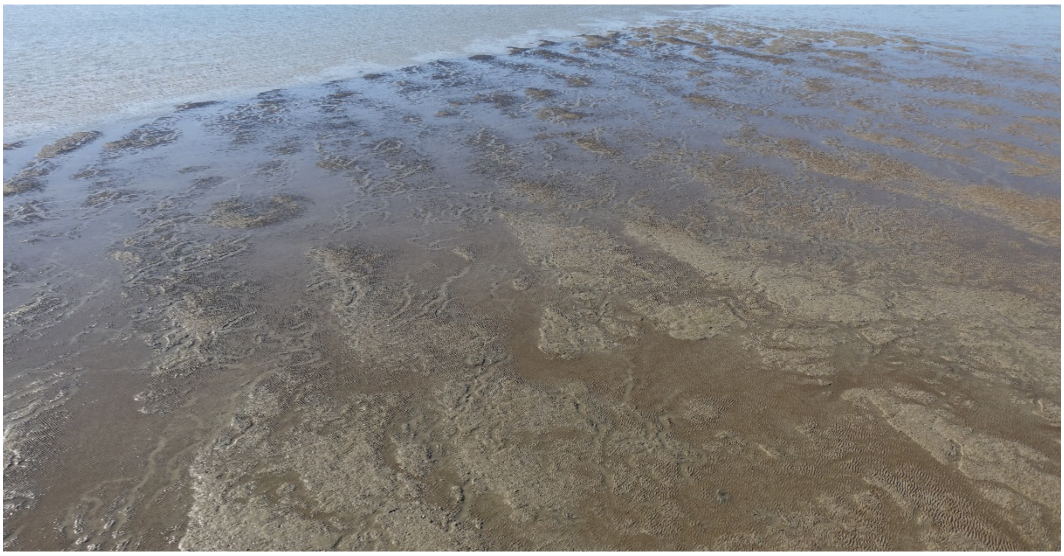

# Mackay-Whitsunday Seagrass Monitoring 2018:

# Marine Inshore South Zone

**Carter AB and Rasheed MA**

**Report No. 19/05**

**March 2019**

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# KEY FINDINGS

- The Mackay-Whitsunday region has extensive seagrass habitat that provides an important food resource for dugong and turtle, and a range of other key ecosystem services.

- TropWATER (James Cook University) were contracted by the Mackay-Whitsunday Healthy Rivers to Reef Partnership (HR2RP) to address a seagrass condition knowledge gap in the southern inshore marine zone, with the objective of providing seagrass report card scores to the Mackay-Whitsunday regional report card.

- 1600 ha of intertidal seagrass and 70 ha of subtidal seagrass were mapped during the 2017 baseline survey. Three intertidal meadows were identified as suitable for annual long-term monitoring, which commenced in 2018.

- Extensive seagrass meadows were recorded in 2018. Meadows were characterised by continuous seagrass cover, area increased in all meadows since 2017, and a new seagrass meadow was present. Biomass and species composition were similar to 2017.

- Dugong feeding trails were present in all meadows and their location coincided with biomass hotspots.

- We recommend ongoing annual monitoring of meadow area, biomass and species composition. This will provide the data necessary to establish accurate and meadow-specific baselines against which seagrass condition can be assessed for the HR2RP south zone report card.

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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 (Scott et al. 2018; Costanza et al. 2014). These services include coastal protection, support of fisheries production, nutrient cycling, particle trapping, removal of bacterial pathogens, and acting as a carbon sink (Lamb et al. 2017; Fourqurean et al. 2012; Hemminga and Duarte 2000). Seagrasses also provide food for herbivores like dugongs (*Dugong dugon*) and green turtles (*Chelonia mydas*) (Unsworth and Cullen 2010; Heck et al. 2008).

Seagrasses are declining globally from natural and anthropogenic effects (Waycott et al. 2009). Natural disturbances include storms, floods, disease, and overgrazing by herbivores (McKenna et al. 2015; Fourqurean et al. 2010; Robblee et al. 1991). Anthropogenic activities identified as the main threats to seagrass ecosystems in the tropical Indo-Pacific region include industrial and urban run-off, port and coastal development, and dredging (York et al. 2015; Grech et al. 2012).

The ecological importance of seagrass, and seagrass' sensitivity to disturbance events and environmental change, make it an ideal indicator for long-term monitoring of marine environmental health (Orth et al. 2006; Abal and Dennison 1996; Dennison et al. 1993). Seagrass condition assessments require adequate baseline information on seagrass presence/absence, biomass, species composition, and meadow area, plus ongoing monitoring to understand and detect change. Long-term monitoring and condition reporting on Queensland's seagrass is primarily undertaken as part of the Queensland Ports Seagrass Monitoring Program (QPSMP) that occurs in the majority of commercial ports (www.jcu.edu.au/portseagrassqld), and the Marine Monitoring Program (MMP) that focusses on the inshore Great Barrier Reef (GBR) (http://www.gbrmpa.gov.au/managing-the-reef/how-the-reefs-managed/reef-2050-marine-monitoring-program) and reports seagrass condition as part of the Reef Water Quality Protection Plan (https://www.reefplan.qld.gov.au/measuring-success/report-cards/).

In recent years the seagrass programs have contributed their condition assessments to a variety of regional report cards. These include the Mackay-Whitsunday Healthy Rivers to Reef Partnership (HR2RP; http://healthyriverstoreef.org.au/), the Wet Tropics Healthy Waterways Partnership (WTHWP; http://wettropicswaterways.org.au/report-card/), the Dry Tropics Partnership for Healthy Waters (DTPHW; https://drytropicshealthywaters.org/report-cards-1), and the Gladstone Healthy Harbour Partnership (GHHP; http://ghhp.org.au/report-cards/2018). Regional report cards at the Natural Resource Management (NRM) scale are divided into zones defined largely by habitat and latitude, and attempts to report seagrass condition at the zone scale has revealed a number of gaps with no long-term monitoring data available to inform report card scores. For the HR2RP report card, condition is reported for five freshwater basins, eight estuaries, four inshore marine zones, and one offshore marine zone (Figure 1a). The southern inshore marine zone was identified as a major data gap, with no scores for any of the four environmental indicators: water quality, coral, seagrass and fish (http://healthyriverstoreef.org.au/report-card-results/).

TropWATER were contracted in 2017 by HR2RP to address the knowledge gaps in environmental condition (seagrass and water quality) for the southern inshore marine zone, with a longer-term objective to provide report card scores for these indicators. TropWATER have conducted seagrass surveys previously in this zone: in 1987, as part of large-scale seagrass assessments along the Queensland coast (Coles et al. 1987); in 1997, during GBR-wide deep water surveys (Coles et al. 2009); in 1999, during assessments for Dugong Protection Areas (Coles et al. 2002); and in 2003-2004, during GBR-wide seabed biodiversity surveys led by CSIRO (Pitcher et al. 2007). These surveys revealed substantial intertidal seagrass meadows along the coast, but sparse and patchy subtidal seagrass. The largest intertidal meadows were located in the Clairview Dugong Protection Area (DPA) that extends from Carmila to Clairview Bluff (Figure 1b). These meadows were mapped in 1987 (Coles et al. 1987), and revisited in 1999 (Roder et al. 2002), and were the focus for a seagrass baseline survey for HR2RP in 2017.

The 2017 baseline survey was an important first step in addressing seagrass knowledge gaps in the HR2RP south zone report card (Carter and Rasheed 2018). The 2017 and 1999 surveys revealed similar seagrass distribution, biomass, and species composition to the original 1987 survey, indicating these seagrass areas are likely to be relatively permanent features and ideal for monitoring. Three meadows were recommended for long-term monitoring between Clairview and Flock Pigeon Island to incorporate the large intertidal *H. uninervis* meadow, mapped as meadows 6 and 7 in 2017 but as a single meadow in 1987, and the intertidal *Z. capricorni* meadow 2 at Flock Pigeon Island (surveyed only in 2017).

This report presents findings from the 2018 seagrass monitoring survey of the HR2RP south inshore marine zone. Our objectives were to:

- Map seagrass distribution, density and community composition of monitoring meadows;
- Compare results with previous seagrass survey data from this region;
- Incorporate results into a Geographic Information System (GIS) database for the zone.

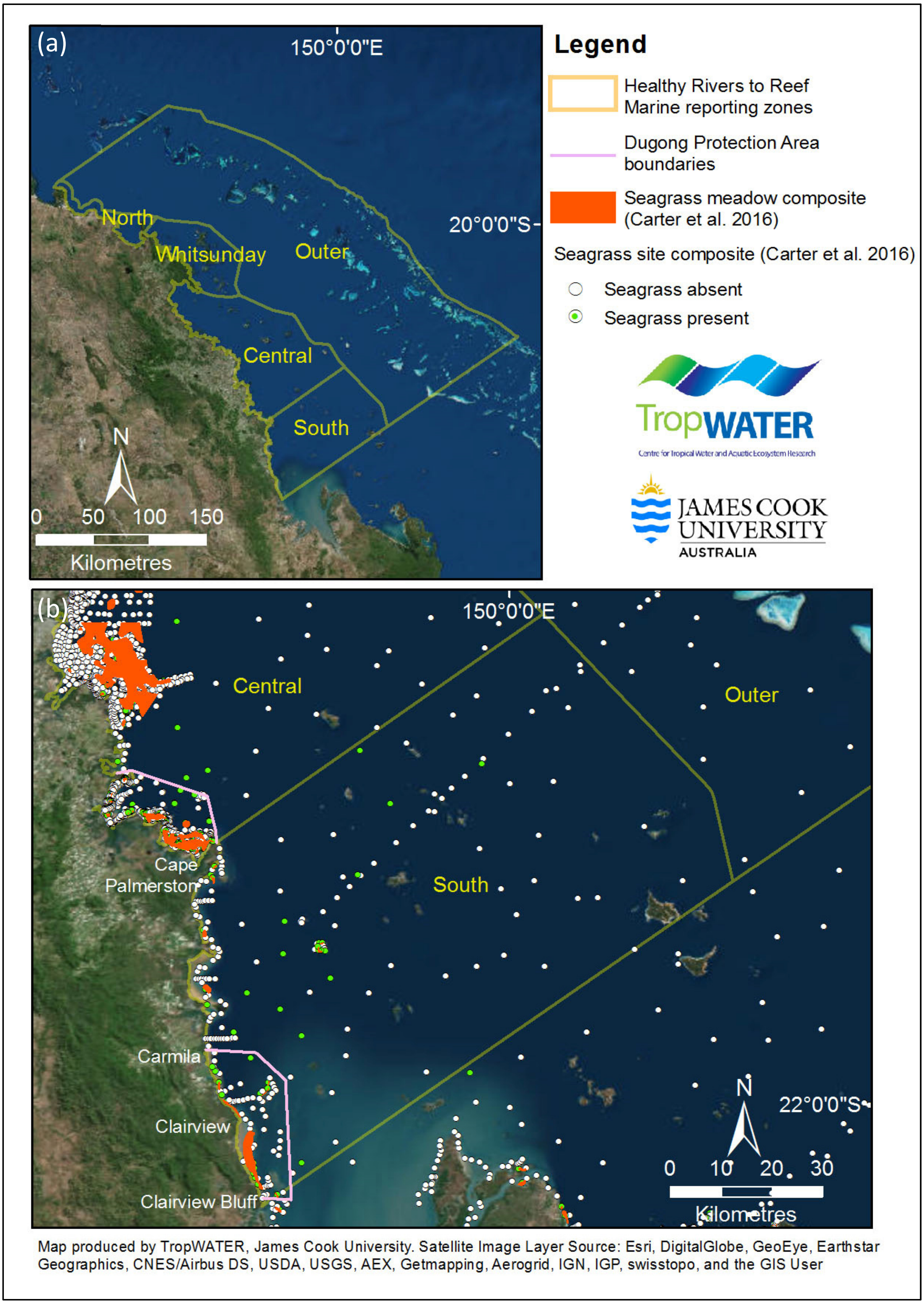


**Figure 1.** Mackay-Whitsunday Healthy Rivers to Reef Partnership reporting zones for inshore marine (north, Whitsunday, central, south) and offshore marine (outer); and (b) historical seagrass survey data collected 1987 – 2004 in the inshore marine south zone.

# 2 METHODS

## 2.1 Survey Approach

The survey was conducted in September 2018 to coincide with the peak seagrass growing season, when meadows are likely to contain maximum biomass and area. Survey methods and the seagrass metrics recorded followed the established methods for Queensland seagrass monitoring which also occur at Townsville (Bryant and Rasheed 2018), Gladstone (Chartrand et al. 2018), Cairns (Reason and Rasheed 2018a), Mourilyan (Reason and Rasheed 2018b), Mackay-Hay Point (York and Rasheed 2018), Abbot Point (Davey and Rasheed 2018), Thursday Island (McKenna and Rasheed 2018), Weipa (Sozou and Rasheed 2018), and Karumba (Shepherd et al. 2018). Using standardised methods ensures seagrass data is comparable with that used to report seagrass condition for other marine inshore zones in the HR2RP report card, and in the WTHWP, DTPHW, GHHP, and QPSMP report cards. Standardisation also allows for comparisons with historical data sets collected previously in the same area.

## 2.2 Field Surveys

Intertidal meadows were sampled at low tide using a helicopter. Monitoring meadows are all intertidal because: (1) the large tidal range (up to 8.5m) means that intertidal seagrasses are exposed during spring low tides so helicopter surveys are likely to capture the majority of seagrasses in the region; and (2) subtidal meadows form a relatively minor component of seagrass area and are restricted to very shallow subtidal water, with the same species composition as adjacent/adjoining intertidal meadows (Carter and Rasheed 2018).

The southern survey limit at Flock Pigeon Island was applied retrospectively because survey sites beyond this limit were exposed in 2018 due to an extremely low tide, but were not exposed in 2017. Excluding data beyond the survey area will allow for ongoing monitoring by helicopter only, and ensures data is comparable among years and appropriate for report card development.

At each site the helicopter came to a low hover (within a metre of the ground) and within a 10m$^2$ circular area seagrass biomass was ranked, and the percent contribution of each species to that biomass was estimated, from three 0.25 m$^2$ randomly placed quadrats. Within the larger 10m$^2$ circular area the percent cover of seagrass, algae, and other benthic macro-invertebrates (BMI) were recorded. GPS was used to record the position of each site, and also intertidal meadow boundaries when visible.

## 2.3 Biomass and Species Composition

Seagrass above-ground biomass was determined using a "visual estimates of biomass" technique (Mellors 1991; Kirkman 1978). For each 0.25 m$^2$ quadrat an observer assigned a biomass rank, made in reference to a series of 12 quadrat photographs of similar seagrass habitats for which the above-ground biomass had previously been measured. The percent contribution of each seagrass species to above-ground biomass within each quadrat was also recorded. At the completion of ranking, the observer also ranked a series of at least five photographs of calibration quadrats that represented the range of seagrass observed during the survey. These calibration quadrats had previously been harvested and the actual biomass determined in the laboratory. A separate regression of ranks and biomass from the calibration quadrats were generated for each observer and applied to the biomass ranks given in the field. Field biomass ranks were converted into above-ground biomass estimates in grams dry weight per square metre (g DW m$^{-2}$).

## 2.4 Seagrass Meadow Mapping and Geographic Information System (GIS)

All survey data were entered into a Geographic Information System (GIS) developed for the HR2RP south zone using ArcGIS 10.4. Three seagrass GIS layers were created to describe spatial features of the region: a seagrass site layer, seagrass meadow layer, and seagrass biomass interpolation layer.

**Site layer**
The site layer contains data collected at each site, including:

- Temporal details – survey date and time.
- Spatial details – latitude and longitude.
- Habitat information – sediment type; seagrass information including presence/absence, above-ground biomass (total and for each species) and biomass standard error (SE); percent cover of seagrass, algae, and open substrate; presence/absence of DFTs.
- Sampling method and any relevant comments.

**Interpolation layer**
The interpolation layer describes spatial variation in seagrass biomass across each meadow and was created using an inverse distance weighted (IDW) interpolation of seagrass site data within each meadow.

**Meadow layer**
The meadow (polygon) layer provides summary information for all sites within each of the three monitoring meadows, including:

- Temporal details – survey date.
- Habitat information – depth category (intertidal/subtidal), mean meadow biomass ± standard error (SE), meadow area (hectares) ± reliability estimate (R), number of sites within the meadow, seagrass species present, meadow density and community type, meadow landscape category (Figure 2).
- Meadow identification number – A unique number assigned to each monitoring meadow to allow comparisons among surveys.
- Sampling method and any relevant comments.

Meadow boundaries were constructed using seagrass presence/absence site data, field notes, GPS marked meadow boundaries, colour satellite imagery of the survey region (Source: Sentinel 2, courtesy Copernicus Open Access Hub www.scihub.copernicus.eu/; and Landsat 2017, courtesy ESRI), and aerial photographs taken during helicopter surveys.

Meadow area was determined using the calculate geometry function in ArcGIS®. Meadows were also assigned a mapping precision estimate (in metres) based on mapping methods used for that meadow. The mapping precision for coastal seagrass meadows ranged from ±20 m for intertidal seagrass meadows with boundaries mapped by helicopter, to ±50 m for boundaries mapped by distance between sites with and without seagrass. The mapping precision estimate was used to calculate a buffer around each meadow representing error; the area of this buffer is expressed as a meadow reliability estimate (R) in hectares.

Meadows were described using a standard nomenclature system. Seagrass community type is defined using the dominant species' percent contribution to mean meadow biomass (for all sites within a meadow) (Table 1). Community density is based on mean biomass and the dominant species within the meadow (Table 2).


*Isolated seagrass patches*
The majority of area within the meadow consists of unvegetated sediment interspersed with isolated patches of seagrass.


*Aggregated seagrass patches*
The meadow consists of numerous seagrass patches but still features substantial gaps of unvegetated sediment within the boundary.


*Continuous seagrass cover*
The majority of meadow area consists of continuous seagrass cover with a few gaps of unvegetated sediment.

**Figure 2.** Seagrass meadow landscape categories: (a) Isolated seagrass patches, (b) aggregated seagrass patches, (c) continuous seagrass cover.

**Table 1.** Seagrass meadow community types.

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

**Table 2**. Seagrass meadow density categories.

| | Mean above-ground biomass (g DW $m^{-2}$) | |
|---|---|---|
| Density | *H. uninervis* (thin)<br>*Z. muelleri* subsp. *capricorni* (thin) | *H. ovalis* |
| Light | < 1 | < 1 |
| Moderate | 1 - 4 | 1 - 5 |
| Dense | > 4 | > 5 |

# 3 RESULTS

Three seagrass species were recorded during the survey: *Zostera muelleri* subsp. *capricorni* (abbreviated to *Z. capricorni* throughout this report), *Halodule uninervis*, and *Halophila ovalis* (Figure 3). Only the thin leaf morphologies of *Z. capricorni* and *H. uninervis* were observed.

Extensive seagrass meadows were recorded in 2018. Seagrass was present at 67% of the 108 intertidal sites surveyed, and meadows were characterised by continuous seagrass cover (Figures 4, 5). Meadow area increased for all monitoring meadows between 2017 and 2018 (Table 3). A new seagrass meadow also was present in 2018 between meadows 6 and 7, and was given the identification number “10” (Figure 5, Table 3).

Mean meadow biomass was approximately 1g DW $m^{-2}$, slightly less than values recorded in 2017 (Table 3). However, biomass varied greatly within a meadow, ranging from 0 to 4.4g DW $m^{-2}$ (Figure 6). Dugong feeding trails were present in all meadows and their location coincided with biomass hotspots (Figure 6).

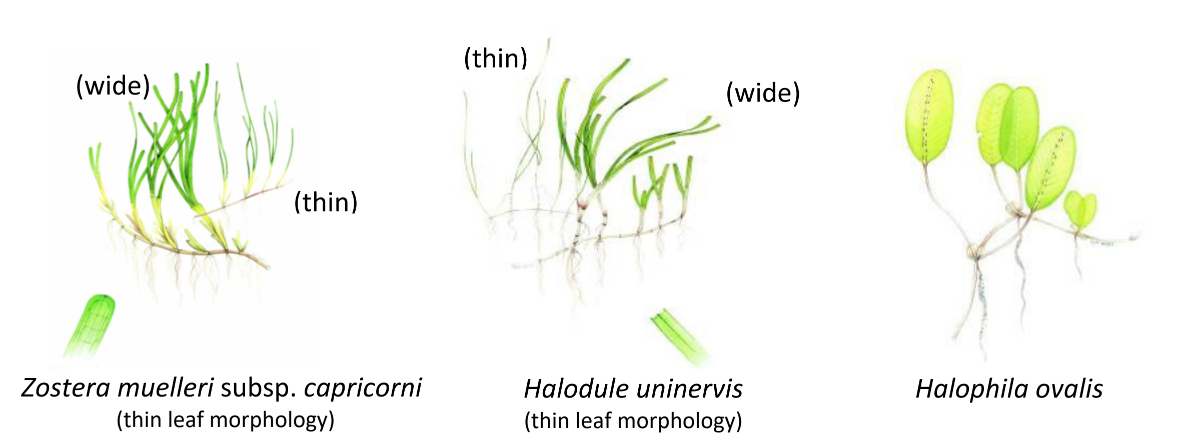


**Figure 3**. Seagrass species present in the HR2RP inshore marine south zone.

**Table 3.** Comparison of seagrass monitoring meadows in the HR2RP inshore marine south zone, 2017 and 2018.

| Meadow ID | Year | Density | Community type | Area (ha ± R) | Biomass (mean ± SE) |
|---|---|---|---|---|---|
| 2 | 2017 | Moderate | *Z. capricorni* (thin) | 97 ± 2 | 1.88 ± 0.53 |
| | 2018 | Light | *Z. capricorni* (thin) | 111 ± 11 | 0.91 ± 0.32 |
| 6 | 2017 | Light | *H. uninervis* (thin) | 1144 ± 103 | 0.83 ± 0.19 |
| | 2018 | Moderate | *H. uninervis* (thin) with *H. ovalis* | 1378 ± 113 | 1.10 ± 0.17 |
| 7 | 2017 | Moderate | *H. uninervis* (thin) | 60 ± 17 | 2.69 ± 1.39 |
| | 2018 | Moderate | *Z. capricorni* (thin) | 154 ± 19 | 1.44 ± 0.50 |
| 10 | 2017 | - | Meadow not present | 0 | 0 |
| | 2018 | Light | *H. uninervis* (thin) | 34 + 5 | 0.48 + 0.29 |

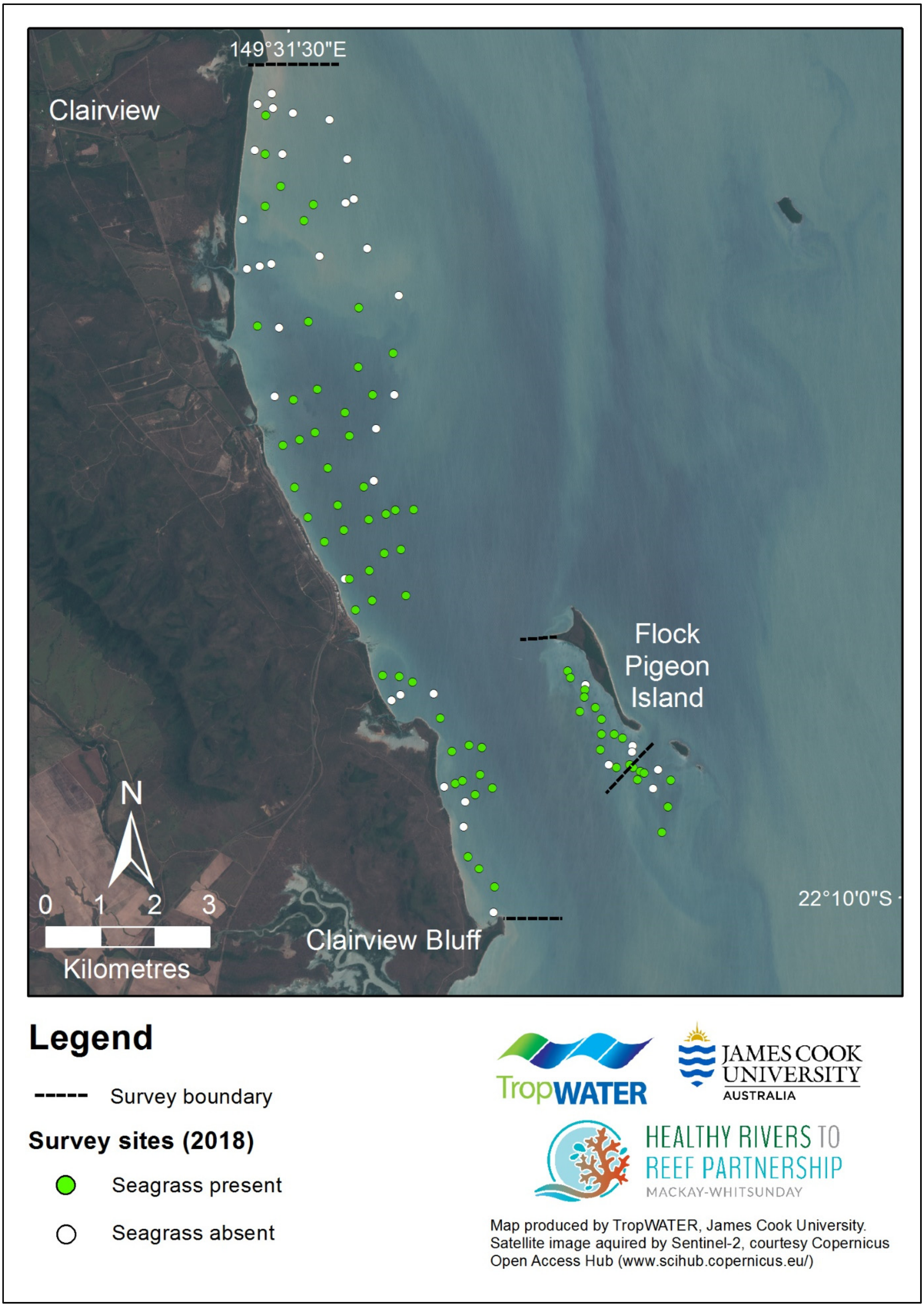


**Figure 4.** Location of intertidal survey sites with seagrass presence/absence in 2018.

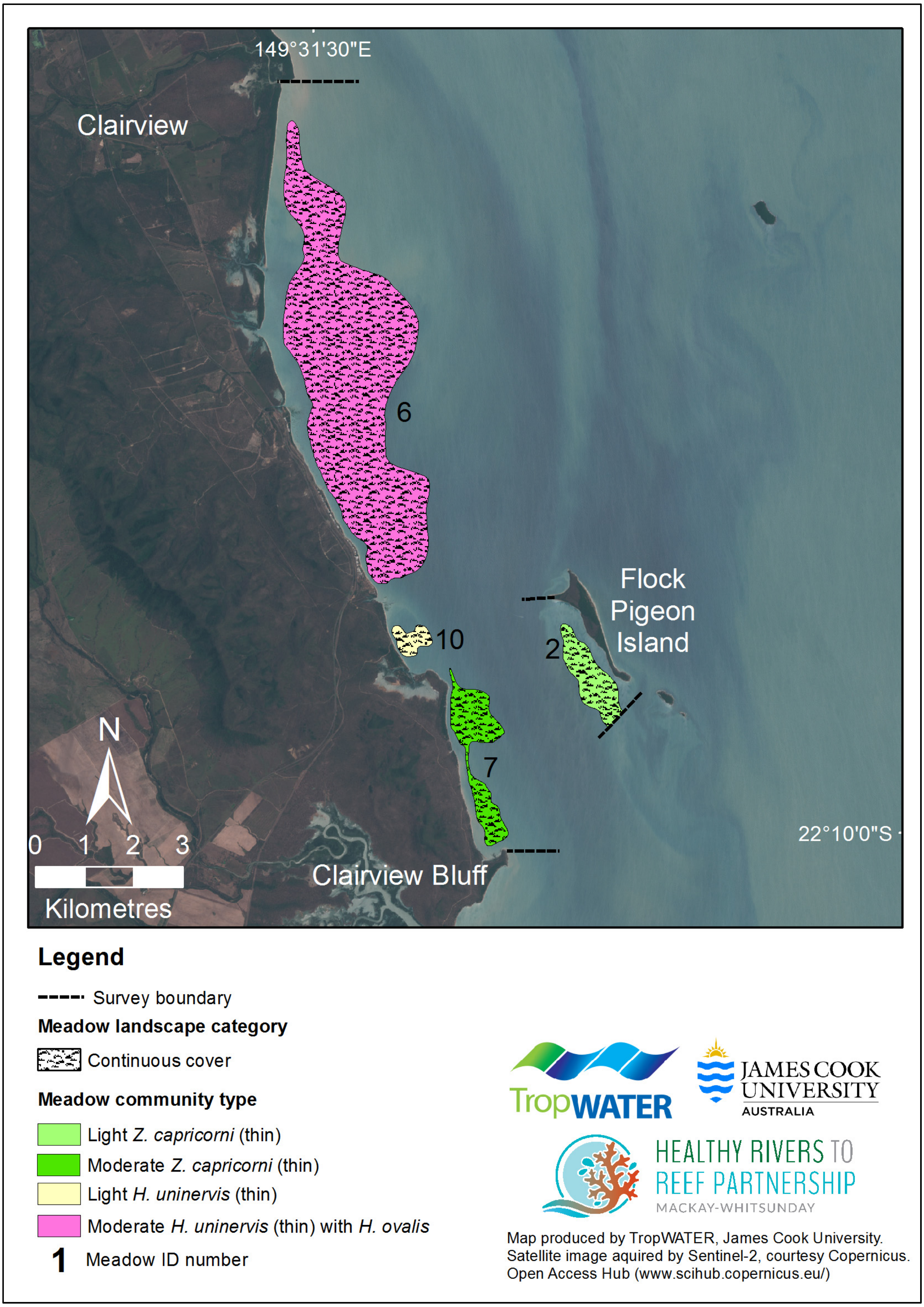


**Figure 5.** Seagrass monitoring meadow landscape category and community type in 2018.

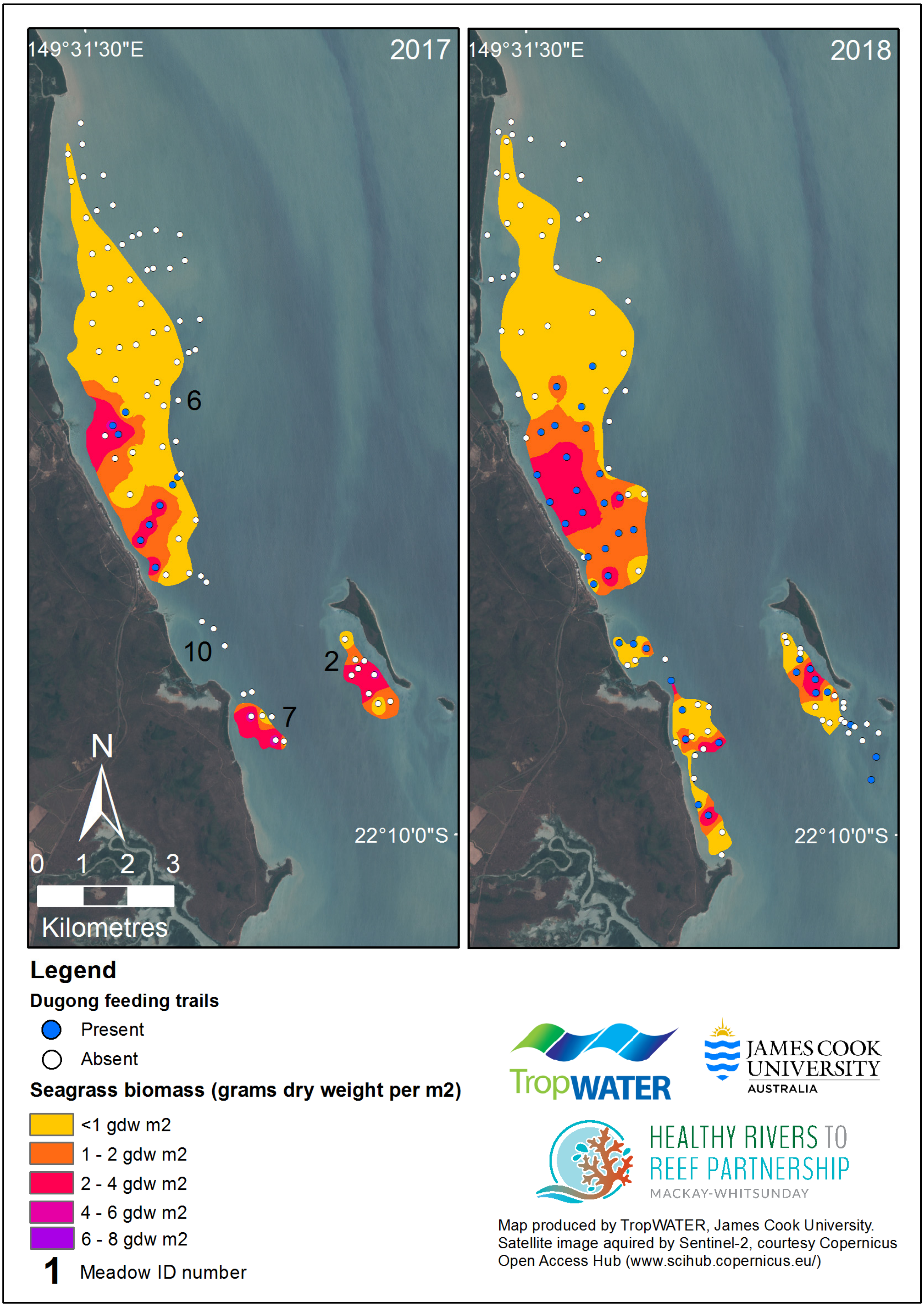


**Figure 6.** Variation in intertidal seagrass biomass and within monitoring meadows, and presence of dugong feeding trails, 2017 and 2018.

# 4 DISCUSSION

Extensive and healthy intertidal seagrass meadows grow throughout the HR2RP marine inshore zones. The 2018 monitoring survey and 2017 baseline survey confirmed findings from previous assessments along the Queensland coast (Coles et al. 2002; Coles et al. 1987) that large intertidal meadows grow in the Clairview region. These meadows are spatially extensive but relatively low density; with mean meadow biomass just ~1g DW $m^{-2}$. This is typical of meadows in the HR2RP marine inshore zones, with mean meadow biomass typically <3g DW $m^{-2}$ for inshore coastal meadows between Dudgeon Point and Hay Point (central zone; York and Rasheed 2018), at Keswick and St Bees Islands (central zone; York and Rasheed 2018), and Abbot Point (north zone; Davey and Rasheed 2018).

Seagrass species can be classed as colonising, opportunistic, or persistent, and vary in their sensitivity and resilience to impacts (Kilminster et al. 2015). The dominance of the opportunistic species *Z. capricorni* and *H. uninervis* in the survey area is characteristic of coastal intertidal and shallow subtidal seagrass meadows in the north (Davey and Rasheed 2018), Whitsundays (McKenzie et al. 2017), and central HR2RP inshore zones (York and Rasheed 2018; McKenzie et al. 2017). Opportunistic and persistent species have the greatest capacity to resist disturbance-related stress; while colonising species tend to be transitory and quick to succumb to disturbances but are often the first to recolonise (Kilminster et al. 2015). The only colonising species recorded in the 2017 and 2018 south zone surveys was *H. ovalis*, which comprised 10% of mean biomass in meadow 6 and <1% in meadow 7 in 2018. The dominance of opportunistic species in this region indicates meadows may be relatively resilient to disturbances.

The largest intertidal meadow in the survey area (meadow 6) was first mapped in 1987 (Figure 1; Coles et al. 1987), was present (but not mapped) when the region was revisited in 1999 (Roder et al. 2002), and was the largest meadow mapped in 2017 (1144 $\pm$ 103 ha). In 2018 meadow 6 area had further increased by 20% to 1378 $\pm$ 113 ha. This large and temporal consistent meadow likely provides a consistent source of primary production that supports the region's marine ecosystems. Extensive dugong feeding was recorded in the southern half of meadow 6 in 2017 and 2018, plus the other monitoring meadows in 2018 (Figure 6). Roder et al. (2002) also recorded evidence of extensive dugong feeding between Carmila and Flock Pigeon Island, and east to Aquila Island. Seagrasses are a critical food for dugong and green turtle (Unsworth and Cullen 2010; Heck et al. 2008). Large-scale seagrass loss associated with flooding in late 2010 and early 2011 along Queensland's east coast saw dugong and turtle deaths increase 215% and 176% respectively (compared to 2010), mainly as a result of starvation (DERM 2011). Future declines in meadow area or biomass in this region would likely impact dugong and green turtle health and survival.

Results of the first two surveys have confirmed that biomass within meadow boundaries in the Clairview region is quite dynamic. This results in areas of high biomass within meadows shifting between surveys (Figure 6). This shifting of biomass hotspots within coastal meadows is a common observation for coastal meadows in tropical Queensland (Chartrand et al. 2018; Reason and Rasheed 2018a; Shepherd et al. 2018; Sozou and Rasheed 2018; York and Rasheed 2018) and has implications for the spatial scale at which effective monitoring is best undertaken. The causes of these shifting mosaics of biomass hotspots may be associated with a range of factors including herbivory, localised biotic disturbance, and seasonal recruitment patterns for seagrass propagules. Recent research work undertaken by the TropWATER Seagrass Group has revealed the importance of dugong and turtle grazing in shaping the spatial patterns of seagrass biomass within coastal meadows of the Great Barrier Reef (Scott et al. in prep). In the Clairview area where high levels of dugong feeding are evident, it is likely these herbivores are an important driver of spatial patterns in seagrass abundance within meadows. In these circumstances monitoring at a larger "meadow" spatial scale is likely to give a much clearer understanding of seagrass condition.

Large tidal ranges (up to 8.5m) and tidal currents generate high coastal turbidity in the south zone. This means most seagrass is confined to intertidal waters, while subtidal seagrasses are sparse and patchy (Carter and Rasheed 2018; Coles et al. 2009; Pitcher et al. 2007). The quality and quantity of light, the primary driver of photosynthesis, affects the growth, survival and depth penetration of seagrass (Dennison 1987; Dennison and Alberte 1985). Seagrass species have different minimum light requirements to maintain a stable state or to achieve positive growth (Collier et al. 2016; Chartrand et al. 2012; Collier et al. 2012). Environmental conditions (e.g. rainfall, river flow, daytime tidal exposure, wind-driven resuspension, water temperature), impacts (e.g. tropical cyclones, floods, dredging), and habitat (e.g. depth, sediment) all influence the available light and therefore seagrass growth/persistence in Queensland (McKenna et al. 2015; York et al. 2015; Carter et al. 2014; Rasheed et al. 2014; Unsworth et al. 2012; Rasheed and Unsworth 2011). Ongoing monitoring in this zone will provide important insight into environmental drivers of seagrass growth and persistence.

## Recommendations

The 2018 monitoring of seagrass meadow area, biomass, and species composition provides the second year of data that will be used to determine baseline seagrass conditions and develop report card scores for the south zone. We recommend:

1. **Ongoing annual monitoring**. The monitoring meadows incorporate ~65% of the south zone's total mapped coastal seagrass, and capture the diversity of meadow sizes and dominant seagrass species in the zone. Ongoing monitoring will build our understanding of seagrass condition in the south zone for adequate reporting.
2. **Five years of data collection before scores are incorporated into the HR2RP report card**. We recommend at least 5 years of data are required to develop an accurate baseline, with the caveat that our confidence in these scores are reduced while baseline values and thresholds are updated annually until a 10-year baseline is reached. We determined 10 years as the ideal length of time to develop an accurate and meadow-specific baseline of seagrass condition in tropical Queensland, against which condition can be assessed, because this period generally incorporates the range of environmental conditions known to influence seagrass condition such as El Niño Southern Oscillation cycles (Bryant et al. 2014).
3. **Continue meadow-scale monitoring**. Meadow area is a fundamental indicator of seagrass condition, i.e. how much of the seagrass resource is present. Meadow area is already incorporated as a condition indicator in a range of seagrass report cards (e.g. QPSMP, WTHWP, HR2RP, DTPHW, GHHP). Meadow-scale monitoring is also important because seagrass biomass (Figure 6) and species composition are rarely uniform across a meadow. Spatial variation caused by aggregated distribution patterns can significantly influence the precision and interpretation of time series analyses, and the scale of sampling relative to the distributional pattern of the organisms to be sampled must be considered (Greig-Smith 1983).
4. **Implement survey limits**. Future surveys should adhere to the survey limits set in 2018 to ensure meadow area comparisons are not biased by variations in tidal exposure.

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