 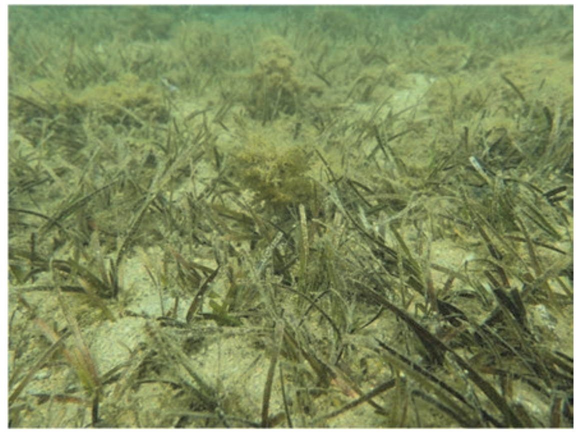

PORT OF ABBOT POINT LONG-TERM SEAGRASS MONITORING PROGRAM - 2017

Davey PA and Rasheed MA

Report No. 18/16

May 2018

PORT OF ABBOT POINT LONG-TERM SEAGRASS MONITORING PROGRAM 2017

A Report for North Queensland Bulk Ports Corporation (NQBP)

Report No. 18/16

May 2018

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KEY FINDINGS

Seagrass Condition 2017

Likely causes of seagrass condition: Unfavorable climate conditions including Tropical Cyclone Debbie.

⬆ Rainfall, river flow, turbidity.

⬇ Available light to seagrass meadows.

⬆ Wind and Waves during TC Debbie leading to physical disturbance

- Seagrass habitat in the Abbot Point area was classified as being in very poor condition in 2017.
  - Shallow inshore seagrass meadows were in poor condition due to the absence of two of the five inshore monitoring meadows. The remaining three inshore monitoring meadows were in good condition.
  - Deeper offshore seagrass was in very poor condition due a decline in biomass at all offshore monitoring locations.

- Decline in seagrass habitat was likely a result of impacts from Tropical Cyclone Debbie and other unfavourable weather events affecting the area in 2017. These resulted in high rainfall and flooding of the Don River in March which lead to levels of benthic light falling below that required to support seagrass growth and survival.

- High winds and wave energy during TC Debbie likely impacted shallow coastal seagrasses which led to a reversal of much of the recovery in coastal seagrasses that had occurred in the previous year.

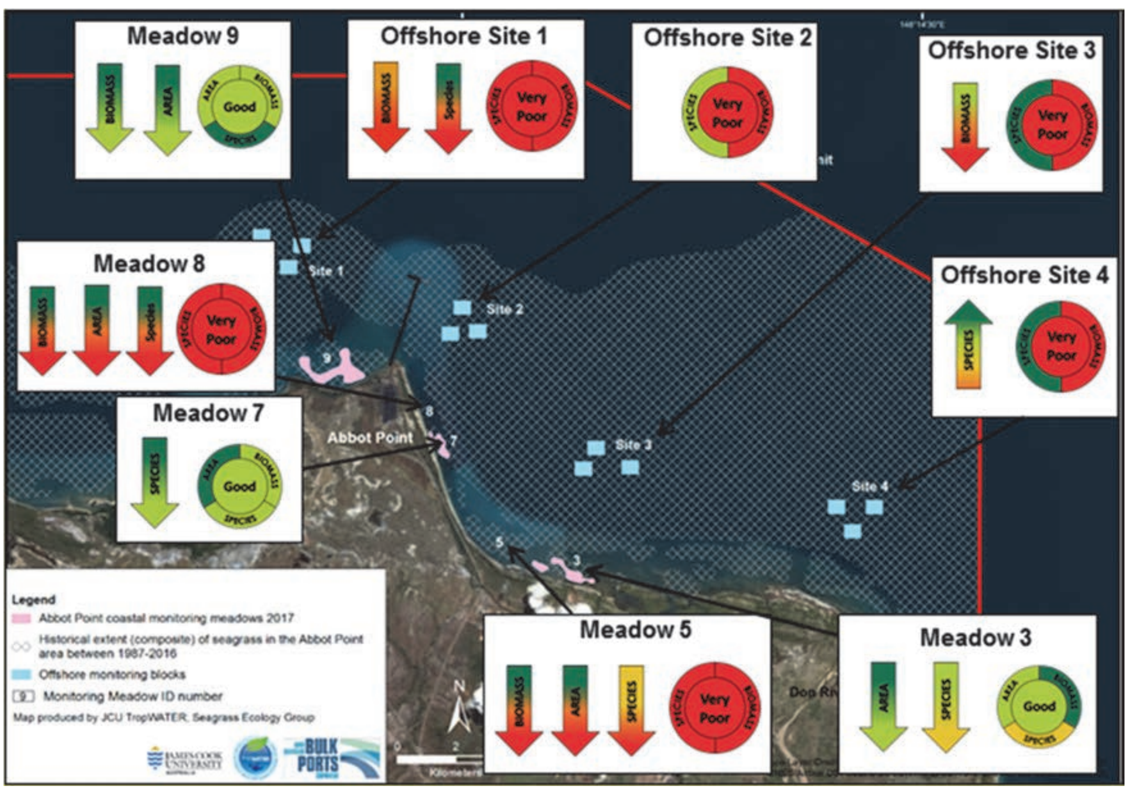
- In spite of meadow condition deteriorating, patches of the key seagrass species remain in both coastal and offshore areas. If favourable conditions occur during 2018, these patches have the capacity to expand and facilitate recovery.

IN BRIEF

A long-term seagrass monitoring program and strategy were established in the Abbot Point region in 2008. The original program involved quarterly monitoring of biomass, distribution and species composition of key representative seagrass meadows. Photosynthetic Active Radiation (PAR) and temperature within the seagrass meadows were also monitored until 2016. In the past, the program has included manipulative experiments investigating seagrass recovery, recruitment processes and seed bank reserves after disturbance, and five broad-scale surveys of all seagrass in the region. In 2015 quarterly monitoring was reduced to annual assessments, with broader scale regional surveys being completed every three years (last completed in 2016 – for a full distribution of seagrasses and species within the broader port limits see McKenna et al. 2017). Monitoring in 2017 focussed on five inshore seagrass meadows and four offshore monitoring sites selected for long term monitoring.

The overall condition of seagrass habitat in the Abbot Point region was very poor in 2017 compared to the satisfactory condition of 2016. Shallow inshore seagrass meadows were poor, whilst the deep offshore seagrasses were classified as very poor (Figure 1). Decline in meadow condition was mainly the result of low (or absent) seagrass biomass and low coverage in the majority of monitoring areas. Seagrass was absent entirely from one of the offshore monitoring sites and two of the five inshore meadows. These changes were likely due to unfavourable weather events that caused a reduction in PAR and an increase in physical disturbance to seagrass habitat in 2017.

Tropical Cyclone (TC) Debbie was the most significant weather event affecting the Abbot Point region in 2017, making landfall 50km south at Airlie Beach on the 28th of March. Strong wind, waves and high rainfall that accompanied the cyclone likely had a significant impact on shallow meadows at Abbot Point. The increased flow and turbidity from the Don River during this period would have further reduced available light (PAR) in the seagrass meadows, which fell below levels required to support seagrass growth and survival during 2017.



*lack of arrows indicates no change in condition index from the previous year

Figure 1. Seagrass condition index for Abbot Point seagrass monitoring areas 2017.

These events resulted in a reversal of the seagrass recovery observed in 2016, particularly for inshore coastal seagrasses. Despite declines, key seagrass species remain in patches within much of the historical footprint of the deep water and inshore monitoring meadows. *Halophila ovalis*, *Zostera muelleri* and *Halodule uninervis* remain within three of the five inshore monitoring meadow locations and *Halophila decipiens*, *Halophila ovalis, Halophila spinulosa* and *Halodule uninervis* remain in three out of four offshore monitoring sites. Under favourable environmental conditions, these seagrasses can facilitate recovery and meadow expansion over time.

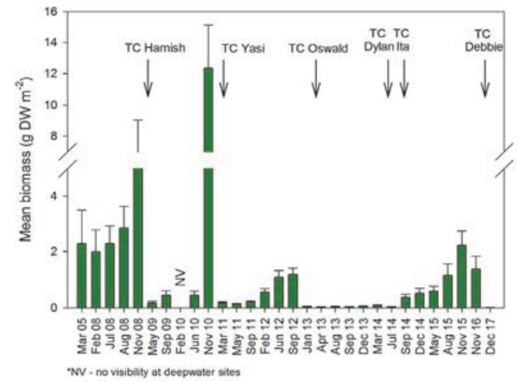


Figure 2. Mean biomass (g dw m^{-2}) of Abbot Point offshore seagrass monitoring sites from 2005 to 2017. Offshore site 1 is excluded from calculations.

The reduced biomass and spatial coverage means these meadows are likely to have a relatively low resilience to further natural or anthropogenic impacts that may occur during 2018. Any recovery will be contingent on future weather being favourable for seagrass growth and given the low resilience, management of activities in the region should focus on minimising additional anthropogenic impacts on the meadows.

The Abbot Point seagrass monitoring program forms part of a Queensland wide program that examines the condition of seagrasses in the majority of Queensland commercial ports, and is a component of James Cook University's (JCU) broader seagrass assessment and research program. For full details of the Queensland ports seagrass monitoring program, see www.jcu.edu.au/portseagrassqld

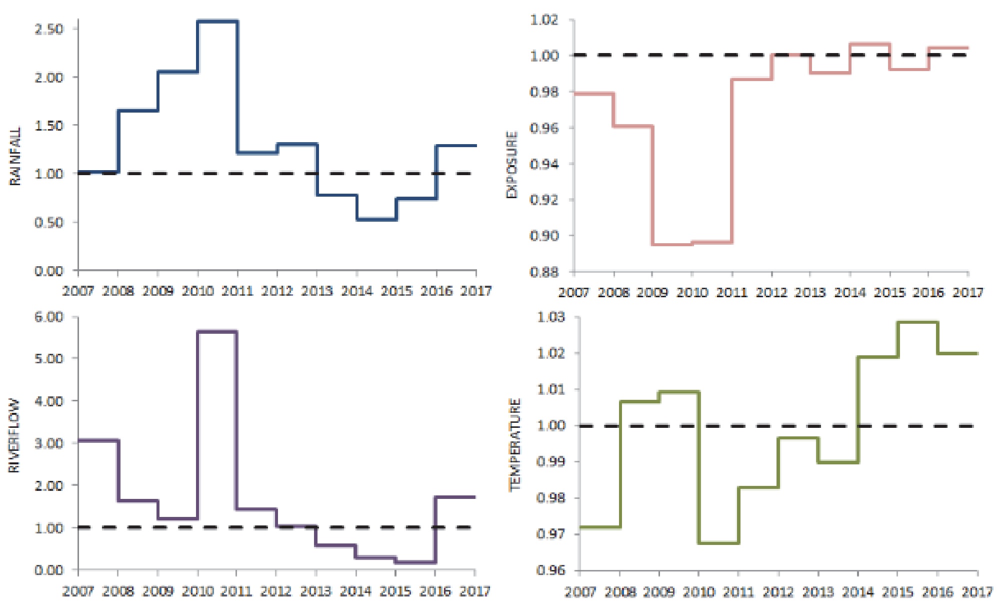


Figure 3. Recent climate trends in the Bowen/Abbot Point area 2000/01 to 2016/17: Change in climate variables as a proportion of the long-term average. See section 3.3 for detailed climate data.

TABLE OF CONTENTS

1. INTRODUCTION

Seagrasses provide a range of critically important and economically valuable ecosystem services including coastal protection, nutrient cycling, sediment entrapment and promotion of aquaculture production (Costanza et al. 1997; Hemminga and Duarte 2000). With respect to carbon markets, the role that seagrasses play in sequestering carbon as a means of carbon offsetting is also widely recognised (McLeod et al. 2011; Fourqurean et al. 2012; Macreadie et al. 2013). Seagrass meadows show measurable responses to changes in water quality, making them ideal candidates for monitoring the long-term health of coastal marine environments (Dennison et al. 1993; Abal and Dennison 1996; Orth et al. 2006).

Globally, seagrasses have been declining due to natural and anthropogenic disturbance events (Waycott et al. 2009). Explanations for seagrass decline include increasing frequency of severe weather; disease; overgrazing by herbivores; anthropogenic stresses including direct disturbance from coastal development, dredging and trawling, coupled with indirect effects through changes in water quality due to sedimentation, pollution and eutrophication (Short and Wyllie-Echeverria 1996). In the Great Barrier Reef (GBR) coastal region, the highest threat exposure for seagrass exists in the southern two thirds, in areas where multiple threats accumulate including urban, port, industrial and agricultural runoff (Grech et al. 2011). These hot spots arise as seagrasses preferentially occur in the same sheltered coastal locations that ports and urban centres are established (Coles et al. 2015). In Queensland, this is recognised and a strategic monitoring program of these high-risk areas has been established to aid in their (Coles et al. 2015).

1.1 Queensland Ports Seagrass Monitoring Program

A long-term seagrass monitoring and assessment program has been established in the majority of Queensland commercial ports. The program was developed by the Seagrass Ecology Group at James Cook University's Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) in partnership with Queensland port authorities. While each location is funded separately and they have a range of requirements for use of the information, a common methodology and rationale is used to provide a network of seagrass monitoring locations throughout the state (Figure 4).

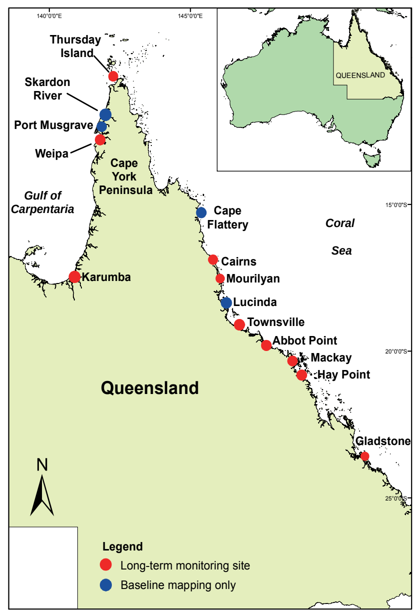


Figure 4. Location of Queensland Port Seagrass monitoring sites.

A strategic long-term assessment and monitoring program for seagrasses provides port managers and regulators with the key information to ensure effective management of seagrass resources. It is useful information for planning and implementing port development and maintenance programs so they have a minimal impact on seagrasses. The program also provides an ongoing assessment of many of the most threatened seagrass communities in the state.

The program not only delivers key information for the management of port activities to minimise impacts on seagrass habitat but has also resulted in significant advances in the science and knowledge of tropical seagrass ecology. It has been instrumental in developing tools, indicators and thresholds for the protection and management of seagrasses, and an understanding of the drivers of tropical seagrass change. It provides local information for individual ports as well as feeding into regional assessments of the status of seagrasses.

For more information on the program and reports from the other monitoring locations, see www.jcu.edu.au/portseagrassqld

1.2 Abbot Point Seagrass Monitoring Program

North Queensland Bulk Ports Corporation (NQBP) in partnership with the Seagrass Ecology Group at TropWATER has been engaged in a seagrass assessment and monitoring program at Abbot Point since 2008. This program has involved six broad scale surveys (2005; two each in 2008 & 2013; 2016) of the marine habitat within the port limits, manipulative experiments investigating seagrass recovery, quarterly long-term monitoring of representative seagrass meadows at inshore and offshore areas, and light (PAR) and temperature assessments within meadows (Figure 5). The long-term monitoring areas represent the range of seagrass communities within the port and include meadows considered most likely to be influenced by port activity and development, and areas outside the zone of influence of port activity and development (Figure 5).

In 2015 the quarterly long-term monitoring program was reduced to an annual program; monitoring the same representative seagrass meadows that have been monitored in the past. The annual monitoring approach is based on periodic re-assessments of all seagrasses within the region (broad scale survey every three years) with a subset of representative areas monitored annually in the intervening years. This same approach is used as part of NQBP's other long-term ambient seagrass monitoring programs in the Ports of Weipa and Mackay/Hay Point, and elsewhere in other Queensland ports. For the 2017 Abbot Point annual survey, a subset of representative inshore and offshore meadows were assessed (Figure 5). Although the PAR and temperature monitoring program ceased in 2015, PAR data has been provided by Vision Environment Pty Ltd to supplement this report. As of March 2018 the PAR and temperature monitoring at key inshore seagrass meadows has been re-established as part of the new JCU and NQBP research and monitoring partnership.

Information collected in these seagrass monitoring programs aims to assist in planning and managing future developments in coastal areas. The monitoring program forms part of Queensland's network of long-term monitoring sites of important fish habitats in high-risk areas. It also provides a key input into the condition and trend of seagrasses in the Mackay-Whitsundays NRM region, an area which otherwise has a poor spatial coverage for seagrass assessment and condition.

This report presents the findings of the annual seagrass monitoring for 2017. The objectives of the annual long-term seagrass monitoring program for the Port of Abbot Point are to:

- Map seagrass distribution and determine seagrass density (biomass), distribution (area) and community type (species composition) at representative long term monitoring meadows;
- Compare results of monitoring surveys and assess any changes in seagrass habitat in relation to natural events or human induced port and catchment activities;
- Provide up to date information to aid in the planning of potential port development that ensures the marine environment is protected and minimally affected;
- Incorporate the results into the Geographic Information System (GIS) database for the Port of Abbot Point;
- Discuss the implications of monitoring results for overall health of the Port of Abbot Point's marine environment and provide advice to relevant management agencies.

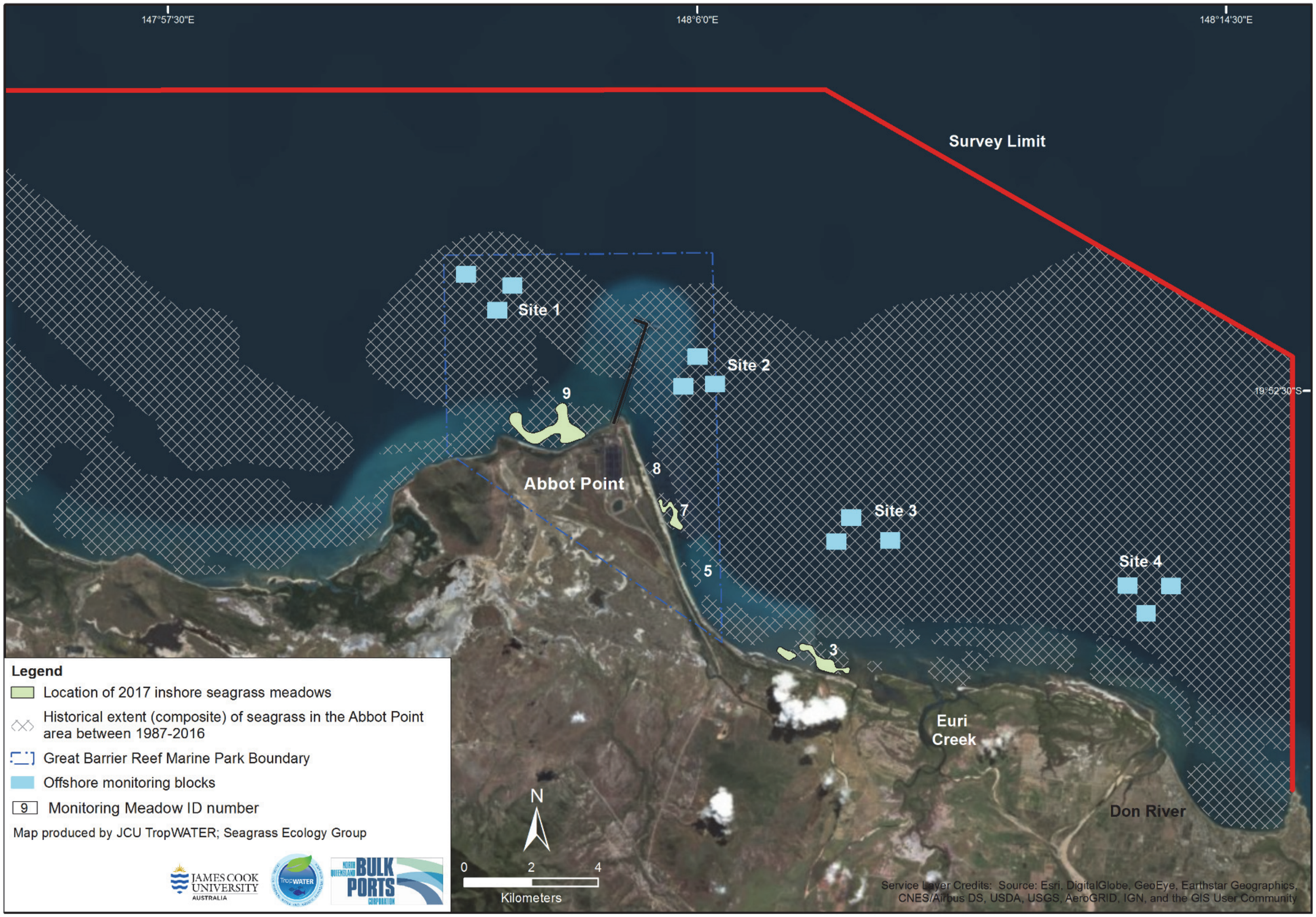


Figure 5. Location of 2017 inshore monitoring meadows and offshore monitoring areas in the Abbot Point region.

2. METHODS

2.1 Sampling Approach and Methods

Five coastal meadows and four offshore areas were identified which were suitable for long term seagrass monitoring (Figure 5; McKenna et al. 2008). Monitoring meadows selected were representative of the range of seagrass communities identified in the 2008 baseline survey, and were located in areas considered ideal sensitive receptor sites for assessing seagrass condition.

Methods for assessing inshore and offshore seagrasses in the Abbot Point region follow those of the established seagrass program at Abbot Point (see McKenna et al. 2008; Unsworth et al. 2010 and McKenna & Rasheed 2011). The application of standardised methods at Abbot Point and throughout Queensland allows for direct comparison of local seagrass dynamics with the broader region.

Free diving and deep-water sled tows using an underwater digital camera system were used to survey inshore and offshore areas for seagrass (Figure 6). At each survey site, seagrass habitat observations included seagrass species composition, aboveground biomass, percent algal cover, depth below mean sea level (MSL), sediment type, time and position (GPS). The percent cover of other major benthos at each site was also recorded.

Seagrass aboveground biomass was measured using a “visual estimates of biomass” technique (Kirkman 1978; Mellors 1991). At free diving sites, this technique involved an observer ranking seagrass biomass within three randomly placed 0.25m^2 quadrats at each site (Figure 6). At digital camera sled tow sites, this technique involved an observer ranking seagrass at 10 random time frames allocated within the 100m of footage for each site.

Ranks at all sites were made in reference to a series of quadrat photographs of similar seagrass habitats for which aboveground biomass has previously been measured. The relative proportion of the aboveground biomass (percentage) of each seagrass species within each survey quadrat was also recorded. Field biomass ranks were then converted into aboveground biomass estimates in grams dry weight per square metre (g dw m^{-2}). At the completion of sampling, each observer ranked a series of calibration quadrats that represented the range of seagrass biomass in the survey. After ranking, seagrass in these quadrats was harvested and the actual biomass determined in the laboratory. A separate regression of ranks and biomass from calibration quadrats were generated for each observer and applied to the field survey data to standardise aboveground biomass estimates.

Figure 6. Assessment of seagrass habitat using sled tows and live camera feed, and free-divers.

All survey data was entered into a GIS for presentation of seagrass species distribution and density. Satellite imagery of the Bowen/Abbot Point area with information recorded during the surveys was combined to assist with mapping seagrass meadows. Three seagrass GIS layers were created in ArcMap:

- **Habitat characterisation sites** – site data containing above-ground biomass (for each species), dbMSL, sediment type, time, latitude and longitude from GPS fixes, sampling method and any comments.
- **Seagrass meadow biomass and community types** – area data for seagrass meadows with summary information on meadow characteristics. Seagrass community types were determined according to species composition from nomenclature developed for seagrass meadows of Queensland (Table 1). Abundance categories (light, moderate, dense) were assigned to community types according to above-ground biomass of the dominant species (Table 2).
- **Seagrass landscape category** – area data showing the seagrass landscape category determined for each meadow.

Isolated seagrass patches
The majority of area within the meadows consisted of un-vegetated sediment interspersed with isolated patches of seagrass

Aggregated seagrass patches
Meadows are comprised of numerous seagrass patches but still feature substantial gaps of un-vegetated sediment within the meadow boundaries

Continuous seagrass cover
The majority of area within the meadows comprised of continuous seagrass cover interspersed with a few gaps of un-vegetated sediment.

Table 1. Nomenclature for seagrass community types in Queensland.

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 in Queensland.

Density	Mean above ground biomass (g DW m^{-2})				
	H. uninervis (narrow)	*H. ovalis* *H. decipiens*	*H. uninervis* (wide) *C. serrulata/rotundata*	*H. spinulosa* *H. tricostata*	*Z. muelleri*
Light	< 1	< 1	< 5	< 15	< 20
Moderate	1 - 4	1 - 5	5 - 25	15 - 35	20 - 60
Dense	> 4	> 5	> 25	> 35	> 60

The boundary of seagrass meadows were mapped by free diving and underwater camera techniques, then assigned a mapping precision estimate (±ha) (Table 3). The precision of the boundary was determined using an estimate of mapping reliability (R) based on the distance between sampling sites and the presence and absence of seagrass at sites. This resulted in a range of meadow sizes, which is expressed as an error (±ha) around the total meadow area (ha).

The boundaries of the offshore annual monitoring areas were not mapped. Boundary mapping of offshore seagrass habitat only occurs during the three yearly broad-scale surveys (2016) (see Figure 5 for offshore monitoring areas).

Table 3. Mapping precision and methodology for seagrass meadows in the Port Abbot Point 2017.

Mapping precision	Mapping methodology
20-50m	Subtidal meadow boundaries determined from free diving surveys; Relatively high density of survey sites; Recent digital maps/ imagery aided in mapping.

2.2 Seagrass meadow condition index

A condition index was developed for the Abbot Point seagrass meadows based on changes in mean above-ground biomass, total meadow area and species composition relative to a baseline. Seagrass condition for each indicator at Abbot Point was scored from 0 to 1 and assigned one of five grades: A (very good), B (good), C (satisfactory), D (poor) and E (very poor). The flow chart in Figure 7 summarises the methods used to calculate seagrass condition.

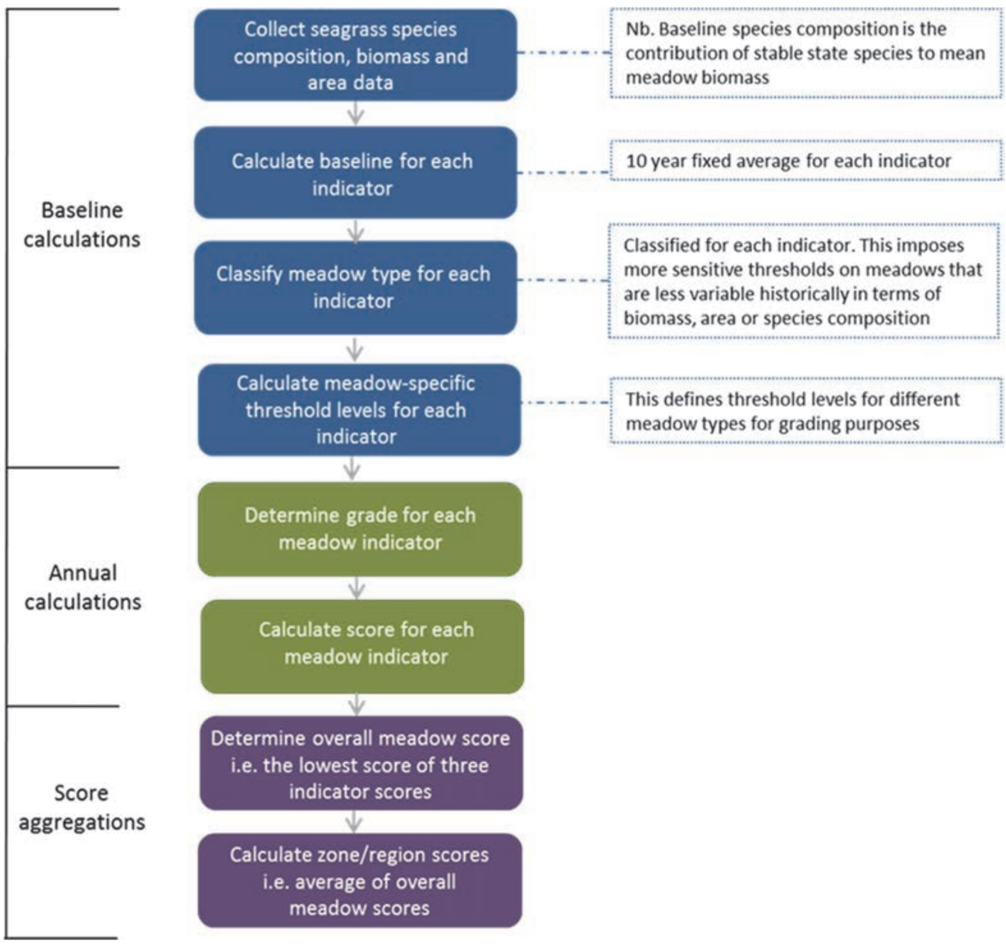


Figure 7. Flow chart detailing the development of Abbot Point grades and scores.

Further information on methodology associated with scoring, grading and seagrass condition can be found in Appendix 1, along with an example of how biomass scores are calculated.

3. RESULTS

3.1 Seagrass in the Abbot Point monitoring areas

Eight seagrass species have been identified within the Abbot Point region since surveys of the area began in 1987 (Figure 8). All species except *Cymodocea rotundata*, *Cymodocea serrulata* and *Halophila tricostata* were present in the 2017 survey of monitoring meadows. However, as this only examines a subset of the total seagrass distribution these species may have been present in areas outside of the monitoring locations.

137 sites were investigated as part of the 2017 Abbot Point monitoring. Seagrass was present at 30% of these sites. Fourteen out of the thirty six offshore monitoring transects within the four offshore sites contained seagrass whilst 30 of 111 sites assessed for the inshore meadows contained seagrass. The inshore monitoring meadows covered 159.2 ± 33.7 Ha (Figure 9). For a full distribution of seagrasses and species within the broader port limits, the full baseline surveys conducted every 3 years should be consulted. The last of these was performed in 2016 (McKenna et al. 2017).

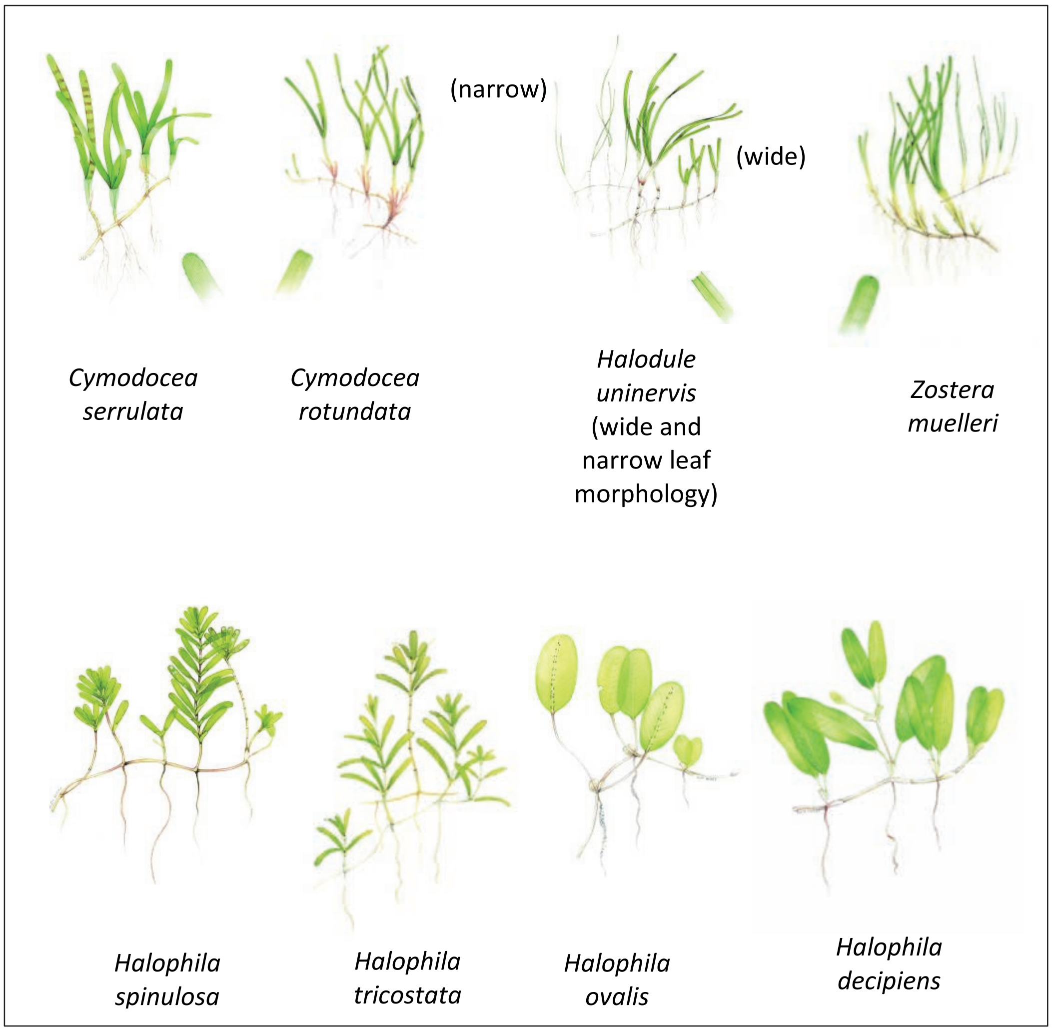


Figure 8. Seagrass species identified in the Abbot Point/Bowen region since 1987.

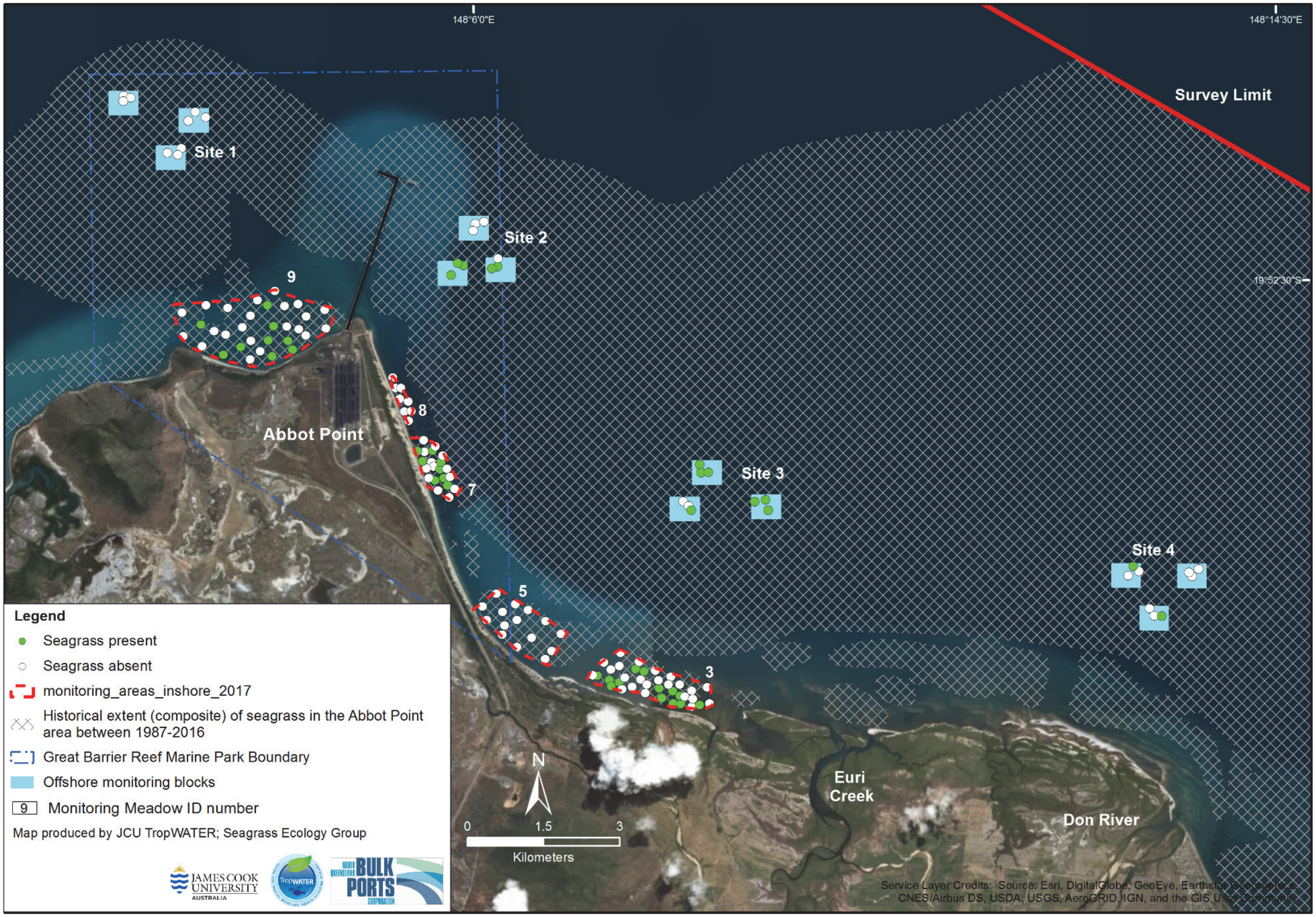


Figure 9. Location of inshore seagrass monitoring meadows, offshore monitoring locations and seagrass assessment sites in 2017

3.2 Seagrass condition in the Abbot Point monitoring areas

The overall condition of seagrass habitat in the Abbot Point region in 2017 was classified as very poor (Table 4) compared to satisfactory in 2016. The deeper offshore seagrass habitat was classified as very poor, while the shallower inshore seagrass habitat was classified as poor. The lower offshore seagrass condition score resulted in the overall Abbot Point condition score being very poor (Table 4).

Meadow	Biomass	Species Composition	Area	Overall Meadow Score	Overall location Score
Offshore Monitoring Areas					
Offshore Site 1	0.00	0.00	N/A	0	0.01
Offshore Site 2	0.01	0.80	N/A	0.01	
Offshore Site 3	0.02	0.97	N/A	0.02	
Offshore Site 4	0.01	01.00	N/A	0.01	
Inshore Monitoring Areas					
Inshore Meadow 3	0.88	0.62	0.82	0.72	0.44
Inshore Meadow 5	0	0	0	0	
Inshore Meadow 7	0.78	0.72	0.87	0.75	
Inshore Meadow 8	0	0	0	0	
Inshore Meadow 9	0.83	1	0.71	0.71	
Overall score for seagrass in the Port of Abbot Point					**0.23**

N/A – area is not measured at offshore monitoring sites

Table 4. Scores for seagrass indicators (biomass, area and species composition) for the Abbot Point region 2017.

Inshore monitoring meadows

Only three of the five inshore monitoring meadows were present in 2017. The three that were present were in a good condition, however the two inshore monitoring meadows that were absent (meadows 5 and 8) were classified as very poor due to the absence of seagrass at these sites (Table 4). The absence of these two meadows lead to an overall decrease in the combined inshore meadow score in 2017 compared to 2016 (Figure 11 and 13). Within the three meadows that were present, species composition was classified as satisfactory to very good and biomass and area remained above, or close to, long-term averages (Figure 10, 12 and 14).

There was a shift in seagrass species composition for 2 of the three meadows that were present in comparison to 2016, with less stable colonising species making up a greater proportion of the species mix for Meadows 3 and 7 (Figure 14).

Offshore monitoring sites

There are three deepwater (>10m below MSL) and one shallow (~5-7m below MSL) offshore monitoring sites that are assessed in the monitoring program. The shallow site 1 is located on Clark Shoal and typically dominated by *Halodule uninervis.* The deepwater, offshore sites 2-4 consist of low light adapted *Halophila* species (Appendix 2). Due to these differences, offshore site 1 is treated separately to the other deeper water offshore sites when conducting analysis of changes.

Seagrass in all offshore monitoring locations (Offshore Sites 1–4) were in very poor condition in 2017 (Table 4). There was no seagrass present on the shallow Clark Shoal site (Offshore Site 1) and biomass for the deeper offshore sites (sites 2-4) was well below the long-term averages (Figure 17; Figure 18; Appendix 3c). Despite low biomass, species composition in the deepwater sites improved between 2016 and 2017 due to an increased presence of *Halophila spinulosa* (Figure 17 -19).

The shallow Offshore Site 1 has been highly variable in its presence and species composition during the monitoring program (Table 2; Appendix 2 and 3c). The meadow has shifted between *Halophila ovalis* and the larger *Halodule uninervis* in the past (Figure 15; Appendix 2) and seagrass has previously been absent from the site between 2011 and 2014 (Figure 15).

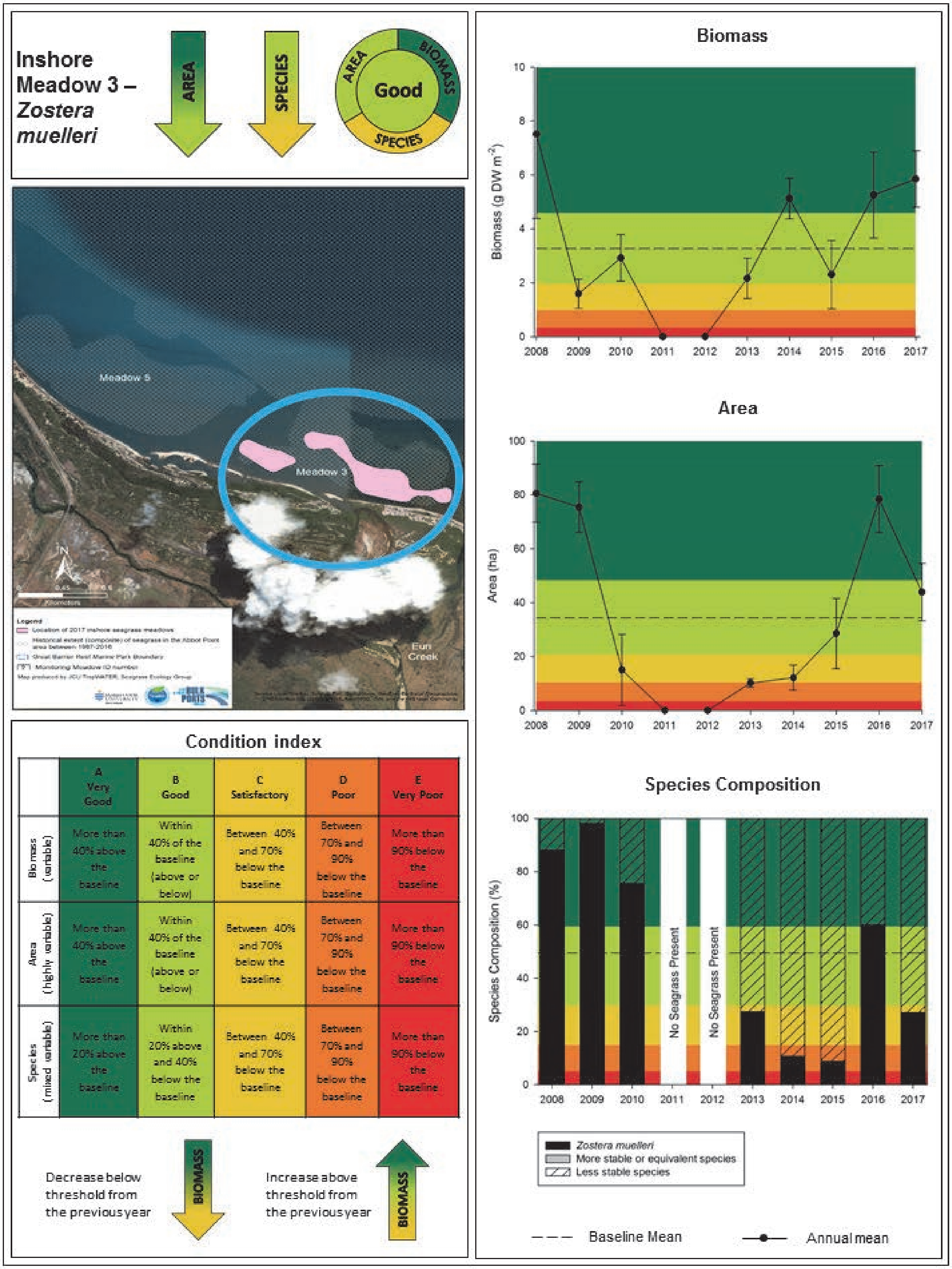


Figure 10. Mean meadow biomass (g DW m^{-2}), total meadow area (ha) and species composition at inshore monitoring Meadow 3.

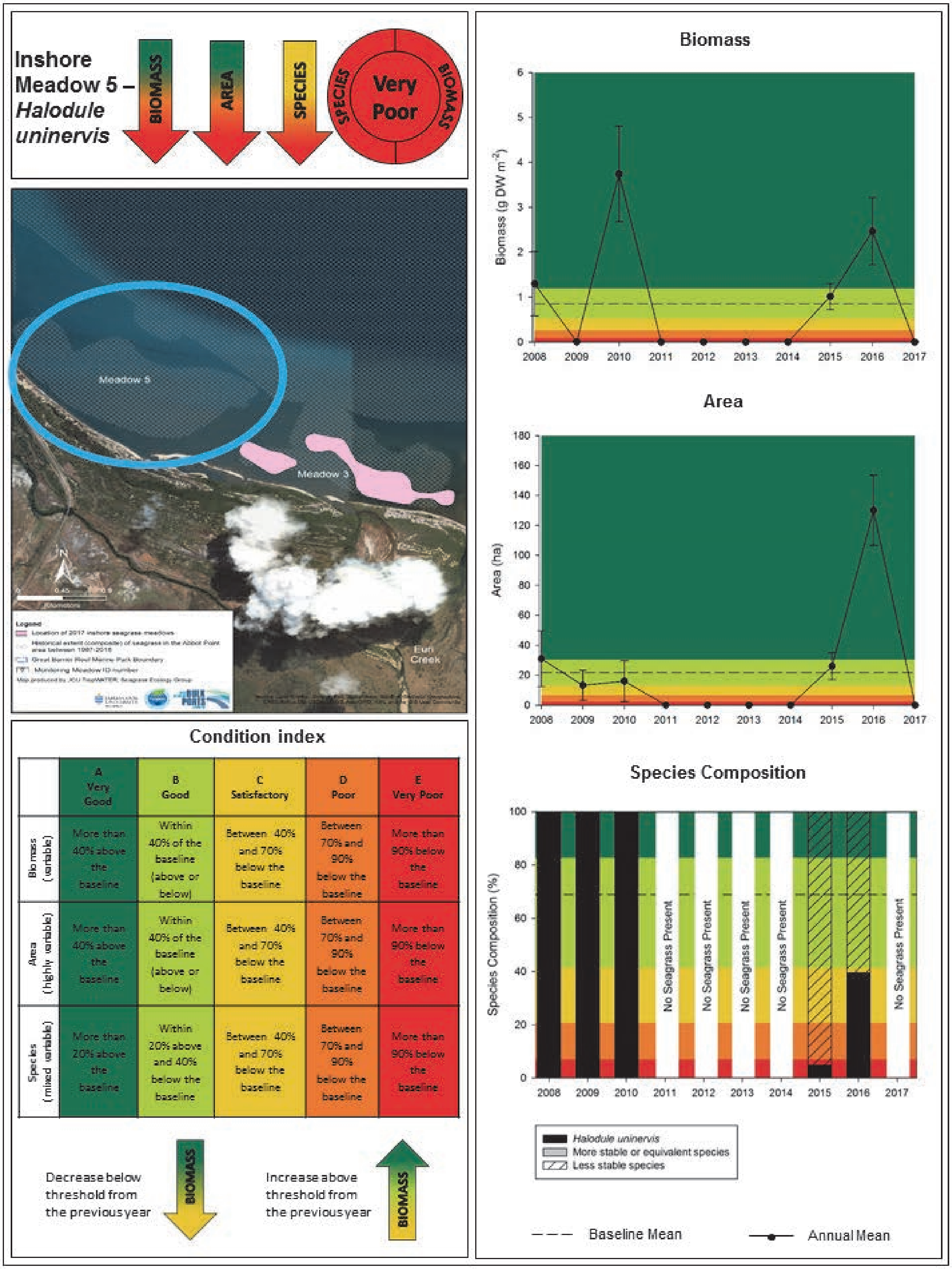


Figure 11. Mean meadow biomass (g DW m^{-2}), total meadow area (ha) and species composition at inshore monitoring Meadow 5.

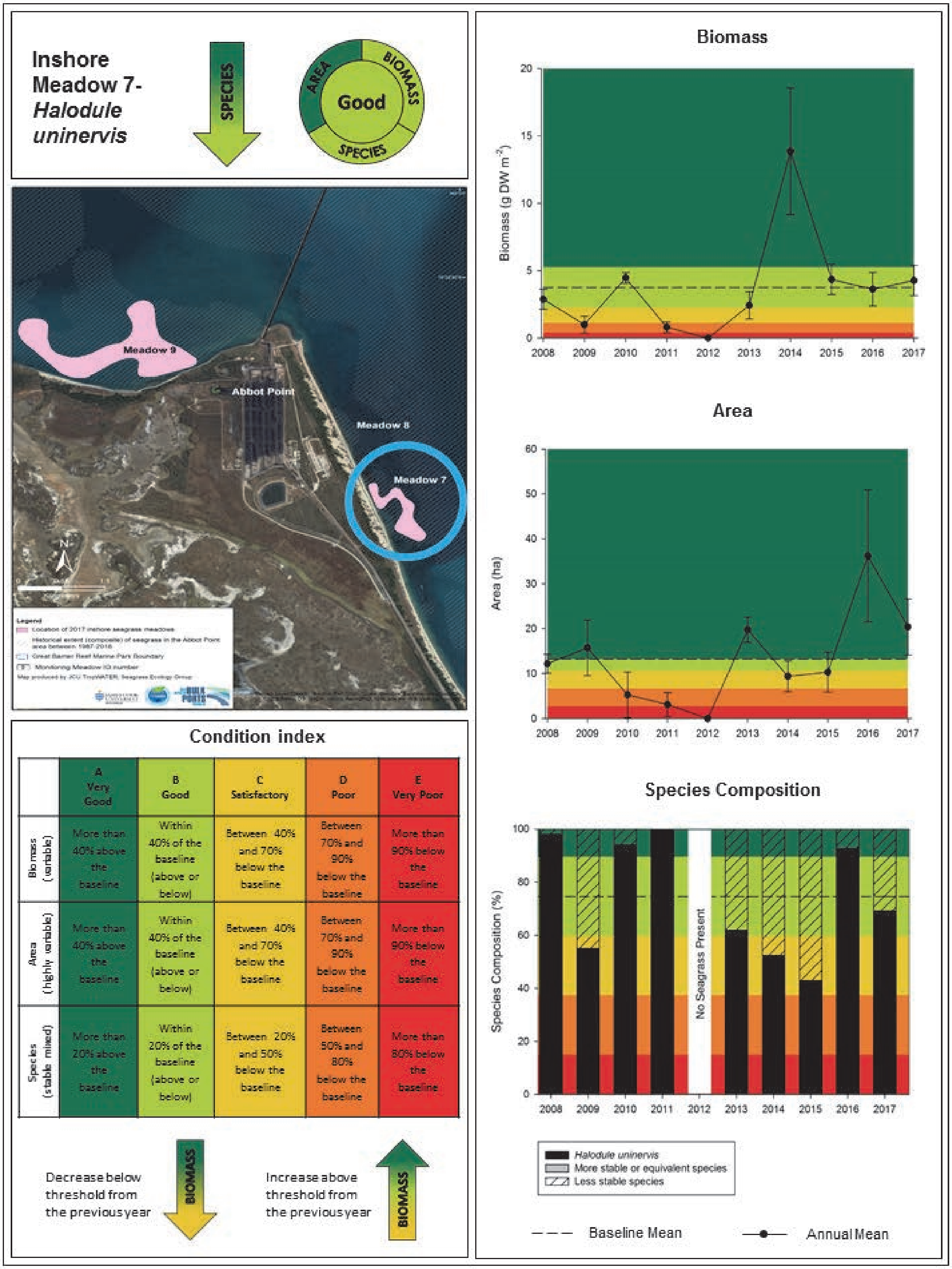


Figure 12. Mean meadow biomass (g DW m^{-2}), total meadow area (ha) and species composition at inshore monitoring Meadow 7.

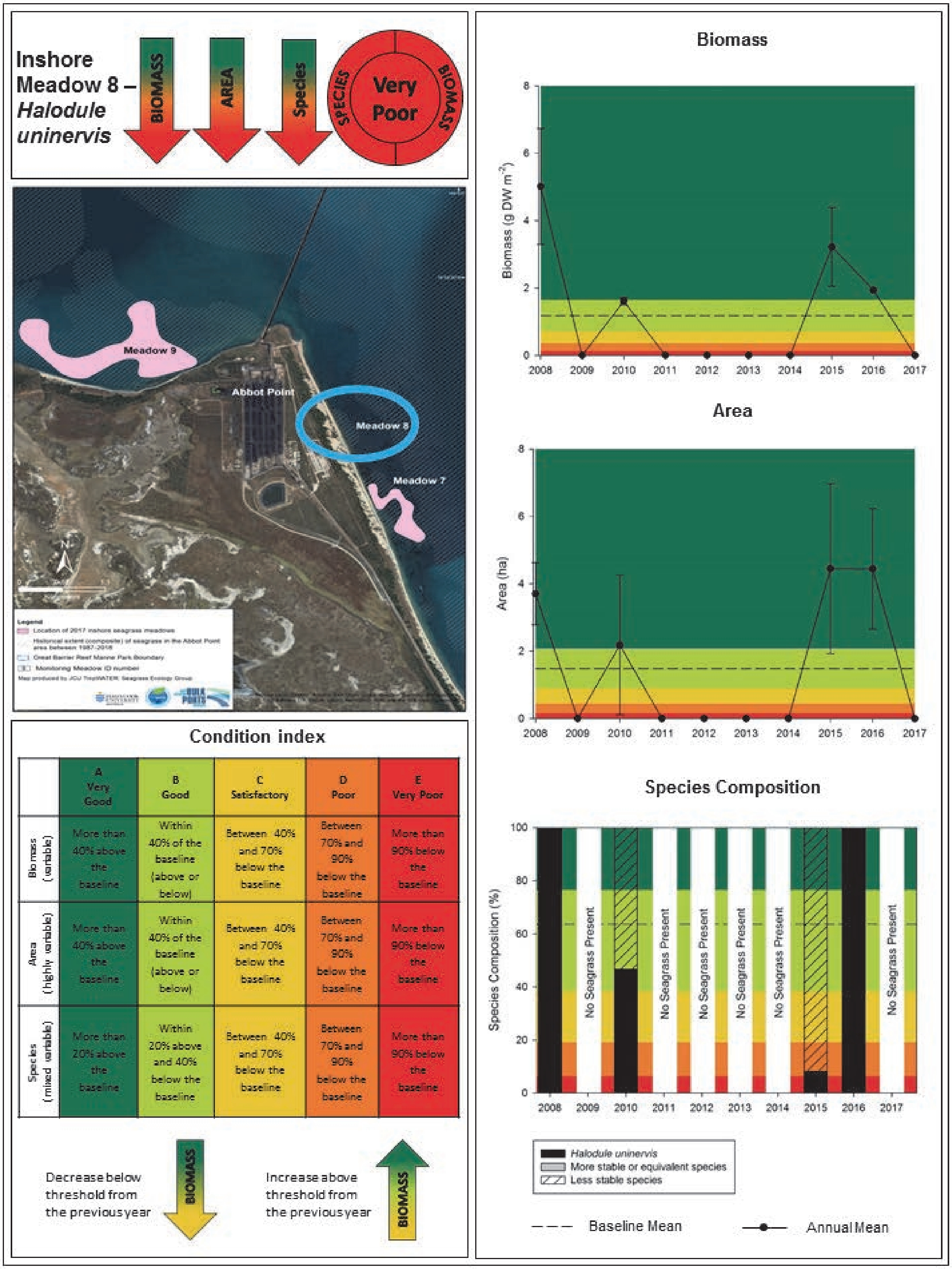


Figure 13. Mean meadow biomass (g DW m^{-2}), total meadow area (ha) and species composition at inshore monitoring Meadow 8.

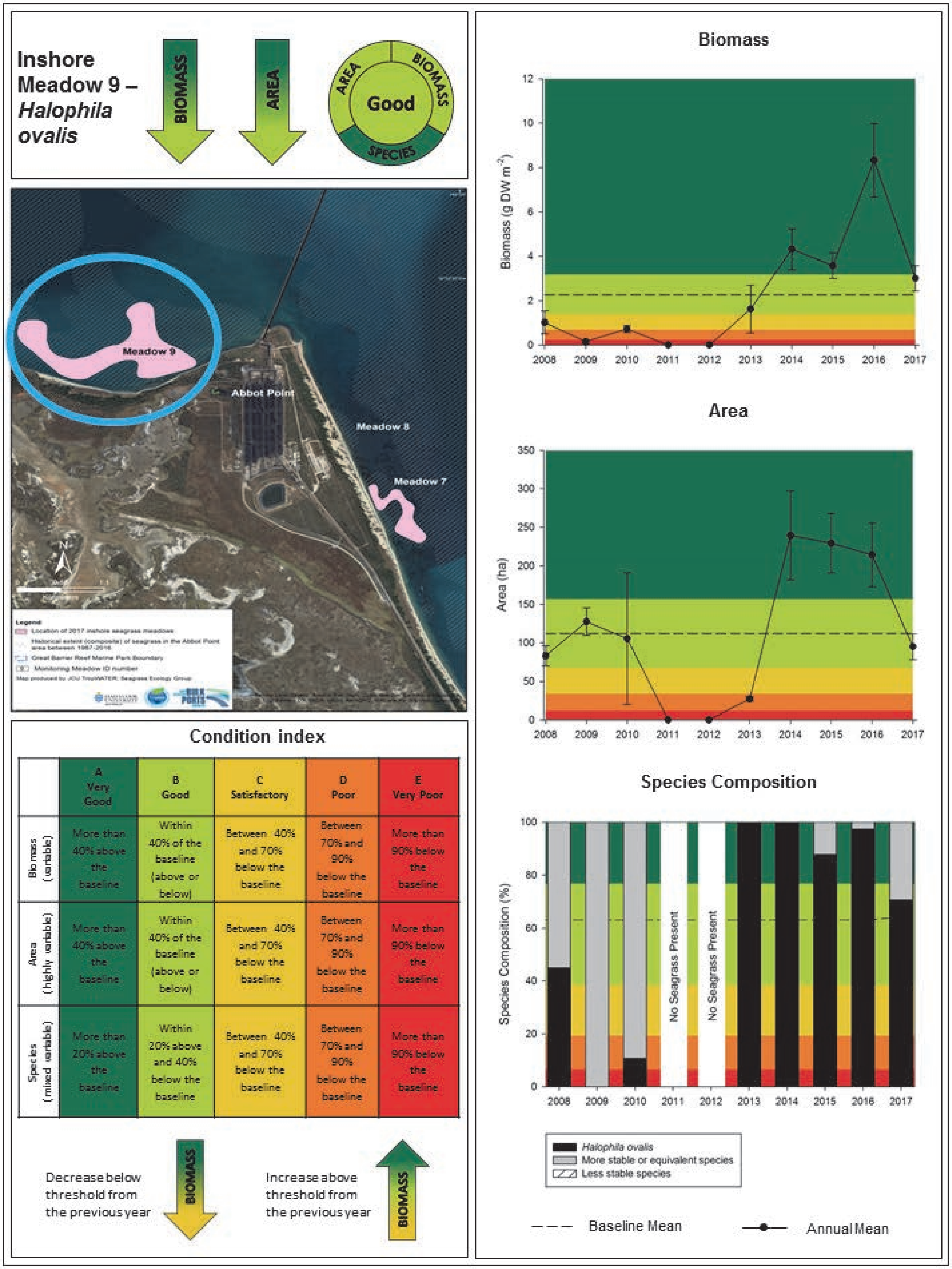
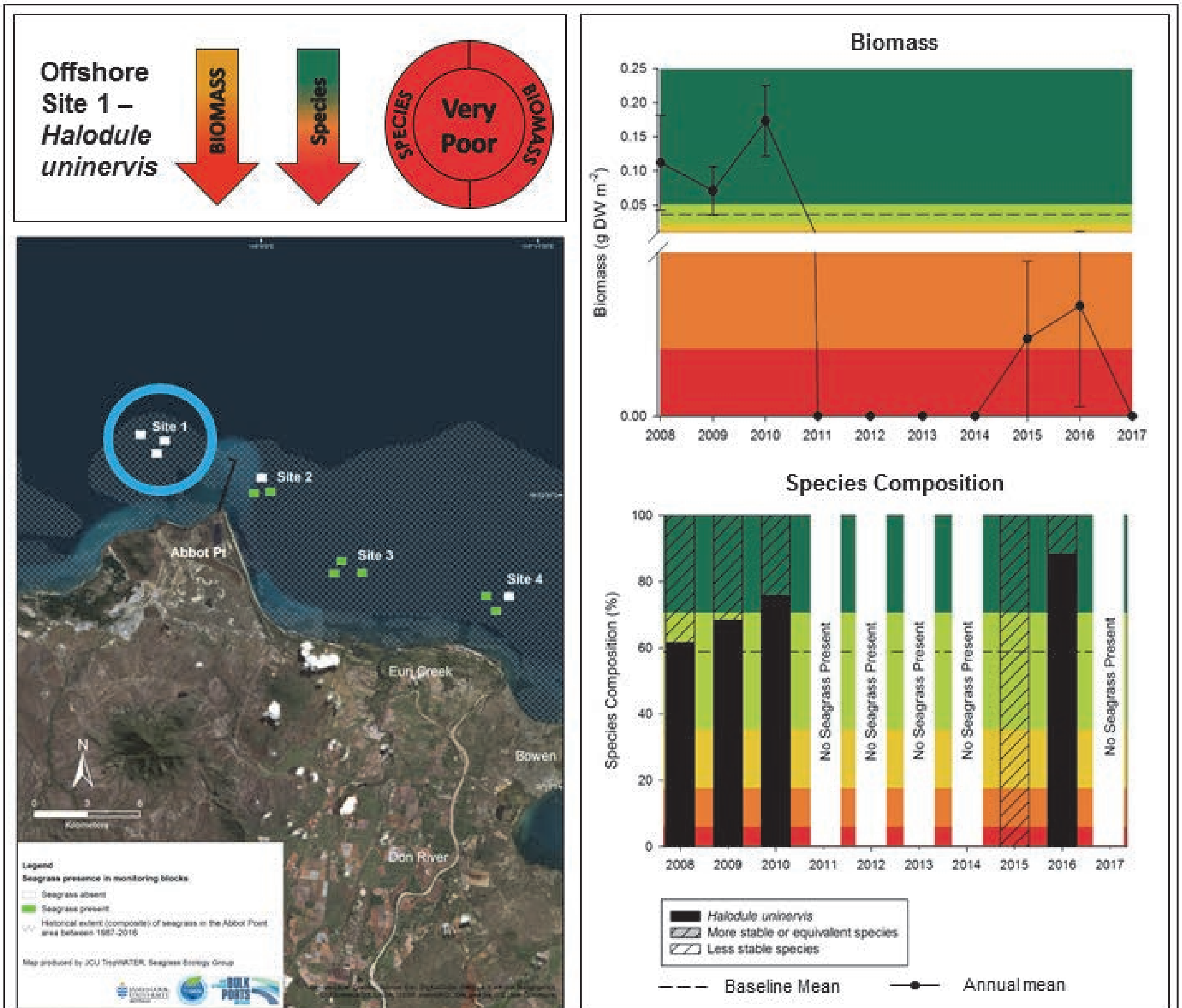


Figure 14. Mean meadow biomass (g DW m^{-2}), total meadow area (ha) and species composition at inshore monitoring Meadow 9.



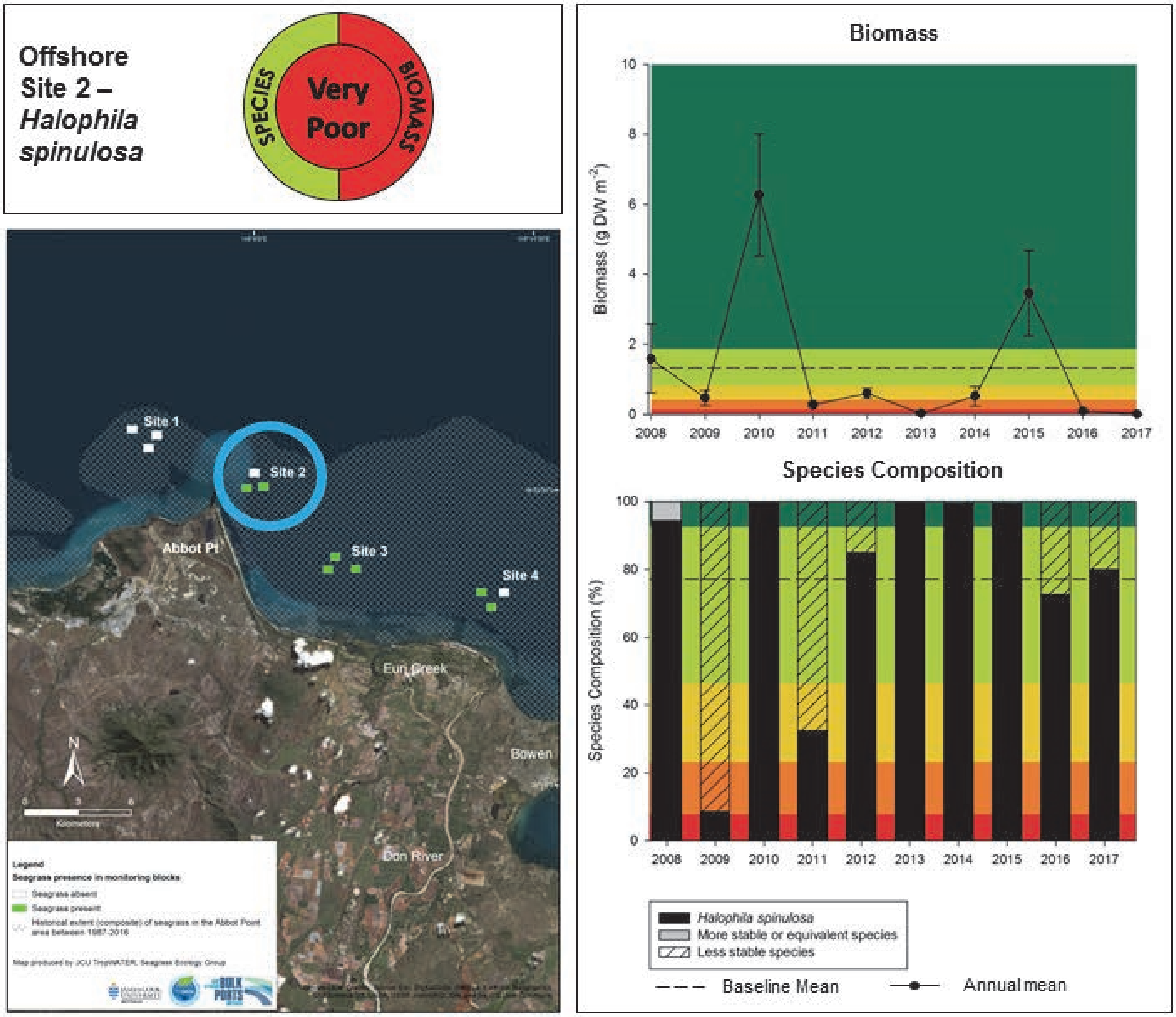
Condition index

	A Very Good	B Good	C Satisfactory	D Poor	E Very Poor
Biomass (variable)	More than 40% above the baseline	Within 40% of the baseline (above or below)	Between 40% and 70% below the baseline	Between 70% and 90% below the baseline	More than 90% below the baseline
Species (mixed variable)	More than 20% above the baseline	20% above and 40% below the baseline	Between 40% and 70% below the baseline	Between 70% and 90% below the baseline	More than 90% below the baseline

Decrease below threshold from the previous year — BIOMASS

Increase above threshold from the previous year — BIOMASS

Figure 15. Mean meadow biomass (g DW m^{-2}) and species composition at offshore monitoring Site 1.



Condition index

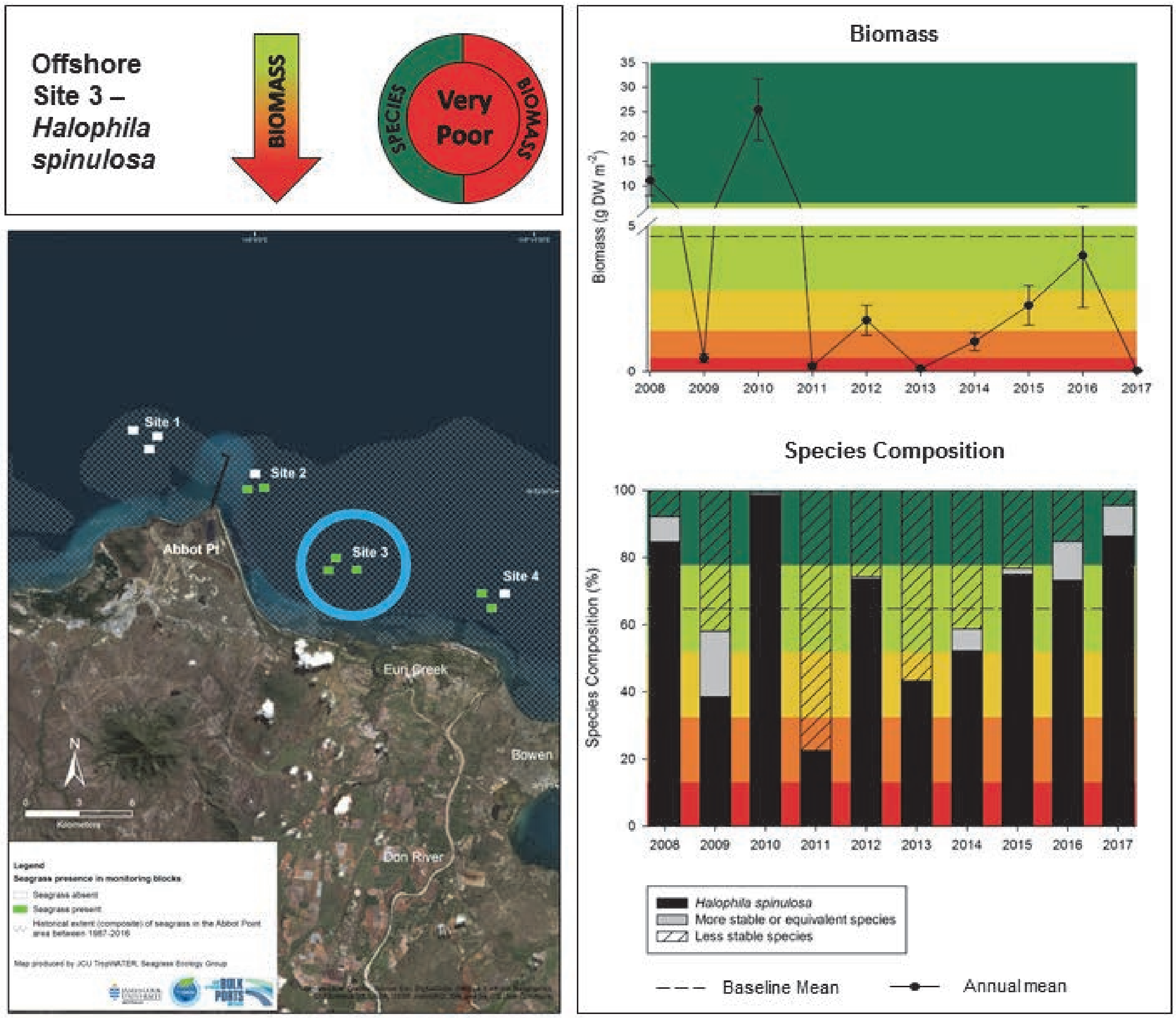
	A Very Good	B Good	C Satisfactory	D Poor	E Very Poor
Biomass (variable)	More than 40% above the baseline	Within 40% of the baseline (above or below)	Between 40% and 70% below the baseline	Between 70% and 90% below the baseline	More than 90% below the baseline
Species (mixed variable)	More than 20% above the baseline	20% above and 40% below the baseline	Between 40% and 70% below the baseline	Between 70% and 90% below the baseline	More than 90% below the baseline

Decrease below threshold from the previous year — BIOMASS

Increase above threshold from the previous year — BIOMASS

*lack of arrows indicates no change in condition index from the previous year

Figure 16. Mean meadow biomass (g DW m-2) and species composition at offshore monitoring Site 2.



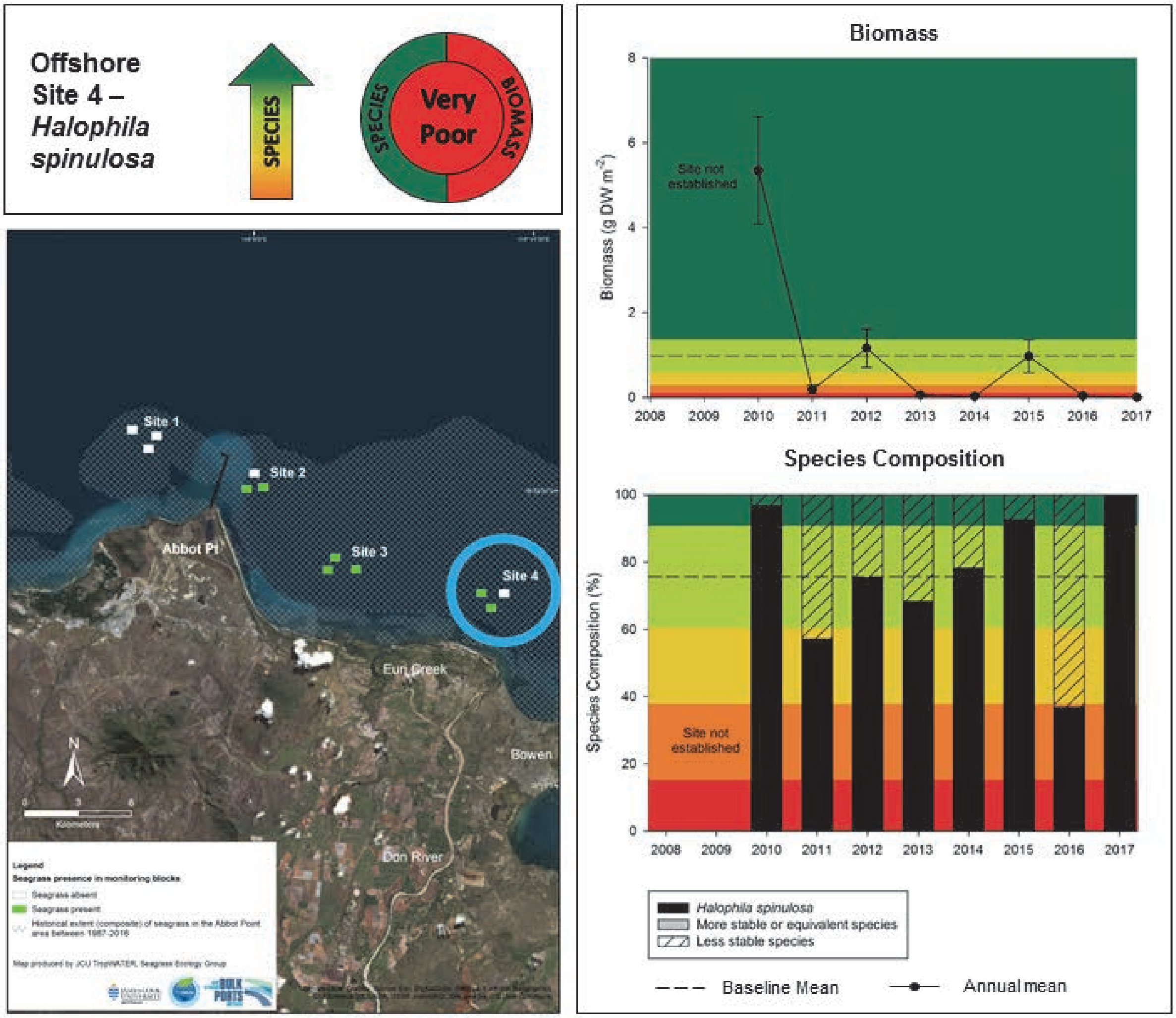
Condition index

	A Very Good	B Good	C Satisfactory	D Poor	E Very Poor
Biomass (variable)	More than 40% above the baseline	Within 40% of the baseline (above or below)	Between 40% and 70% below the baseline	Between 70% and 90% below the baseline	More than 90% below the baseline
Species (mixed variable)	More than 20% above the baseline	20% above and 40% below the baseline	Between 40% and 70% below the baseline	Between 70% and 90% below the baseline	More than 90% below the baseline

BIOMASS: Decrease below threshold from the previous year

BIOMASS: Increase above threshold from the previous year

Figure 17. Mean meadow biomass (g DW m^{-2}) and species composition at offshore monitoring Site 3.



Condition index

	A Very Good	B Good	C Satisfactory	D Poor	E Very Poor
Biomass (variable)	More than 40% above the baseline	Within 40% of the baseline (above or below)	Between 40% and 70% below the baseline	Between 70% and 90% below the baseline	More than 90% below the baseline
Species (stable mixed)	More than 20% above the baseline	20% above and below the baseline	Between 20% and 50% below the baseline	Between 50% and 80% below the baseline	More than 80% below the baseline

Decrease below threshold from the previous year — BIOMASS

Increase above threshold from the previous year — BIOMASS

Figure 18. Mean meadow biomass (g DW m^{-2}) and species composition at offshore monitoring Site 4.

3.2 Light (PAR) and sea surface temperature trends within the seagrass meadows

The original TropWATER/NQBP light and temperature monitoring program within seagrass meadows was discontinued in 2015. While two of the shallow meadow logging stations have since been re-established in 2018 (TW1 and TW2), no light data was available for these stations during the 2017 monitoring period. Benthic light data collected by Vision Environment Pty Ltd between December 2016 and October 2017 was used from PAR loggers at AMB1 and AMB4 that coincide with areas of deepwater seagrass. AMB1 is located close to Offshore Monitoring Site 3 whilst AMB4 is located further to the north-west (Figure 19).

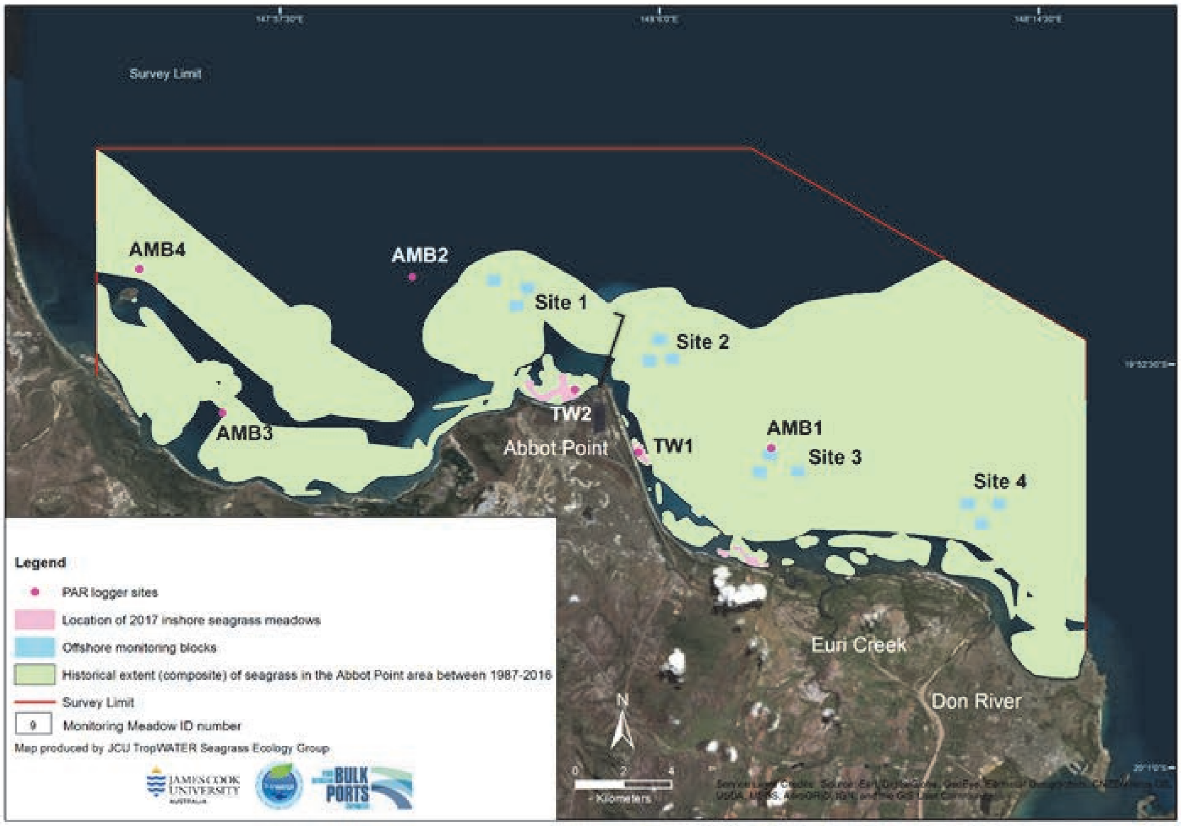


Figure 19. Location of Vision Environment PAR logger sites (AMB 1-4) at Abbot Point.

Total daily PAR (7 day rolling average) at AMB 1; the closest logging station to the long term seagrass monitoring areas ranged from 0 to 5.73 mol photons m^{-2} day^{-1} between December 2016 and October 2017. At AMB 4 totally daily PAR ranged from 0.03 mol photons m^{-2} day^{-1} to 5.62 mol photons m^{-2} day^{-1} (Figure 20). At both logging sites, a substantial reduction in PAR was observed from March 2017 around the time in which Cyclone Debbie made landfall. Light levels were sustained well below the *acute management threshold* (2 mol m^{-2} day^{-1} & integration time of 7 days) for extended periods of time. The longest period of time where PAR was below the threshold was 161 days between March and August (recorded at AMB1).

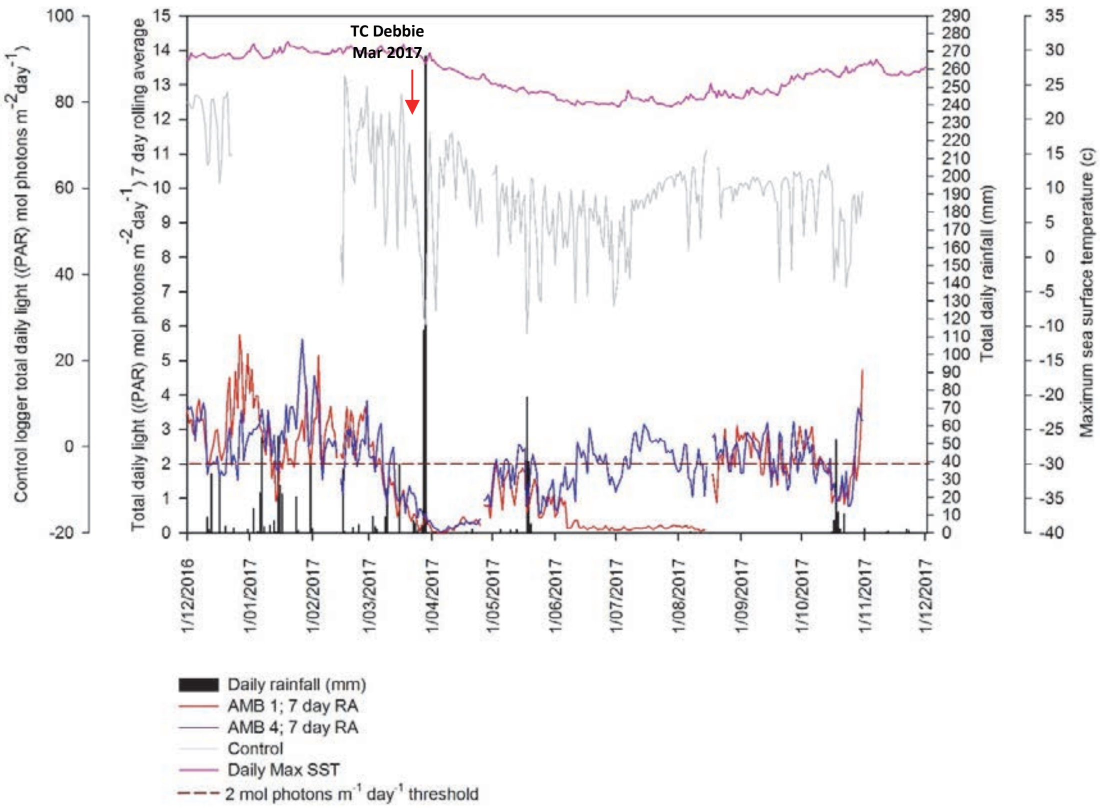


Figure 20. Seven day rolling average total daily PAR (mol photons $m^{-1}day^{-1}$), total daily rainfall, maximum daily sea surface temperature (°C) at ambient monitoring sites (AMB) 1 and 4, December 2016 – October 2017. Source: Vision Environment.

3.3 Abbot Point Environmental Parameters

Rainfall

Total annual rainfall exceeded the long term average in 2016/17 (Figure 21a). In 2016/17, total monthly rainfall exceeded the long term average in the months of January,March, May and October (Figure 21b). Of these months, March received 468mm of total rainfall, coinciding with the end of the wet season and occurrence of TC Debbie.

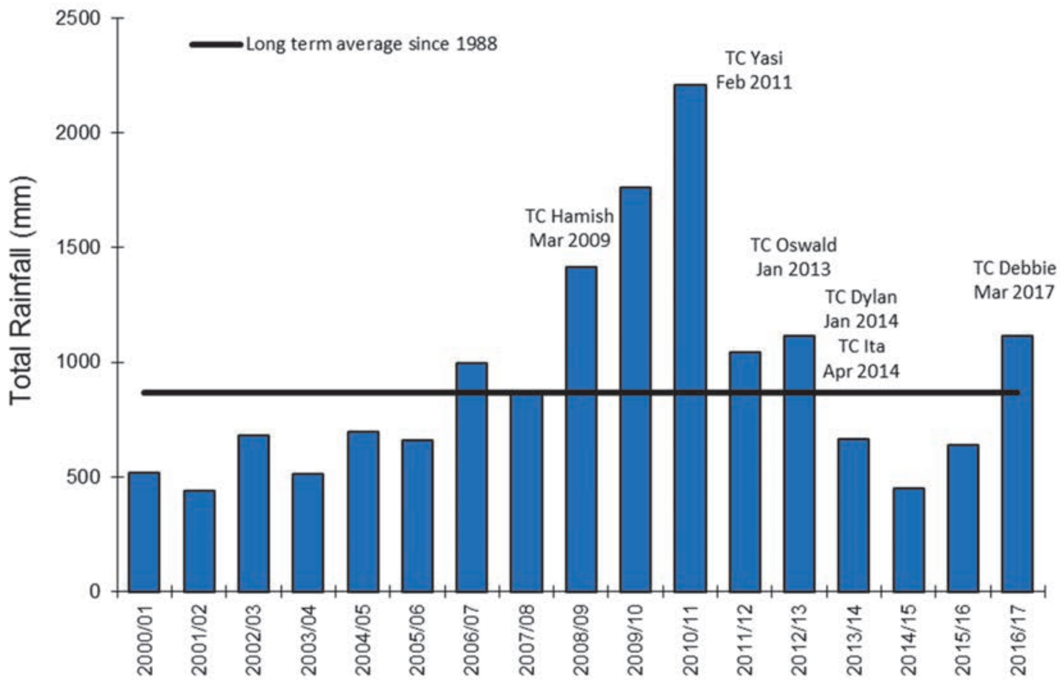


Figure 21a. Total annual rainfall (mm) recorded at Bowen, 2001/02-2016/17. Twelve month year is twelve months prior to the survey. Source: Bureau of Meteorology (BOM), Station number 033257.

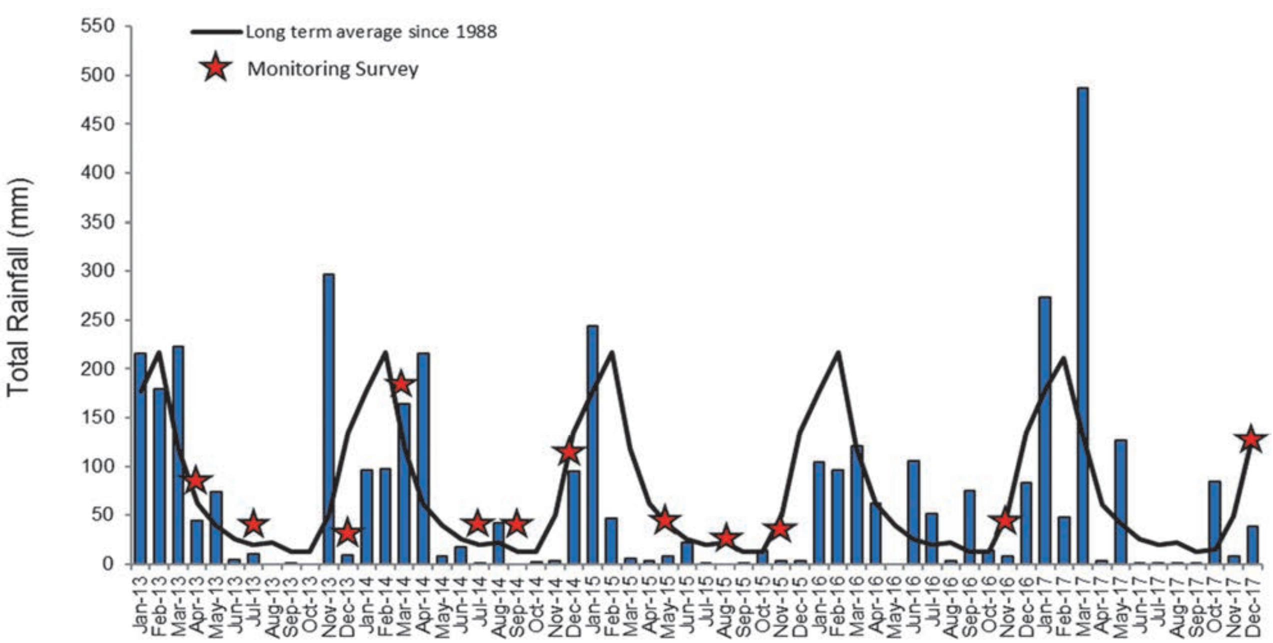


Figure 21b. Total monthly rainfall (mm) recorded at Bowen, January 2013- December 2017. Source: BOM, Station number 033257.

River Flow - Don River

River flow discharge was above the long-term annual average of 155,407 ML in 2016/17 (Figure 22a). In comparison, the lowest annual river flow (27,478 ML) was recorded in 2015/16 since 2000/01. In the 2016/17 survey year, most water was discharged from the Don River in March (228,744 ML) and May (21,988ML; Figure 22b).

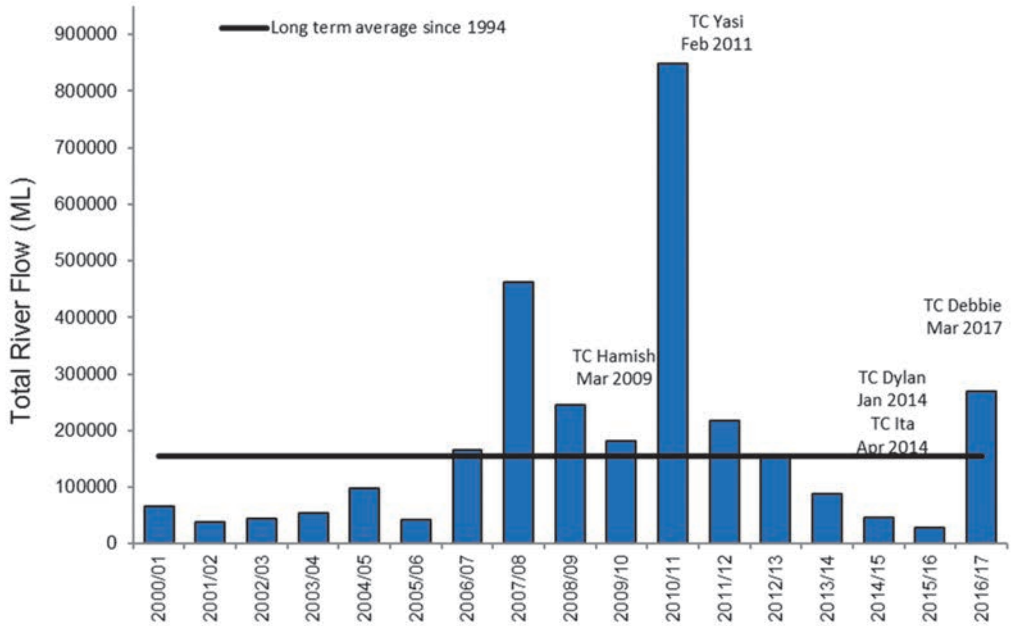


Figure 22a. Total annual river discharge of the Don River (Station 121003A) from 2000/01 to 2016/17. Twelve month year is twelve months prior to the survey. Source: Department of Natural Resources and Mines (DNRM).

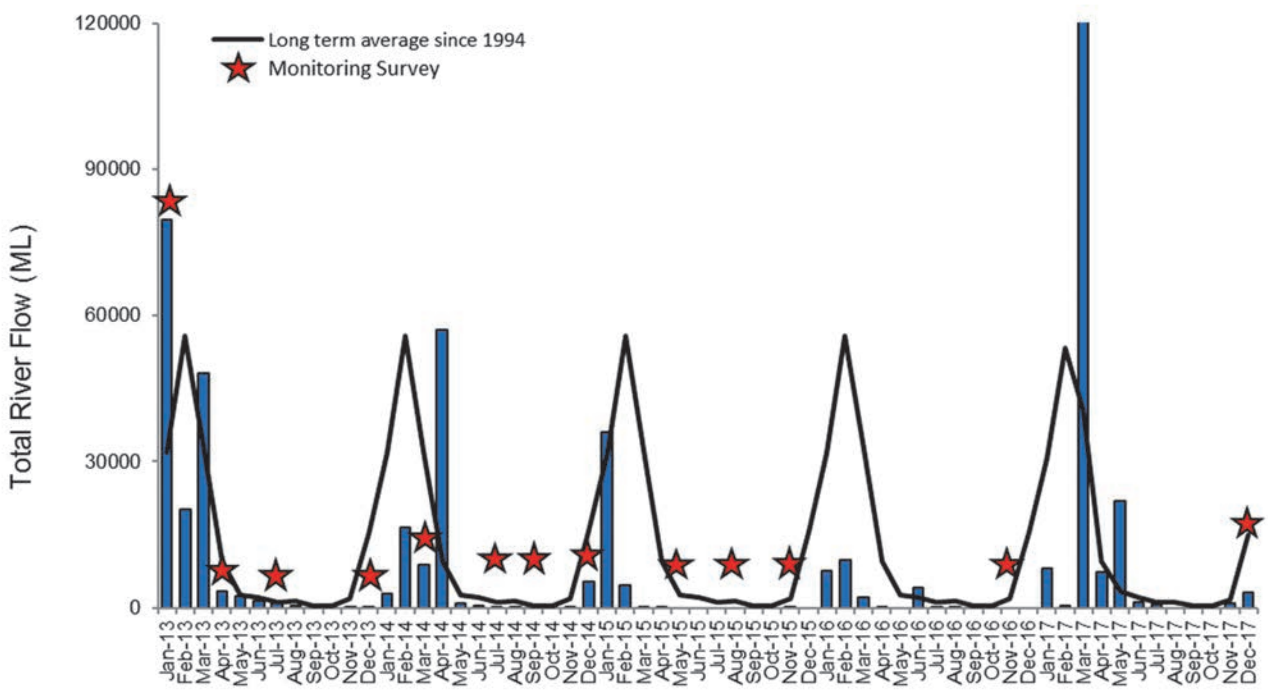


Figure 22b. Total monthly river discharge of the Don River (Station 121003A) from January 2013 to December 2016. Source: DNRM.

Air and Sea Surface Temperature

The annual average maximum air temperature was 0.58°C above the long term annual average (28.73°C) in 2016/17; a 0.23°C decrease from 2015/16 (Figure 23a). Sea surface temperature has been collected half hourly at Abbot Point since May 2014 (QLD Department of Science, Information Technology and Innovation 2017). Mean monthly maximum surface temperature ranged between 22.03°C in June and 29.23°C in February for the 2016/17 period.

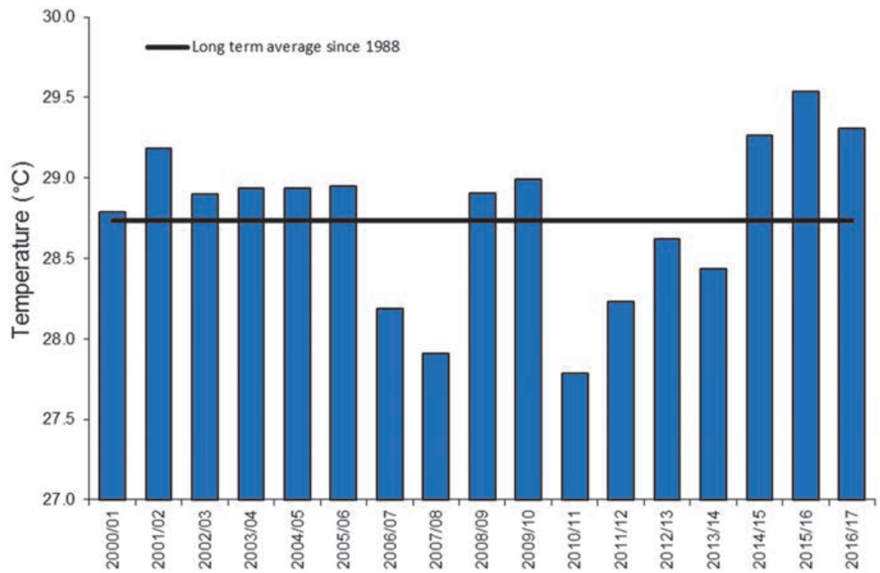


Figure 23a. Annual average maximum air temperature in the Bowen area (Station 33257) between 2000/01 and 2016/17. Source BOM.

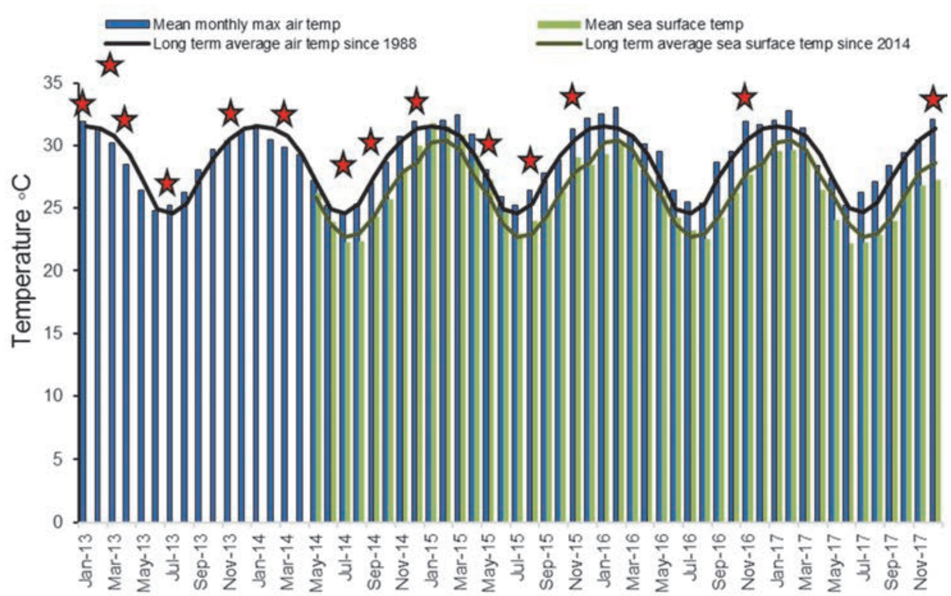


Figure 23b. Monthly mean maximum air temperature (Station 33257) and monthly mean maximum sea surface temperature at Abbot Point January 2013 – December 2017. Source: BOM and DSITI.

Daily Global Solar Radiation

Daily global exposure is a measure of the amount of the total solar energy falling on a horizontal surface in one day. Values are generally highest in clear sunny days during spring/summer and lowest during winter. Solar exposure (21.50 MJ m^{-2}) in the Bowen area was slightly above the long-term yearly average in 2016/17 (Figure 24a). Solar exposure was above or near the monthly long term average except in March 2017 and October 2017 which recorded values of 2.2 MJ m^{-2} and 1.9 MJ m^{-2} less than the long term average (Figure 24b). December 2017, the month the annual survey was conducted recorded a significantly higher amount of solar radiation compared to previous years.

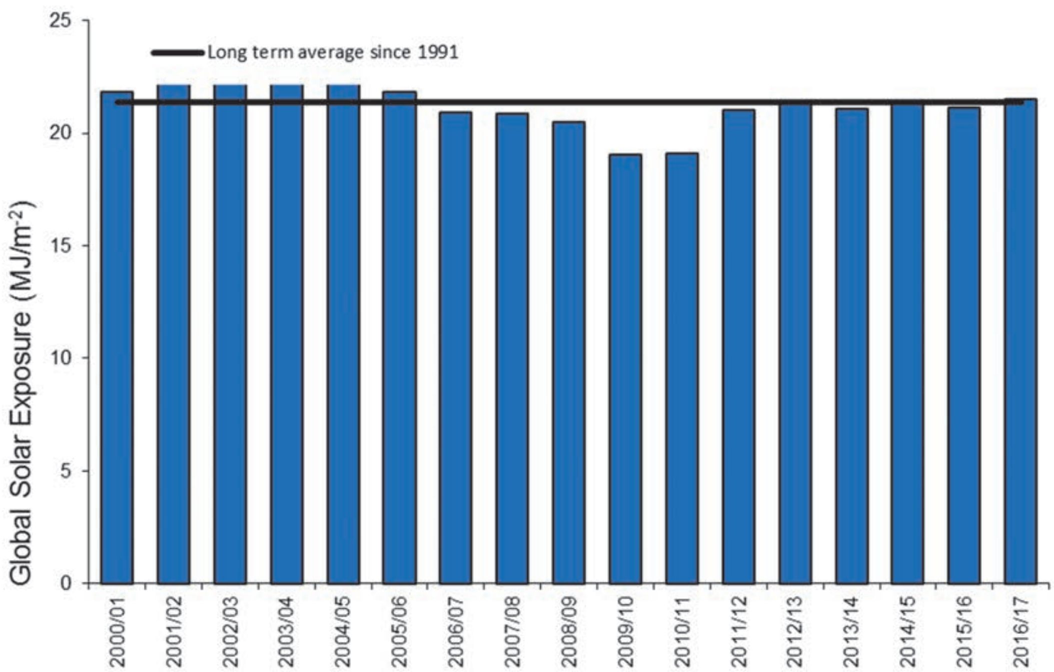


Figure 24a. Mean annual solar radiation (MJ/m^{-2}) recorded in the Bowen area (Station 033327) 2000/01 -2016/17. Twelve month year is twelve months prior to the survey. Source: BOM.

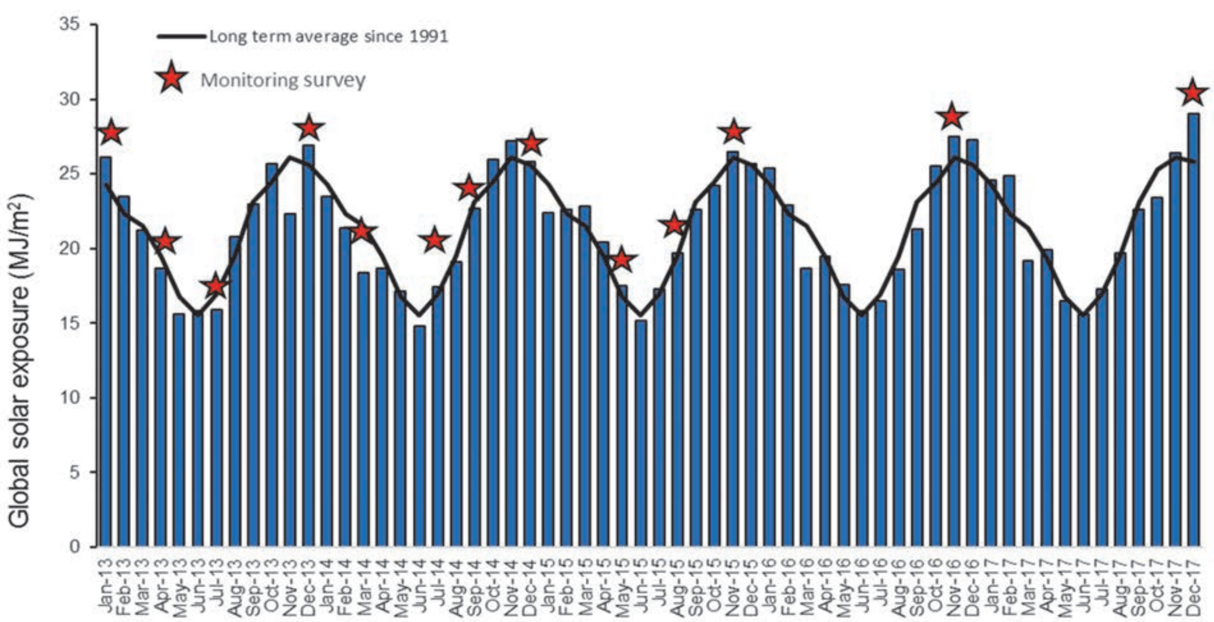


Figure 24b. Mean monthly daily global solar exposure (MJ/m^{-2}) recorded in the Bowen area (Station 033327) January 2013 - December 2017. Source: BOM.

Significant Wave Height

Wave height data has been collected half hourly at Abbot Point since May 2014. Maximum wave height is the maximum wave height in a record (26.6 minute recording period) (DSITI 2015). In 2017, a maximum average wave height of 1.25m was recorded for the month of November (Figure 25a). Although the average maximum wave height for March 2017 was relatively low (1.05m) a significant increase in average daily maximum wave heights occurred associated with TC Debbie between the 28th and 30th of March with wave heights approaching 4m (Figure 25b).

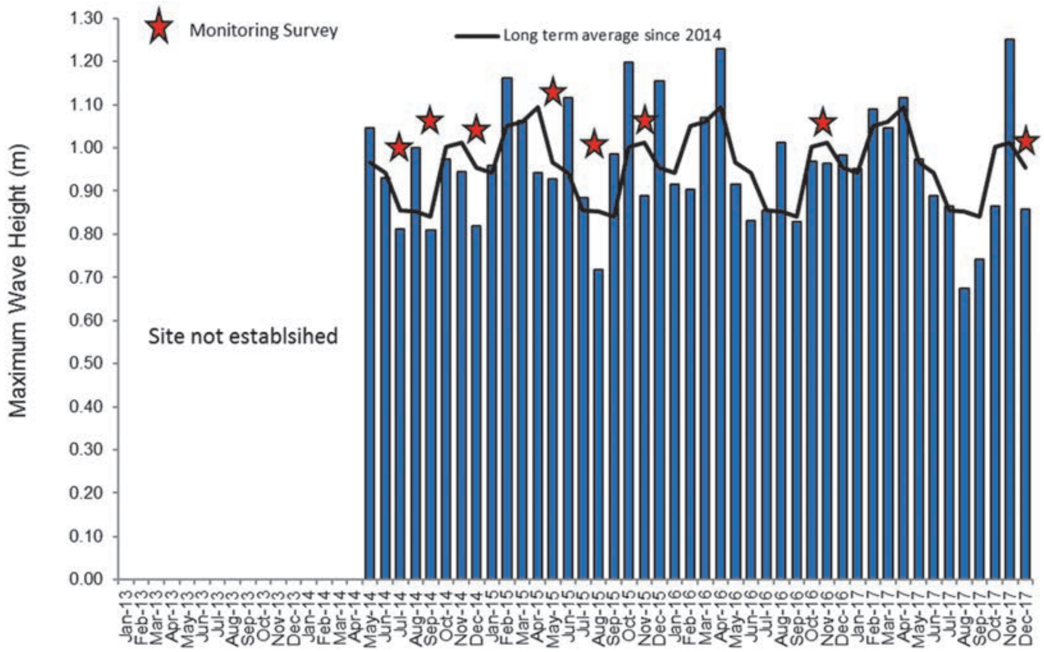


Figure 25a. Mean monthly maximum wave height (m) recorded at Abbot Point May 2014 - December 2017. Source: DSITI.

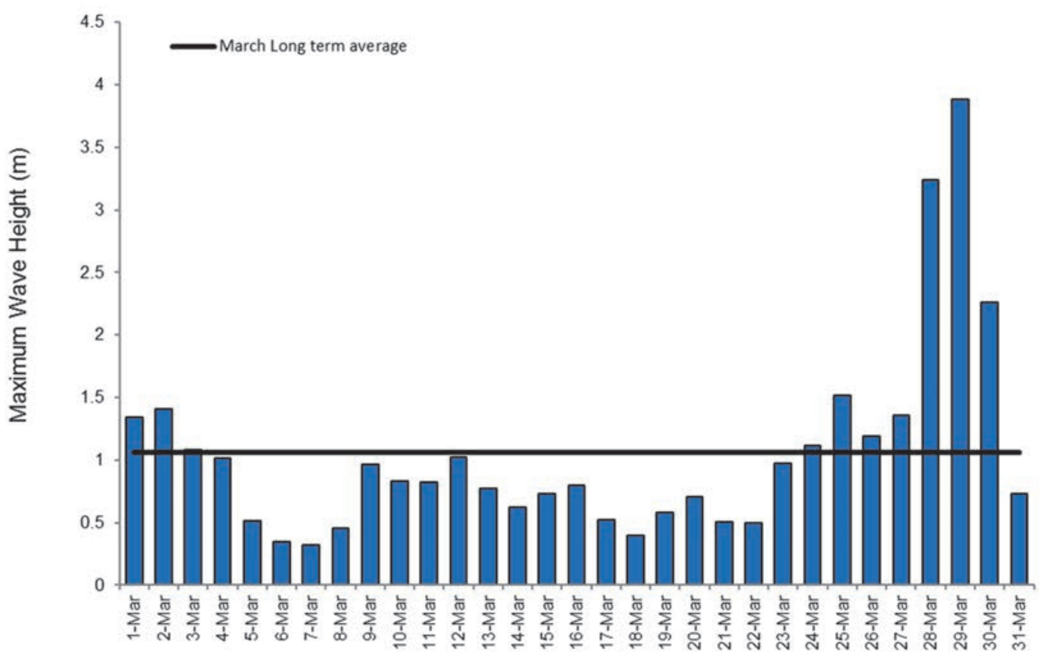


Figure 25b. Mean daily maximum wave height (m) recorded at Abbot Point in March 2017.

4. DISCUSSION

The 2017 annual monitoring survey found the condition of offshore and inshore seagrass at Abbot Point had declined. This decline reversed much of the seagrass recovery recorded during 2016 and was likely associated with impacts from Tropical Cyclone Debbie. The loss of two of the five shallow coastal monitoring meadows, and a reduction in seagrass biomass in the deeper offshore areas was associated with reduced benthic light and high wind and wave action linked to the cyclone and other weather events during 2017.

During 2016, the first substantial signs of seagrass recovery were recorded for coastal meadows following several years of impacts associated with cyclones and severe weather events including TC Yasi in 2011, TC Dylan in January 2014 and TC Ita in April 2014 (McKenna et al. 2017). Much of this recovery was reversed in 2017 with climate and storm events once again creating conditions that were unfavourable for seagrasses. The most notable of these was TC Debbie, which resulted in high rainfall, flooding of local rivers (Don River) and large waves impacting the coastline in the Abbot Point area.

Following TC Debbie in March 2017 benthic PAR (light) was substantially reduced and fell below levels likely required to support seagrass growth for extended periods. For *Halophila*, the dominant genus of seagrass in offshore areas at Abbot Point, an acute light management threshold of between 2–2.5 mol m^{-2} day^{-1} over an integration time of 1-7 days has been suggested (Collier et al. 2016). This is likely to be a conservative threshold and higher than the biological thresholds derived from studies and long-term datasets that take into account species and site specificity (Collier et al. 2016). Recent studies of deep water *Halophila* in the GBR suggest a biological management threshold between 1.5-2 mol m^{-2} day^{-1} over an integration time of 7-14 days to incorporate the range in morphological and physiological capacity of the genus (Chartrand et al. 2017). PAR measured at our offshore seagrass monitoring sites (AMB1), adjacent to where the Don river discharges, did not exceed 2 mol m^{-2} day^{-1} between March and August 2017. A significant number of those days fell within the seagrass germination and growing season (July to December; Chartrand et al. 2017) which is a critical time for the annual recruitment and expansion of deepwater *Halophila* meadows.

Seagrass loss due to reduced light is common (Ralph et al. 2007; McMahon et al. 2013) with resultant limitation of seagrass photosynthesis and metabolism leading to mortality (Davey et al. 2018). Low light also increases the susceptibility of seagrass plants to the toxic effects of sulphides commonly present in anoxic marine sediments that dominate many seagrass meadows (Broderson et al. 2015).

It is likely that low light levels also contributed to the declines in the shallower coastal meadows, but in 2017, there were no direct measurements of benthic light for these areas. Since the 2017 survey, two PAR-logging stations have been re-introduced in shallow coastal areas, as part of enhancements to the Abbot Point ambient marine monitoring program so more direct links will be possible in the future. The coastal seagrass meadows were also more likely to have been directly impacted by the physical disturbance associated with large waves during the cyclone. Significant waves of around 4 metres were recorded during the cyclone at Abbot Point and the shallow coastal seagrass meadows are relatively exposed to wave impacts with little protection along the open coastline.

Despite unfavourable conditions in 2017 and the corresponding seagrass declines, the key seagrass species remained within many of the coastal meadows and offshore areas of Abbot Point. The continued presence of these species is a positive sign that seagrasses may maintain a capacity for recovery should conditions return to be more favourable. A key to previous recovery of seagrasses at Abbot Point has been the presence of seagrass remnants or seeds in the sediments (Rasheed et al. 2014), and as long as seagrass persists in meadows recovery could potentially be quite rapid. This is especially the case for the *Halophila* species that dominate the deeper areas of Abbot Point, which although highly susceptible to disturbance, also have the ability to rapidly recover (Collier et al. 2012; York et al. 2015; Chartrand et al. 2017). For the coastal seagrass meadows that were lost entirely, recovery may take more time, as recruitment from seeds or via dispersal will be required for them to re-establish. The continued presence of meadows of the same species within a few hundred metres of the lost meadows provides a good potential source for new seagrass recruits (Grech et al 2016).

Abbot Point was one of the worst affected seagrass areas in 2017 compared with other similarly monitored sites in the Queensland seagrass monitoring network. The condition of coastal seagrass habitat improved in Cairns (Reason and Rasheed, 2018) and seagrass habitat remained stable in Gladstone and Townsville (Bryant and Rasheed, 2018; Chartrand et al. 2018). However for Hay Point and Mackay, that were also impacted by TC Debbie, similar declines in seagrass to Abbot Point were recorded (York and Rasheed 2018).

The reduced biomass and spatial coverage of Abbot Point seagrasses means these meadows are likely to have a relatively low resilience to further natural or anthropogenic impacts that may occur during 2018. Any recovery will be contingent on future weather being favourable for seagrass growth and given the low resilience, management of activities in the region should focus on minimising additional anthropogenic impacts to allow seagrass habitat the best possible chance of recovery.

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6. APPENDICES

Appendix 1. Scoring, grading and classification of seagrass meadows

Baseline Calculations
Baseline conditions for seagrass biomass, meadow area and species composition were established from annual means calculated from 2008-2017 inclusive (10 years) following the methods of Carter et al. (2015). Using a long-term-average of 10 years is an accurate representation of baseline conditions, as a 10 year period incorporates a range of environmental conditions present including El Niño and La Niña weather oscillations. A 10 year long-term average will be used for future assessments and reassessed each decade.

Baseline conditions for species composition were determined based on the annual percent contribution of each species to mean meadow biomass of the baseline years. The meadow was classified as either single species dominated (one species comprising ≥80% of baseline species), or mixed species (all species comprise ≤80% of baseline species composition). Similar to seagrass biomass and area, the species composition baseline was calculated from 2008-2017 (only in the years where species were present). From 2016 onwards, an additional rule has been applied: where by a meadow baseline which contains an approximate equal split in two dominant species (i.e. both species accounted for 40–60% of the baseline) is set according to the percent composition of the more persistent/stable species of the two (Figure A1).

Meadow Classification
A meadow classification system was developed for three condition indicators (biomass, area, species composition) in recognition that for some seagrass meadows these indicative measures are historically stable, while in other meadows they are relatively variable. The coefficient of variation (CV) for each meadow baseline was used to determine historical variability. Meadow biomass, area and species composition were classified as either stable or variable (Table A1). One further classification for meadow area was added in the 2016 reporting year: highly stable (Table A1). The CV was calculated by dividing the standard deviation of the baseline years by the baseline for each condition indicator.

Table A1. Coefficient of variation (CV; %) thresholds used to classify historical stability or variability of meadow biomass, area and species composition.

Indicator	Class			
	Highly stable	Stable	Variable	Highly variable
Biomass	-	< 40%	≥ 40%	-
Area	< 10%	≥ 10, < 40%	≥ 40, <80%	≥ 80%
Species composition	-	< 40%	≥ 40%	-

Threshold Definition
Seagrass condition for each indicator was assigned one of five grades (very good (A), good (B), satisfactory (C), poor (D), very poor (E)). Threshold levels for each grade were set relative to the baseline and based on meadow class. This approach accounted for historical variability within the monitoring meadows and expert knowledge of the different meadow types and assemblages in the region (Table A2).

Table A2. Threshold levels for grading seagrass indicators for various meadow classes relative to the baseline. Upwards/downwards arrows are included where a change in condition has occurred in any of the three condition indicators (biomass, area, species composition) from the previous year.

Seagrass condition indicators/ Meadow class		Seagrass grade				
		A Very good	B Good	C Satisfactory	D Poor	E Very Poor
Biomass	Stable	>20% above	20% above - 20% below	20-50% below	50-80% below	>80% below
Biomass	Variable	>40% above	40% above - 40% below	40-70% below	70-90% below	>90% below
Area	Highly stable	>5% above	5% above - 10% below	10-20% below	20-40% below	>40% below
Area	Stable	>10% above	10% above - 10% below	10-30% below	30-50% below	>50% below
Area	Variable	>20% above	20% above - 20% below	20-50% below	50-80% below	>80% below
Area	Highly variable	> 40% above	40% above - 40% below	40-70% below	70-90% below	>90% below
Species composition	Stable and variable; Single species dominated	>0% above	0-20% below	20-50% below	50-80% below	>80% below
Species composition	Stable; Mixed species	>20% above	20% above - 20% below	20-50% below	50-80% below	>80% below
Species composition	Variable; Mixed species	>20% above	20% above- 40% below	40-70% below	70-90% below	>90% below
	Increase above threshold from previous year			Decrease below threshold from previous year		

Grade and Score Calculations

A score system (0–1) and score range was applied to each grade to allow numerical comparisons of seagrass condition among meadows in the Port of Abbot Point (Table A3; see Carter et al. 2015 for a detailed description).

Score calculations for each meadow's condition required calculation of the biomass, area and species composition for that year, allocating a grade for each indicator by comparing 2017 values against meadow-specific thresholds for each grade, then scaling biomass, area and species composition values against the prescribed score range for that grade.

Scaling was required because the score range in each grade was not equal (Table A3). Within each meadow, the upper limit for the very good grade (score = 1) for species composition was set as 100% (as a species could never account for >100% of species composition). For biomass and area the upper limit was set as the maximum mean plus standard error (SE; i.e. the top of the error bar) value for a given year, compared among years during the baseline period.

In previous report cards the upper limit was based on the mean + SE of any survey year, meaning biomass and area values in the very good range potentially would require constant recalculation; defining the upper limit using baseline years is a new approach in 2016 that "locks in" the upper value.

Table A3. Score range and grading colours used in the 2017 Abbot Point report card.

Grade	Description	Score Range	
		Lower bound	Upper bound
A	Very good	≥0.85	1.00
B	Good	≥0.65	<0.85
C	Satisfactory	≥0.50	<0.65
D	Poor	≥0.25	<0.50
E	Very poor	0.00	<0.25

Where species composition was determined to be anything less than in "perfect" condition (i.e. a score <1), a decision tree was used to determine whether equivalent and/or more persistent species were causing this grade/score (Figure A1). If this was the case then the species composition score and grade for that year was recalculated including those species. Concern regarding any decline in the stable state species should be reserved for those meadows where the directional change from the stable state species is of concern (Figure A1). This would occur when the stable state species is replaced by species considered as opportunistic / earlier colonisers. Such a shift indicates a decline in meadow stability (e.g. a shift from *H. uninervis* to *H. ovalis*). An alternate scenario can occur where the stable state species is replaced by what is considered an equivalent species (e.g. shifts between *C. rotundata* and *C. serrulata*), or replaced by a species indicative of an improvement in meadow stability (e.g. a shift from *H. decipiens* to *H. uninervis* or any other species). The directional change assessment was based largely on dominant traits of colonising, opportunistic and persistent seagrass genera described by Kilminster et al. (2015). Adjustments to the Kilminster model included: (1) positioning *S. isoetifolium* further towards the colonising species end of the list, as successional studies following disturbance demonstrate this is an early coloniser in Queensland seagrass meadows (Rasheed 2004); and (2) separating and ordering the *Halophila* genera by species. Shifts between *Halophila* species are ecologically relevant; for example, a shift from *H. ovalis* to *H. decipiens*, the most marginal species found in Gladstone Harbour, may indicate declines in water quality and available light for seagrass growth as *H decipiens* has a lower light requirement (Collier et al. 2016) (Figure A1).

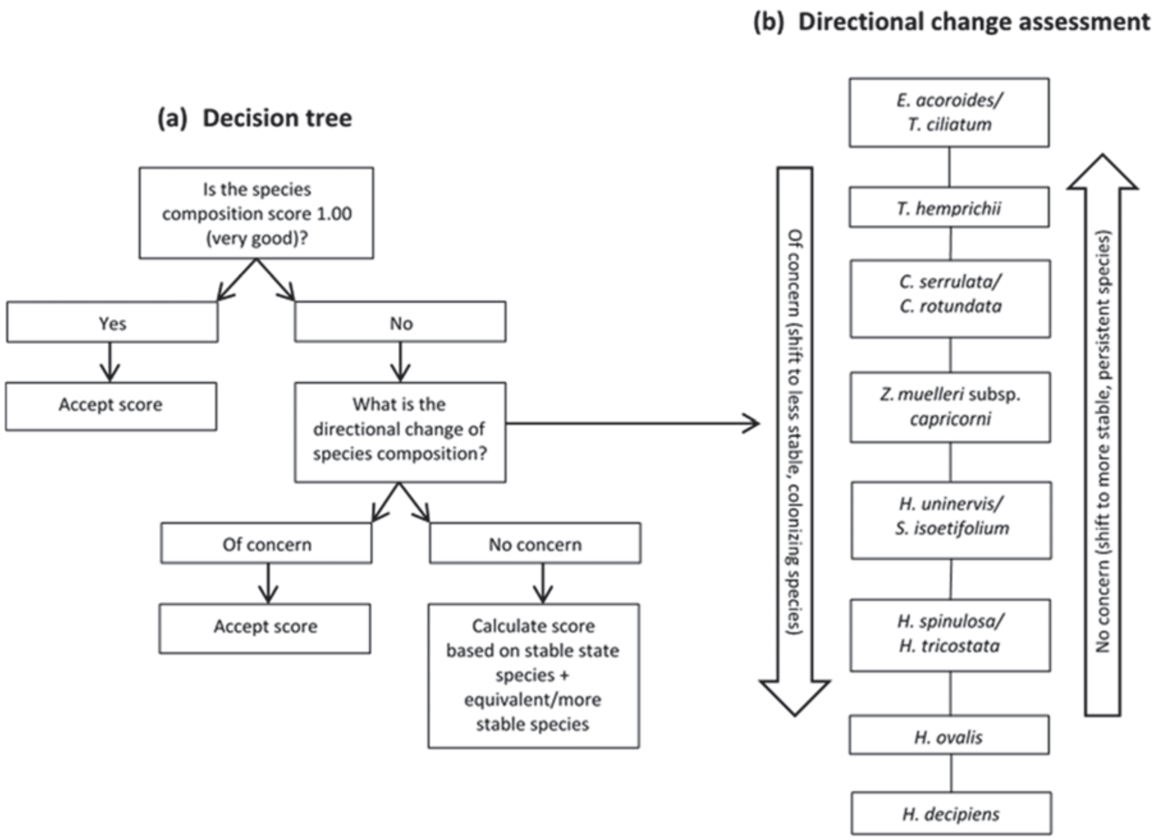


Figure A1. (a) Decision tree and (b) directional change assessment for grading and scoring species composition at Abbot Point.

Score Aggregation

Each overall meadow grade/score was defined as the lowest grade/score of the three condition indicators within that meadow. The lowest score, rather than the mean of the three indicator scores, was applied in recognition that a poor grade for any one of the three described a seagrass meadow in poor condition. Maintenance of each of these three fundamental characteristics of a seagrass meadow is required to describe a healthy meadow. This method allowed the most conservative estimate of meadow condition to be made (Bryant et al. 2014).

Abbot Point grades/scores were determined by averaging the overall meadow scores for each monitoring meadow within the port, and assigning the corresponding grade to that score (Figure 7; Table A3). Where multiple meadows were present within the port, meadows were not subjected to a weighting system at this stage of the analysis. The classification process (outlined in Meadow Classification) at the meadow analysis stage applied smaller and therefore more sensitive thresholds for meadows considered stable, and less sensitive thresholds for variable meadows. The classification process served therefore as a proxy weighting system where any condition decline in the (often) larger, stable meadows was more likely to trigger a reduction in the meadow grade compared with the more variable, ephemeral meadows.

Example of calculating a meadow score for biomass in satisfactory condition

1. Determine the grade for the 2017 (current) biomass value (i.e. satisfactory).

2. Calculate the difference in biomass (B_{diff}) between the 2016 biomass value (B_{2017}) and the area value of the lower threshold boundary for the satisfactory grade ($B_{satisfactory}$):

$$\mathrm{B_{diff}} = \mathrm{B_{2017}} - \mathrm{B_{satisfactory}}$$

Where $B_{satisfactory}$ or any other threshold boundary will differ for each condition indicator depending on the baseline value, meadow class (highly stable [area only], stable, variable, highly variable [area only]), and whether the meadow is dominated by a single species or mixed species.

3. Calculate the range for biomass values (B_{range}) in that grade:

$$\mathrm{B_{range}} = \mathrm{B_{good}} - \mathrm{B_{satisfactory}}$$

Where $B_{satisfactory}$ is the upper threshold boundary for the satisfactory grade.
Note: For species composition, the upper limit for the very good grade is set as 100%. For area and biomass, the upper limit for the very good grade is set as the maximum value of the mean plus the standard error (i.e. the top of the error bar) for a given year during the baseline period for that indicator and meadow.

4. Calculate the proportion of the satisfactory grade (B_{prop}) that B_{2017} takes up:

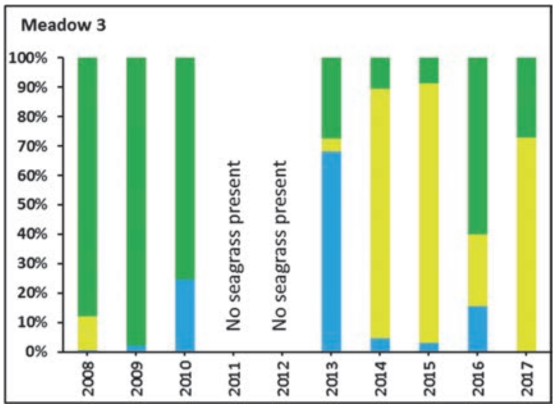
$$\mathrm{B_{prop}} = \frac{\mathrm{B_{diff}}}{\mathrm{B_{range}}}$$

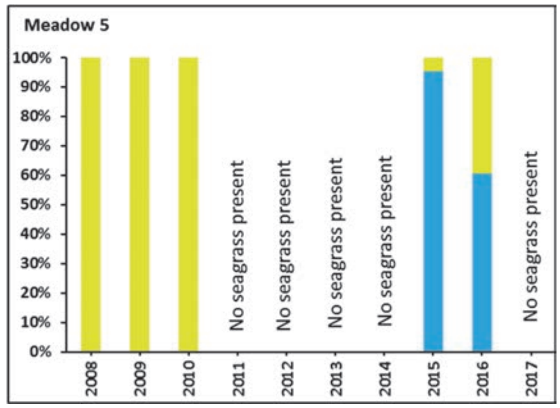
5. Determine the biomass score for 2017 ($Score_{2017}$) by scaling B_{prop} against the score range (SR) for the satisfactory grade ($SR_{satisfactory}$), i.e. 0.15 units:

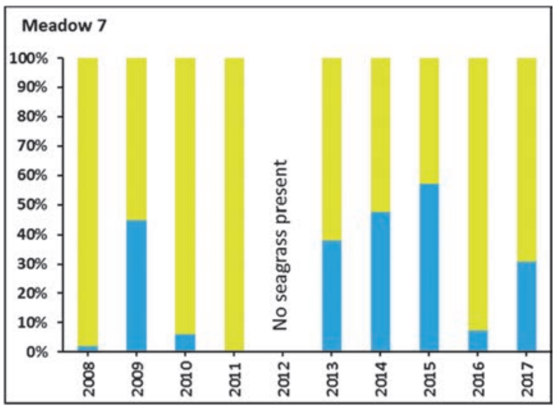
$$\mathrm{Score_{2017}} = \mathrm{LB_{satisfactory}} + \left(\mathrm{B_{prop}} \times \mathrm{SR_{satisfactory}}\right)$$

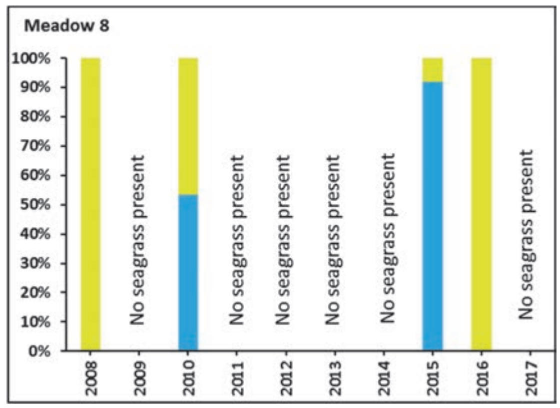
Where $LB_{satisfactory}$ is the defined lower bound (LB) score threshold for the satisfactory grade, i.e. 0.50 units.

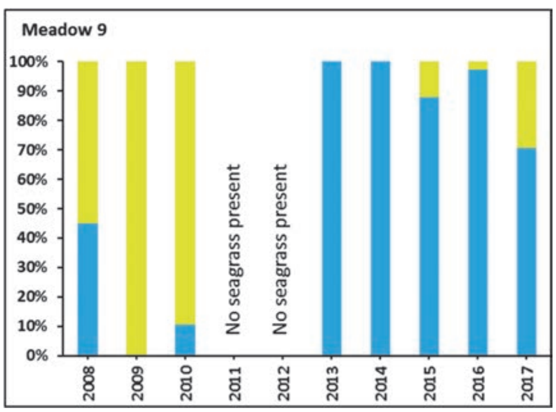
Appendix 2. Species composition of inshore and offshore monitoring meadows in the Abbot Point region: 2008 – 2017

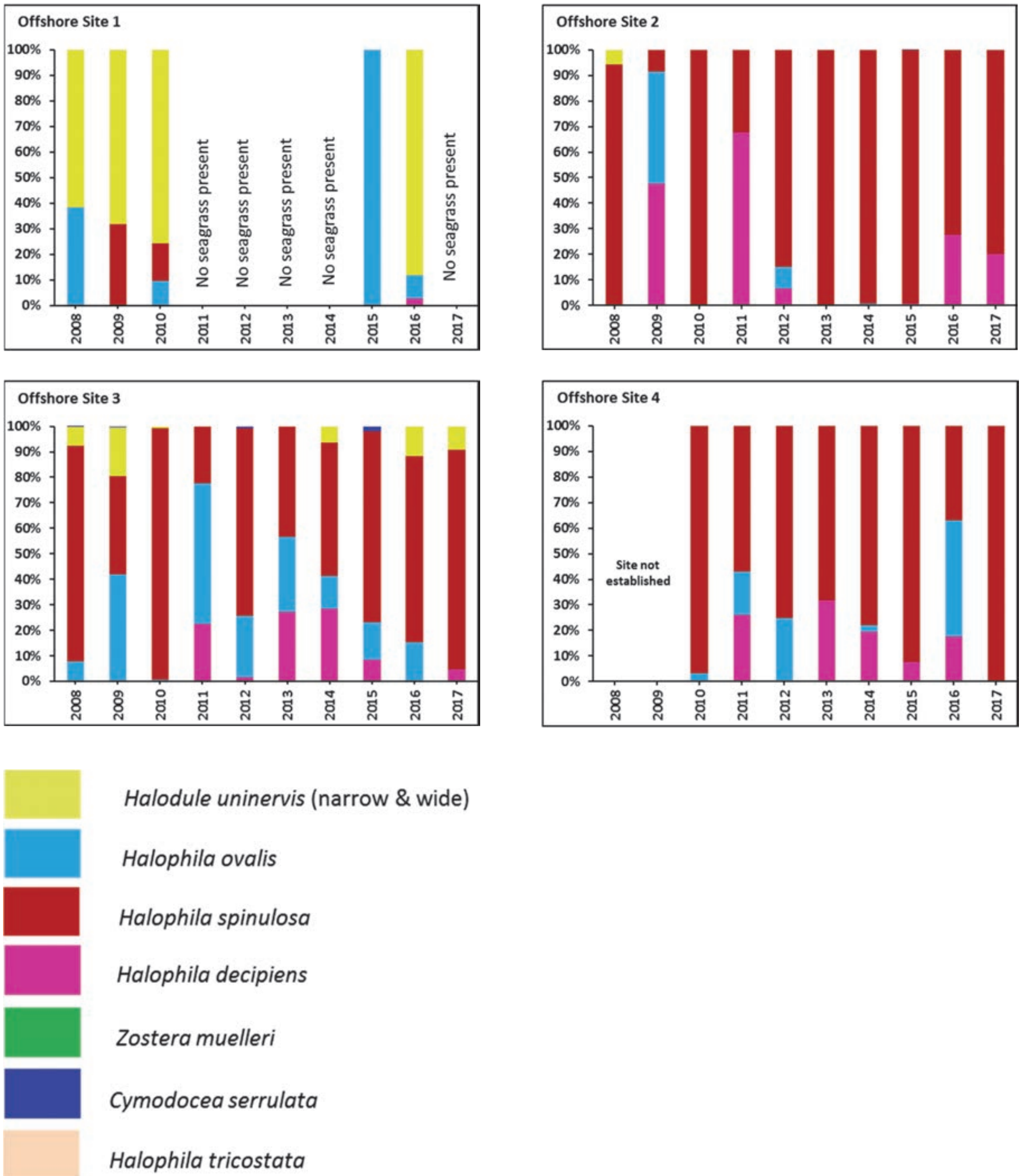











Offshore Site 1
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
No seagrass present
No seagrass present
No seagrass present
No seagrass present
No seagrass present
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Offshore Site 2
Offshore Site 3
Offshore Site 4
Site not established
Halodule uninervis (narrow & wide)
Halophila ovalis
Halophila spinulosa
Halophila decipiens
Zostera muelleri
Cymodocea serrulata
Halophila tricostata

Appendix 3. Biomass and area of inshore and offshore meadows

3A. Mean biomass of inshore monitoring meadows in the Abbot Point region; quarterly 2005, 2008 – 2017.

Mean Biomass ± SE (g DW m^{-2}) (no. sites present in meadow)					
Meadow #	**3**	**5**	**7**	**8**	**9**
Mar 05	0.09 ± 0.03 (6)	0.03 ± 0 (1)	0.06 ± 0 (1)	0.03 ± 0 (1)	1.63 ± 0.54 (16)
Mar 08	3.71 ± 1.72 (8)	0.05 ± 0.02 (9)	2.84 ± 0 (1)	0.52 ± 0.52 (2)	0.86 ± 0.47 (17)
Jul 08	4.55 ± 1.68 (15)	1.57 ± 0.08 (3)	3.72 ± 0.33 (4)	NP	1.10 ± 0.53 (12)
Sep 08	8.91 ± 4.17 (11)	1.54 ± 0.57 (6)	6.7 ± 2.21 (12)	1.65 ± 0.33 (2)	0.40 ± 0.15 (17)
Nov 08	6.98 ± 2.95 (14)	1.34 ± 0.71 (6)	2.87 ± 0.74 (9)	5.01 ± 1.72 (3)	1.02 ± 0.51 (20)
Apr 09	3.34 ± 0.95 (9)	NP	1.68 ± 0.46 (8)	NP	0.17 ± 0.08 (10)
Aug 09	2.76 ± 0.99 (14)	NP	0.43 ± 0.18 (7)	1.57 ± 1.18 (2)	0.63 ± 0.30 (23)
Dec 09	1.59 ± 0.55 (31)	0.005 ± 0.003 (5)	1.0 ± 0.62 (13)	NP	0.15 ± 0.08 (15)
Jun 10	0.84 ± 0.4 (13)	0.06 ± 0 (1)	0.76 ± 0.4 (4)	5.04 ± 0 (1)	0.11 ± 0.02 (6)
Nov 10	2.92 ± 0.86 (5)	3.74 ± 1.06 (3)	4.46 ± 0.41 (3)	1.61 ± 0 (2)	0.73 ± 0.16 (12)
Mar 11	NP	NP	2.03 ± 1.16 (5)	0.07 ± 0 (4)	NP
May 11	NP	NP	0.40 ± 0 (1)	NP	NP
Sept 11	NP	NP	0.69 ± 0.4 (3)	NP	NP
Feb 12	0.23 ± 0 (1)	NP	4.58 ± 0.19 (3)	NP	NP
Jun 12	NP	NP	0.82 ± 0.31 (5)	NP	NP
Sep 12	NP	NP	NP	NP	NP
Jan 13	NP	NP	NP	NP	NP
Apr 13	3.10 ± 0 (1)	NP	0.25 ± 0 (1)	NP	4.42 ± 0 (1)
3.40	NP	NP	2.74 ± 0.91 (5)	NP	1.67 ± 0 (1)
Sept 13	NP	NP	1.53 ± 0.72 (4)	NP	3.07 ± 1.55 (3)
Dec 13	2.16 ± 0.75 (3)	NP	2.40 ± 1 (4)	NP	1.60 ± 1.07 (3)
Mar 14	NP	NP	6.11 ± 1.2 (2)	NP	1.71 ± 0.7 (4)
Jul 14	0.06 (1)	NP	1.73 ± 0.73 (5)	NP	2.31 ± 0.65 (6)
Sep 14	1.67 ± 0.34 (3)	1.2 ± 0.04 (2)	3.98 ± 1.29 (3)	NP	4.36 ± 0.91 (8)
Dec 14	5.13 ± 0.76 (4)	NP	13.84 ± 4.6 (3)	NP	4.31 ± 0.93 (18)
May 15	0.83 ± 0.28 (5)	0.57 ± 0.39 (2)	4.61 ± 1.07 (4)	NP	3.40 ± 0.59 (15)
Aug 15	4.21 ± 3.96 (3)	2.14 ± 0.94 (5)	4.89 ± 1.91 (5)	1.84 ± 0 (2)	2.80 ± 0.50 (20)
Nov 15	2.3 ± 1.26 (6)	1.01 ± 0.29 (5)	4.35 ± 1.12 (5)	3.22 ± 1.17 (3)	3.57 ± 0.58 (16)
Nov 16	5.3 ± 1.59 (10)	2.47 ± 0.74 (5)	3.62 ± 1.24 (7)	1.94 ± 0 (1)	8.32 ± 1.66 (14)
Dec 17	5.85 ± 1.05 (13)	NP	4.27 ± 1.13 (9)	NP	3.0 ± 0.57 (20)

NP – No seagrass present in meadow

3B. Area (ha) of inshore monitoring meadows in the Abbot Point region; quarterly 2005, 2008 – 2017.

Area ± R (ha)						
Meadow #	**3**	**5**	**7**	**8**	**9**	**TOTAL meadow area**
Mar 05	25.6 ± 6	21.5 ± 6.1	19.5 ± 7.1	5.6 ± 2.7	125.8 ± 41	198 ± 62.9
Mar 08	55.5 ± 8	67.9 ± 27.6	4.2 ± 0.9	2.1 ± 0.7	120.8 ± 71.4	250.5 ± 108.6
Jul 08	53.1 ± 8.3	9.7 ± 1.9	3.6 ± 0.9	NP	67.0 ± 9	133.4 ± 20.1
Sep 08	56.95 ± 8.06	19.83 ± 17.1	21.47 ± 2.38	4 ± 0.81	83.96 ± 10.26	186.21 ± 38.61
Nov 08	83.6 ± 10.5	30.9 ± 18.6	12 ± 2.1	3.7 ± 1	83.1 ± 13.1	213.3 ± 45.3
Apr 09	32.4 ± 19.9	NP	9.2 ± 5.6	NP	38.20 ± 28.7	79.8 ± 54.2
Aug 09	44.2 ± 9.3	NP	13.2 ± 2.6	3 ± 0.7	22.9 ± 5.1	83.3 ± 17.7
Dec 09	75.4 ± 9.3	13.3 ± 10.1	15.7 ± 6.2	NP	127.5 ± 17.8	231.9 ± 43.4
Jun 10	24.6 ± 6.8	1.4 ± 1	5.1 ± 3	1.6 ± 1	56.3 ± 33.3	89 ± 45.1
Nov 10	15.04 ± 13.2	16.04 ± 13.67	5.25 ± 5.09	2.18 ± 2.07	105.38 ± 85.44	143.89 ± 119.47
Mar 11	NP	NP	8.58 ± 6.46	3.88 ± 2.78	NP	12.46 ± 9.24
May 11	NP	NP	3.01 ± 2.23	NP	NP	3.01 ± 2.23
Sep 11	NP	NP	3.12 ± 2.66	NP	NP	3.12 ± 2.66
Feb 12	2.48 ± 2.05	NP	5.55 ± 4.16	NP	NP	8.03 ± 6.21
Jun 12	NP	NP	10.97 ± 7.79	NP	NP	10.97 ± 7.79
Sep 12	NP	NP	NP	NP	NP	NP
Jan 13	NP	NP	NP	NP	NP	NP
Apr 13	6.28 ± 5.3	NP	6.81 ± 6.4	NP	1.2 ± 1	14.29 ± 12.7
Jul 13	NP	NP	13.27 ± 4.84	NP	1.23 ± 1.02	14.5 ± 5.86
Sept 13	NP	NP	28.86 ± 13.86	NP	35.11 ± 15.47	63.97 ± 29.33
Dec 13	10.19 ± 1.6	NP	19.76 ± 2.79	NP	27.08 ± 2.89	57.03 ± 7.28
Mar 14	NP	NP	6.3 ± 4.73	NP	45.46 ± 23.84	51.76 ± 28.57
Jul 14	3.31 ± 0.7	NP	15.55 ± 7.9	NP	64.97 ± 58.5	83.83 ± 67.1
Sep 14	12.19 ± 3.84	3.93 ± 1.02	6.56 ± 1.46	NP	92.42 ± 71.5	115.1 ± 77.82
Dec 14	12.17 ± 4.66	NP	9.38 ± 3.41	NP	239.56 ± 57.53	261.11 ± 65.6
May 15	14.18 ± 5.31	7.81 ± 3.51	5.40 ± 1.95	NP	189.48 ± 47.7	264.39 ± 58.47
Aug 15	8.84 ± 4.55	19.83 ± 16.83	4.50 ± 2.07	0.91 ± 0.68	180.27 ± 62.26	214.34 ± 86.39
Nov 15	28.58 ± 13.01	25.92 ± 9.04	10.30 ± 4.43	4.45 ± 2.52	229.36 ± 38.62	298.61 ± 67.62
Nov 16	78.40 ± 12.43	130.11 ± 23.32	36.17 ± 14.69	4.44 ± 1.79	214.02 ± 41.28	463.14 ± 93.51
Dec 17	43.91 ± 10.67	NP	20.38 ± 6.28	NP	94.91 ± 16.76	159.20 ± 33.71

NP – No seagrass present

3C. Mean above-ground biomass (g DW m^{-2}) of offshore monitoring sites in the Abbot Point region; quarterly 2005, 2008 – 2017.

Sampling Date	Mean Biomass ± SE (g DW m^{-2}) (dominating seagrass species)			
	Site 1	Site 2	Site 3	Site 4
Mar 05*	0.08 ± 0.07	0.59 ± 0.15	3.98 ± 1.43	Site not established
Feb/Mar 08*	0.04 ± 0.04	0.60 ± 0.57	3.28 ± 1.38	Site not established
Jul 08	0.17 ± 0.06	1.27 ± 0.44	3.31 ± 0.38	Site not established
Sept 08	0.02 ± 0.02	0.61 ± 0.17	5.10 ± 0.65	Site not established
Nov 08	0.11 ± 0.06	1.58 ± 0.55	11.07 ± 1.33	Site not established
Apr/May 09	0.0006 ± 0.0006	NP	0.34 ± 0.06	Site not established
Aug 09	0.07 ± 0.04	0.46 ± 0.11	0.45 ± 0.09	Site not established
Feb 10**	0.07	3.75	12.69	Site not established
June 10	NP	0.14 ± 0.05	0.77 ± 0.12	Site not established
Nov 10	0.17 ± 0.07	6.26 ± 0.89	25.76 ± 2.52	5.34 ± 0.76
Mar 11	0.03	0.20 ± 0.08	0.20 ± 0.08	0.14 ± 0.06
May 11	NP	0.23 ± 0.09	0.20 ± 0.08	0.07 ± 0.05
Sep 11	NP	0.26 ± 0.07	0.18 ± 0.06	0.19 ± 0.06
Feb 12	NP	0.31 ± 0.09	0.97 ± 0.17	0.37 ± 0.10
Jun 12	NP	0.44 ± 0.09	1.97 ± 0.24	0.83 ± 0.18
Sep 12	NP	0.59 ±0.16	1.76 ± 0.26	1.16 ± 0.21
Jan 13	0.01 ± 0.009	NV	0.14 ± 0.03	0.04 ± 0.02
Apr 13	0.01 ± 0.009	0.04 ± 0.01	0.03 ± 0.02	0.01 ± 0.009
Jul 13	NP	0.02 ± 0.01	0.09 ± 0.05	NP
Sept 13	NP	0.08 ± 0.03	0.02 ± 0	0.02 ± 0.01
Dec 13	NP	0.03 ± 0.02	0.09 ± 0.03	0.06 ± 0.02
Mar 14	NP	0.06 ± 0.03	0.14 ± 0.04	0.05 ± 0.02
Jul 14	0.2 ± 0.1	0.04 ± 0.02	0.03 ± 0.01	0.03 ± 0.02
Sep 14	0.009 ± 0.005	0.81 ± 0.2	0.32 ± 0.12	0.004 ± 0.002
Dec 14	NP	0.51 ± 0.16	1.02 ± 0.19	0.02 ± 0.01
May 15	0.09 ± 0.03	0.22 ± 0.07	1.41 ± 0.23	0.10 ± 0.05
Aug 15	0.09 ± 0.08	0.61 ± 0.31	2.71 ± 1.04	0.15 ± 0.10
Nov 15	0.004 ± 0.003	3.46 ± 1.22	2.27 ± 0.68	0.97 ± 0.39
Nov 16	0.006 ± 0.005	0.09 ± 0.04	3.98 ± 1.80	0.03 ± 0.02
Dec 17	NP	0.007 ± 0.003	0.03 ± 0.015	0.004 ± 0.002

* - Mar 05 & Feb/Mar 08 surveys were Baseline surveys so the location of Monitoring Blocks were not established thus Biomass is derived from transects in the baseline survey that were located closest to monitoring blocks that were established in July 2008.

** - No visibility at monitoring sites; Biomass calculations approximate only: Biomass derived from calculation of shoot counts converted to biomass based on biomass and shoot relationships of similar meadow and species composition

NP – No seagrass present in monitoring blocks NV – No visibility at site