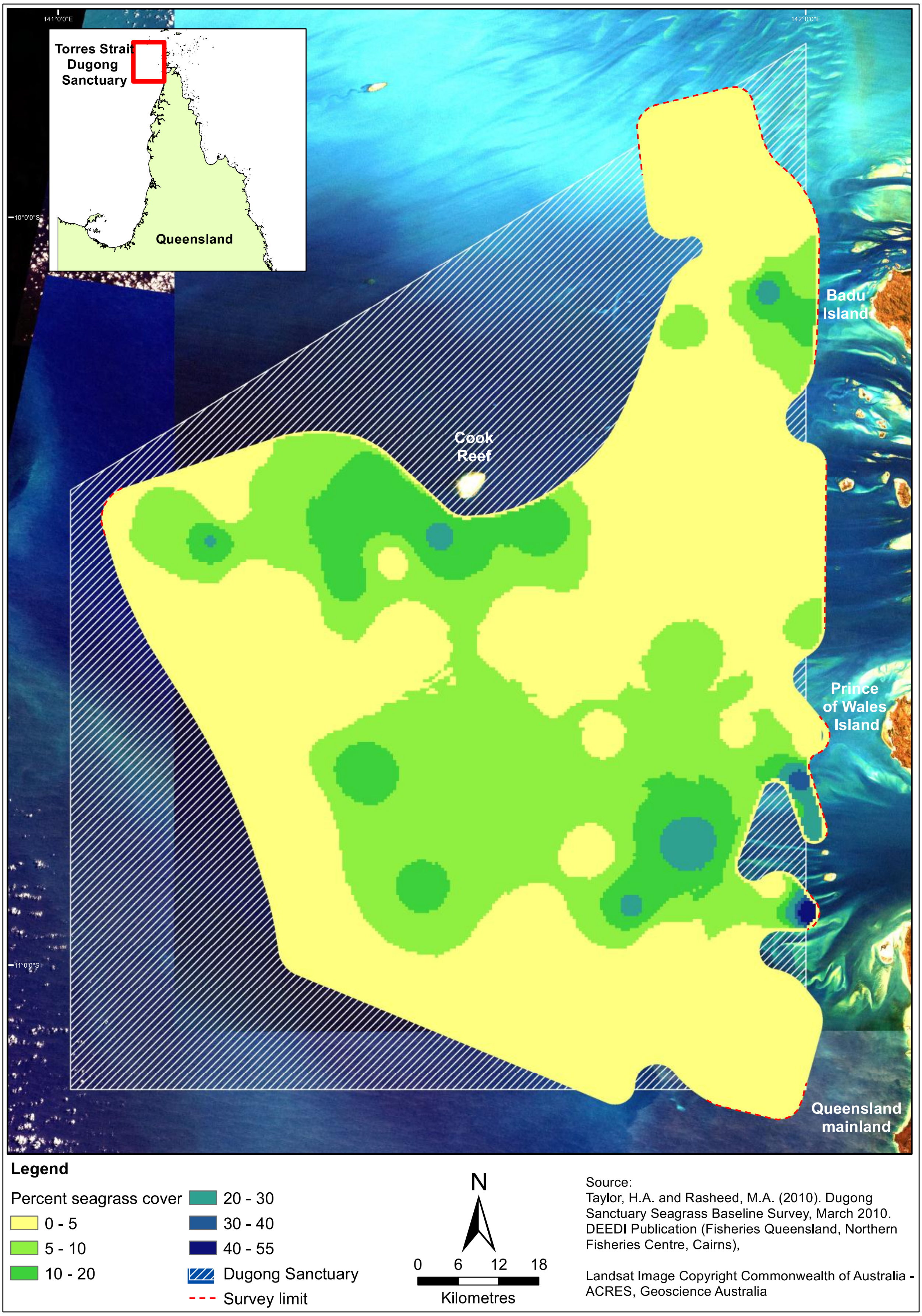

Figure 1. Seagrass meadow location and percent cover in the Dugong Sanctuary, March 2010 (Source: Taylor and Rasheed, 2010).

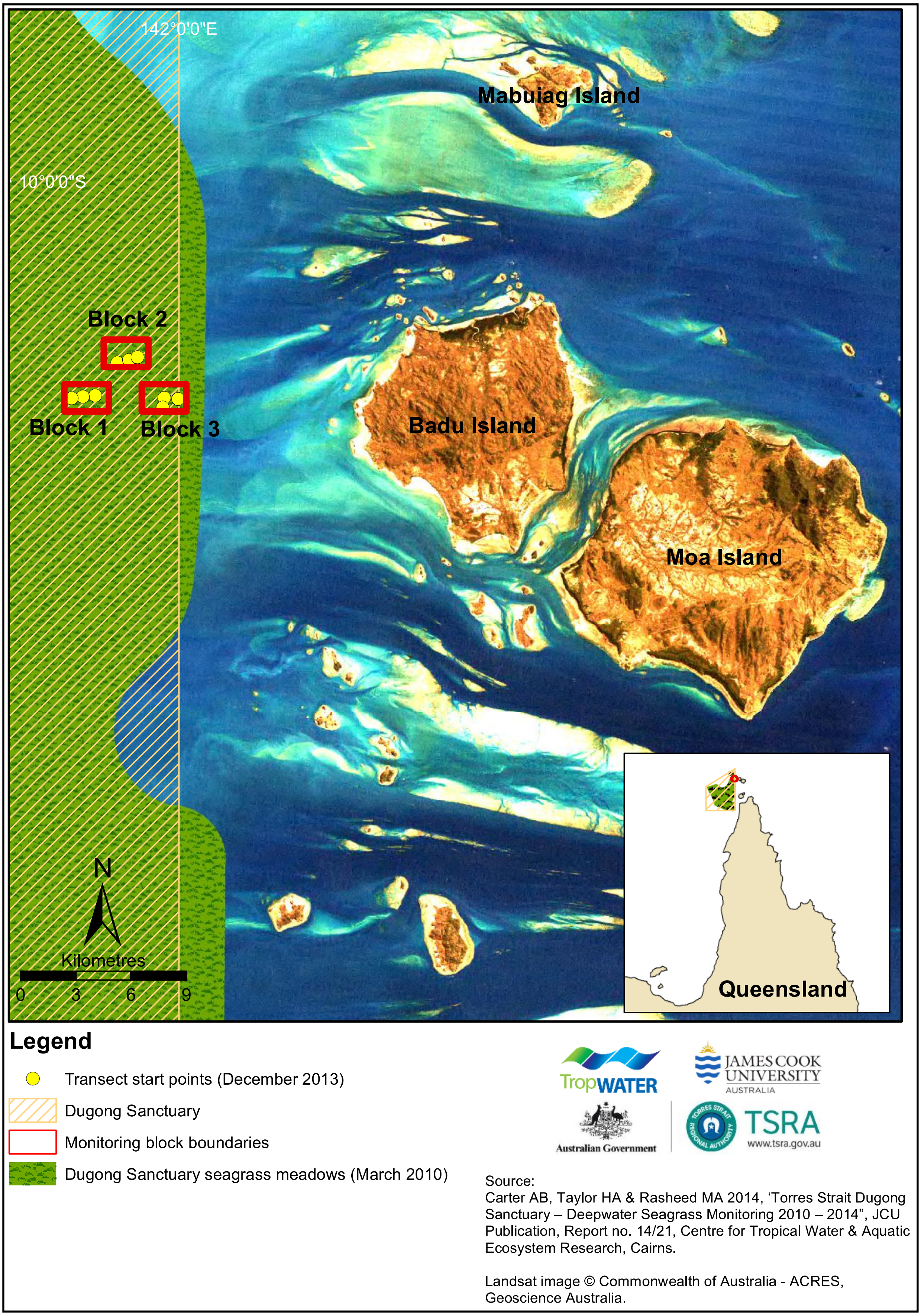

Figure 2. Location of seagrass long-term monitoring blocks in the Dugong Sanctuary.

2 METHODS

2.1 Sampling Methods

Surveys were conducted in March 2010, November 2010, December 2011, April 2012, December 2013 and June 2014. Due to the large area of the Dugong Sanctuary and the associated logistical constraints in re-surveying the entire area, three representative blocks of seagrass within the Dugong Sanctuary have been sampled since December 2011 (Figure 2). These areas represent the range of seagrass species identified in the 2010 surveys, contain high seagrass biomass, and provide relatively easy access from Badu and Mabuiag Islands, as the long-term goal is that the monitoring program will be conducted by Torres Strait LSMU Rangers. The sampling method applied was a modified version of those developed by the TropWATER Seagrass Group for seagrass habitat surveys previously used at Mabuiag Island (Chartrand et al. 2009), Badu Island (Taylor and Rasheed 2010a) and Moa Island (Taylor 2011). Within each of the three blocks, three random waypoints were used as a starting position from which to survey a transect. At each transect site an underwater CCTV camera system was lowered from the vessel to the bottom (Figure 3). 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.

2.2 Habitat characterisation sites

Data recorded at each site included:

1. **Seagrass species composition** –A sample of seagrass was collected to identify species present at each transect. Samples were collected using a van Veen grab (grab area 0.0625 m^2) (Figure 3). Species identified from the grab sample were used to inform species composition assessments made from the recorded video transects (Kuo and McComb 1989).
2. **Seagrass biomass** – Above-ground biomass was determined using a “visual estimates of biomass” technique (Mellors 1991) and was based on the ten random drops of the video camera within the video footage for each transect site. 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 at least 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. A linear regression was calculated for the relationship between the observer ranks and the actual harvested value. 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}).
3. **Site details** – Location by GPS, depth below mean sea level (dbMSL).

Seagrass community types within blocks were determined according to species composition from nomenclature developed for seagrass meadows in Queensland (Table 1). Density categories (light, moderate, dense) were assigned to community types according to above-ground biomass of dominant species (Table 2).

Figure 3. Shallow subtidal mapping of seagrass meadows using CCTV system and van Veen sediment grab.

Table 1. Nomenclature for community types in the Dugong Sanctuary.

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	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 categorizing seagrass biomass in the Dugong Sanctuary.

Density	Mean above-ground biomass (g DW m^{-2})		
	H. ovalis	*H. uninervis* (wide), *C. serrulata, S. isoetifolium, T. hemprichii*	*H. spinulosa*
Light	< 1	< 5	< 15
Moderat	1 - 5	5 – 25	15 - 35
Dense	> 5	> 25	> 35

2.3 Statistical analysis

A linear mixed effects model was used to compare differences in above-ground biomass between sampling periods. Sampling date was entered as the fixed effect and block was entered as a random effect into the model. Biomass data was log(x+1) transformed after residual plots were inspected for homogeneity and normality. P-values were obtained from likelihood ratio tests of the full model against the null model where the effect of sampling date was removed. A Tukey post hoc comparison with Holm adjustment was used for pairwise comparisons of biomass between sampling dates. Statistical analysis was conducted using the lme4 package (Bates et al. 2013) and multcomp (Hothorn et al. 2008) package in R (R Development Core Team 2013). Due to differences in sampling methods between 2010 and 2011-2014, 2010 data was not included in the analysis.

3 RESULTS

3.1 Seagrass species

Eight seagrass species from 2 families were identified in the Dugong Sanctuary between 2010 and 2014 (Figure 4). Seagrass was present at all three monitoring blocks in April 2012 and December 2013 and six species were recorded: *Halophila spinulosa*, *Halophila decipiens*, *Halophila ovalis*, *Halodule uninervis*, *Cymodocea serrulata* and *Syringodium isoetifolium*. In June 2014 seagrass was absent from Block 3 and only *H. spinulosa*, *C. serrulata* and *S. isoetifolium* were present. The most dominant species in the Dugong Sanctuary from 2010 to 2014 was *H. spinulosa* which accounted for 86 – 91% of seagrass biomass in the 2010 surveys (whole meadow), and 62 – 66% of biomass in 2011 – 2014 surveys (representative area surveys; Figure 5). The second most abundant species was *C. serrulata* which accounted for 20 – 34% of biomass between 2011 and 2014 (Figure 5).

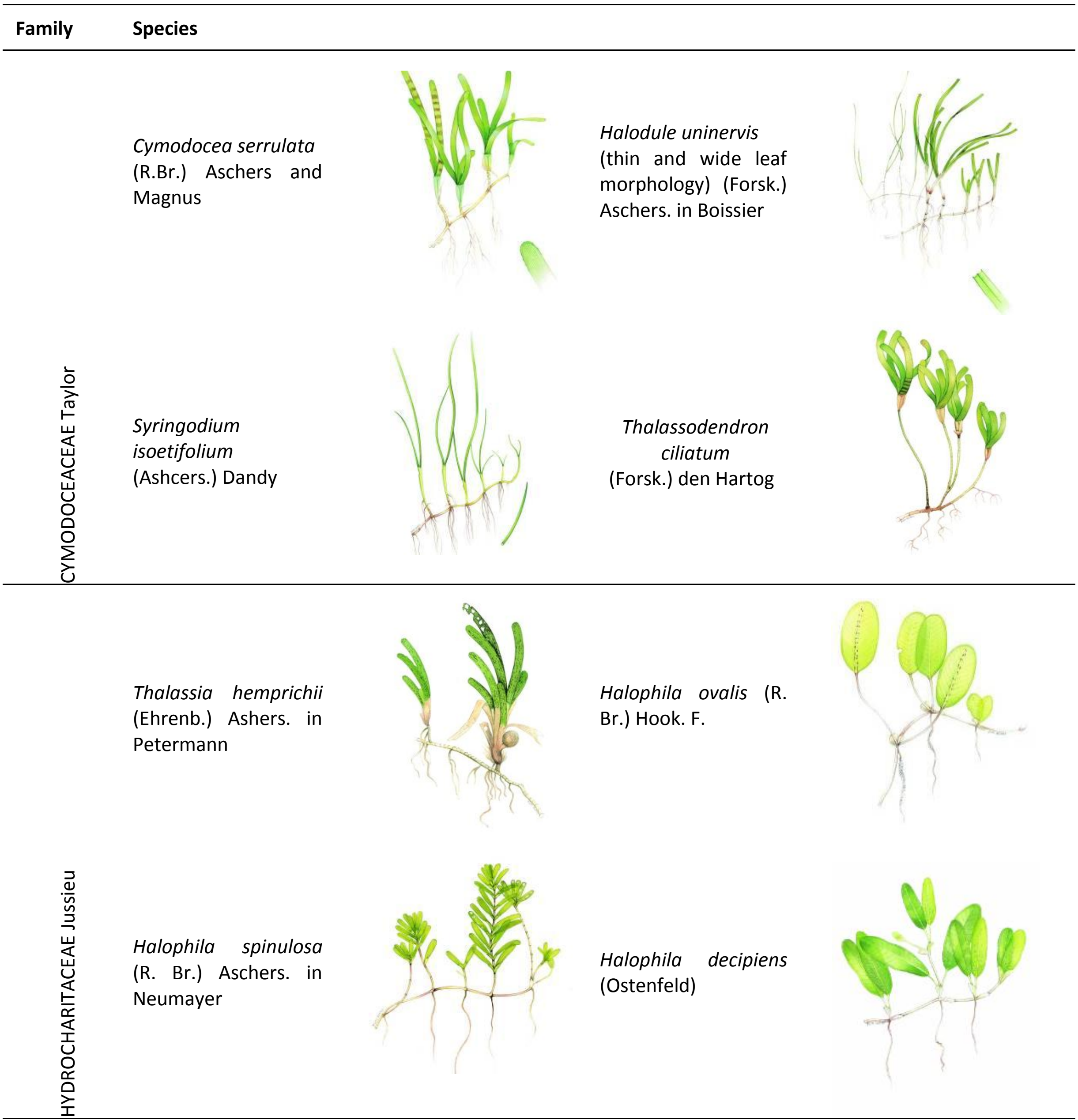

Figure 4. Seagrass species present at monitoring meadows in the Dugong Sanctuary, 2010-2014.

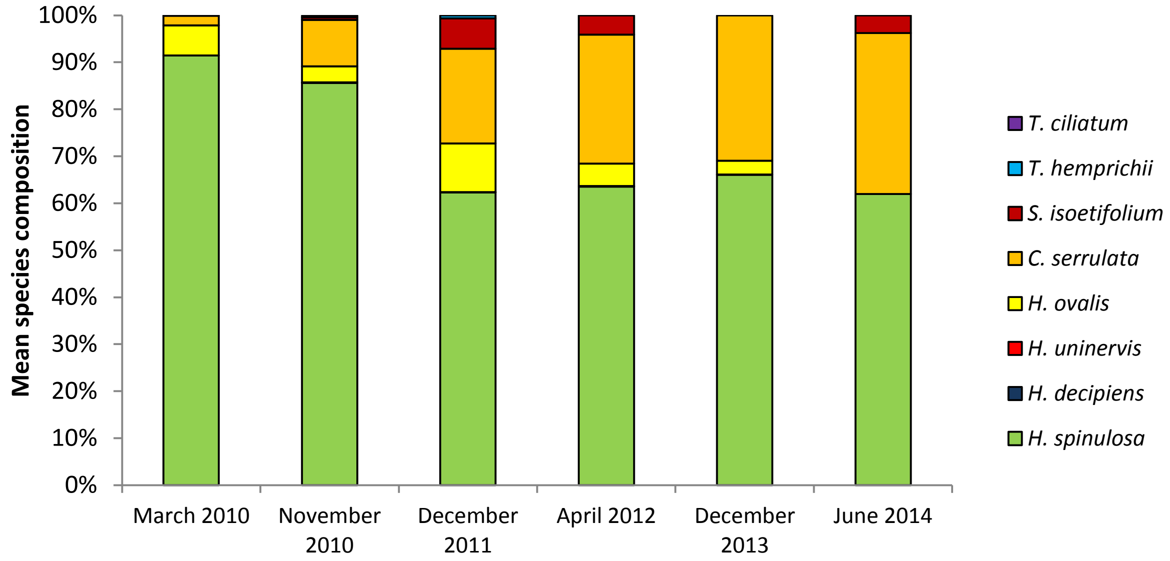

Figure 5. Seagrass species composition in the Dugong Sanctuary, 2010 - 2014.

3.2 Seagrass biomass

Above-ground seagrass biomass varied significantly between surveys ($\chi^2(3)=1067$, $p<0.001$). A clear seasonal trend existed where biomass peaked in late spring/ early summer (growing season) and reduced by more than half in the autumn/winter senescent season. The lowest biomass was recorded in June 2014 (0.73 + 0.15 g DW m^{-2}) and the greatest biomass was recorded in December 2011 (4.37 ± 0.23 g DW m^{-2}; Figure 6). Although not included in the statistical analysis due to different sampling methods, a similar pattern was present in 2010 where biomass was greatest in late spring (November; 8.67 + 1.32 g DW m^{-2}) and lowest in autumn (March; 2.62 + 0.60 g DW m^{-2}). The dominance of *H. spinulosa* and biomass < 15 g DW m^{-2} means that the Dugong Sanctuary meadow was categorised as a light *H. spinulosa* meadow with *C. serrulata* between 2011 and 2014.

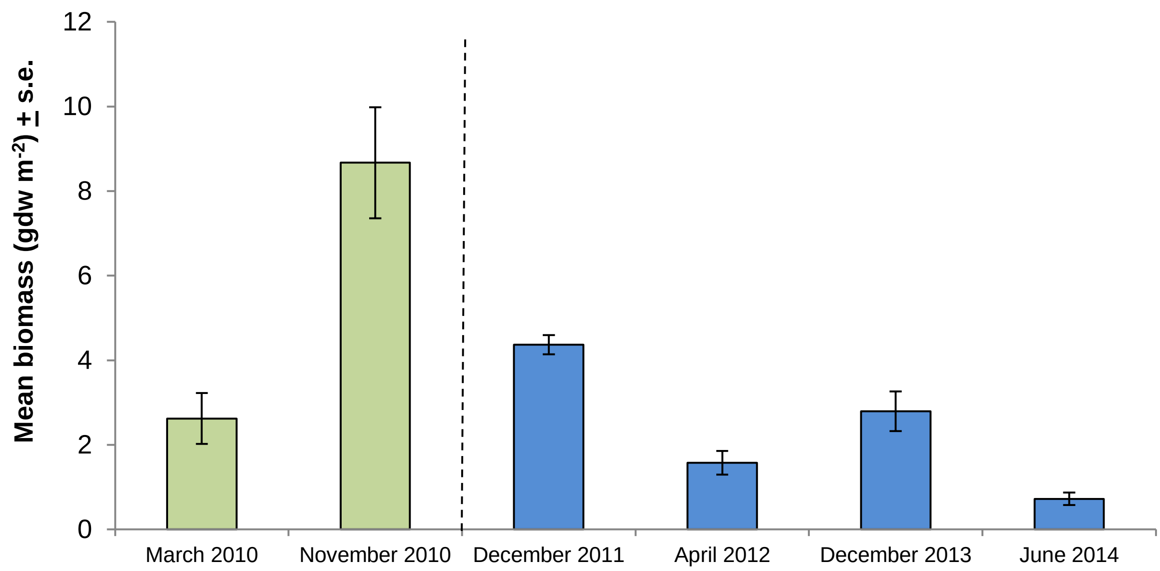

Figure 6. Seagrass above-ground biomass (mean + standard error, s.e.) in the Dugong Sanctuary in 2010 (whole Dugong Sanctuary; green bars) and 2011 – 2014 (representative blocks; blue bars).

4 DISCUSSION

The Dugong Sanctaury contains the largest recorded single continuous seagrass meadow in Australia and 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). Indications from the monitoring program and the baseline surveys are that seagrass remains in the area throughout the year providing an important and consistent food source for dugong and turtle.

The March and November 2010 surveys provided baseline information against which changes to seagrass distribution and abundance could be measured through the long-term monitoring program. These surveys provided an indication of natural intra-annual and seasonal change and its implications for dugong, turtle and fisheries that depend on this habitat. Monitoring of representative areas within the Dugong Sanctuary has occurred on four further occasions, two summer surveys (December 2011 and 2013) and two autumn/winter surveys (April 2012 and June 2014). The timing of the monitoring surveys was chosen to best capture the extent of seagrass seasonal change.

4.1 Seagrass biomass seasonality

Seagrass biomass in the Dugong Sanctuary representative areas demonstrated distinct changes among seasons, with biomass significantly greater in the summer than in autumn/winter. Seasonal variation is typical for tropical seagrass meadows (Rasheed 2000; 1999; Erftemeijer and Herman 1994; McKenzie 1994) and investigations of seagrass change at nearby Mabuiag Island demonstrated the difference in biomass between seasons was up to four-fold in subtidal meadows (Taylor et al. 2013). The drivers of natural seasonal change in seagrass are linked to seasonality in a wide range of environmental factors (Duarte et al. 2006). On the east coast of Australia seagrasses flourish from August to November when sediment resuspension is at its lowest, light levels are higher and nutrient fluctuations are minimised. During the wet season, increases in turbidity from river flow and increased sediment resuspension cause light levels to drop, leading to a decrease in seagrass growth (Coles et al. 2007; Mellors 2003).

Preliminary results indicate that light availability is the most important driver of change in nearby Mabuiag Island subtidal seagrasses (Taylor et al. 2013) and this may also be the case for Dugong Sanctuary seagrasses. The growth, survival and depth penetration of seagrass is directly related to the quality and quantity of light (Dennison 1987; Dennison and Alberte 1985), which is the primary driver of photosynthesis. Seagrass species are known to have differing minimum light requirements to maintain a stable state or to achieve positive growth (Chartrand et al. 2012; Collier et al. 2012). Species that are most commonly found in the subtidal region are characterised by their low light requirements. *Halophila* species (the dominant genera in the Dugong Sanctuary) only require between 10-30% surface light intensity (Freeman et al. 2008) whilst other tropical seagrass genera such as *Zostera* and *Cymodocea* require around 40% surface light intensity (Collier and Waycott 2009; Bach et al. 1998; Grice et al. 1996).

4.2 Importance of Dugong Sanctuary Seagrasses

The Dugong Sanctuary has a high diversity of seagrass species, containing more than 50% of the known species occurring in the entire Great Barrier Reef World Heritage Area (Coles et al. 2007). This species diversity is relatively unusual for deepwater seagrass communities as the lack of varying habitats (i.e. coastal, inland, fringing reef habitat types) and changes in the availability of light with increasing depth would typically be limiting. 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). Dugongs are believed to selectively forage for seagrass species that are highly digestable (*Halophila* spp.) and have a high nutrient content (*Halodule* spp.) (Aragones 1996). When feeding, they 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).

Seagrasses in the Dugong Sanctuary are likely to be regionally important as the area covered is several orders of magnitude greater than nearby subtidal seagrasses that have been described such as at Mabuiag Island (19,517 ha) (Chartrand et al. 2009), Badu Island (3,363 ha) (Taylor and Rasheed 2010a) and Moa Island (Taylor 2011). The vast area of highly diverse seagrasses provides a consistent source of primary production supporting the region's marine ecosystem. Studies at the nearby Orman Reefs and Mabuiag Island have shown Torres Strait seagrass meadows are extremeley 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).

4.3 Resilience of Dugong Sanctuary Seagrasses

Seagrass species vary in their sensitivity and resilience to impacts including those associated with shipping activities and shifting sediments from the complex tidal movement found in the Torres Strait. The resilience of seagrass meadows is a result of a complex interaction of many factors including the plant's carbohydrate reserves, ability of photosystems to recover from disturbance, capacity for vegetative propagation, seed bank occurrence and disturbance regime. As the Dugong Sanctuary contains a wide range of species it follows that there would be a corresponding range of tolerances and capacity to recover from impacts among species. The capacity of seagrass species to withstand burial by shifting sediments, for example, is size-dependant with small species less tolerant. However small species such as *Halophila decipiens* often dominate in regularly used spoil grounds (Chartrand et al. 2008) despite as little as 2cm of sediment causing 100% mortality (Cabaço et al. 2008). This is due to their ability to rapidly colonise disturbed areas through high reproductive output and generation of large seed banks (Kenworthy 2000). Results from a study on seed reserves in a shallow mixed species subtidal seagrass meadow at Mabuiag Island have found high densities of *Halophila* spp. seeds and low densities of *S. isoetifolium* and *C. serrrulata,* 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; which may be particularly relevant to subtidal seagrasses in the Dugong Sanctuary if seed reserves are limited (Taylor et al. 2012; Cabaço et al. 2008).

4.4 Implications for local dugong and turtle populations

Potential changes in 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.

While there is little to be done locally in the Torres Strait to prevent global climate-related change, 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. Repeated pulse impact events on the east coast of Queensland have resulted in reduced resilience of seagrass in some areas and reduced recovery capacity following losses, despite general climate conditions being favourable for growth (i.e. Mourilyan Harbour; Reason et al. 2012). The seagrass species most favoured as food for dugong in the Torres Strait, *H. uninervis* and *H. ovalis*, have high levels of resilience with dense seed banks established and an ability to rapidly re-colonise disturbed areas through sexual and asexual means. Many other species found in the Torres Strait that form more minor components of dugong and turtle diets have moderate levels of resilience as they rely more heavily on asexual reproduction, with the potential to take in excess of a year to recover from large-scale loss (Taylor et al. 2013).

Seasonal and inter-annual observations of seagrass biomass in the Dugong Sanctuary have so far only been conducted over two seasonal cycles, a relatively short timeframe for climate studies. Considering the differences among seasons and years in seagrass biomass and environmental conditions, continued seasonal monitoring by TSRA Rangers in conjunction with TropWATER in 2014-2015 will substantially improve our understanding of the range of natural seasonal change meadows experience.

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6 APPENDICES

Appendix 1.

Table 1. Tukey's pairwise comparison with Holm adjustment comparing biomass between sampling dates. Significance levels: *p<0.05, ***p<0.001, Ns. = not significant p>0.05.

	December 2011	April 2012	December 2013	June 2014
December 2011				
April 2012	***			
December 2013	***	Ns.		
June 2014	***	*	***	