 

ANNUAL SEAGRASS MONITORING IN THE MACKAY-HAY POINT REGION – 2015

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KEY FINDINGS

A long term monitoring strategy for seagrasses has been developed for the Mackay-Hay Point region following updated baseline surveys in 2014. The strategy continues the long term monitoring sites established for offshore seagrasses in the Port of Hay Point in 2005, and adds new sites in coastal and offshore areas of the Port of Mackay, Hay Point and around Keswick Island.

Offshore Seagrass Condition 2015

- Offshore seagrass habitat in the Hay Point area was in a satisfactory condition in 2015 with seagrass biomass the highest it has been since 2012 and species composition remaining in very good condition.

- 2015 was the first year of monitoring for the other seagrass areas (outside of Hay Point). As a result, these areas do not yet qualify to being graded under the condition index method. The following key findings were identified in these areas;

    - The small inshore seagrass meadows between Hay Point and Dudgeon Point increased in area between 2014 and 2015.

    - There were small declines in biomass in some of the inshore meadows near Dudgeon Point and around Keswick Island.

    - A new offshore *Halophila spinulosa* meadow identified in the 2015 survey off the Mackay Marina was added to the long-term monitoring program.

- Favourable climate conditions for deep water seagrasses (low rainfall; below average river flow) are likely to have facilitated the increases in biomass and area of these meadows in 2015.

- Declines in biomass of the smaller shallow meadows at Dudgeon Point were likely associated with higher temperatures and increased levels of exposure in 2015.

IN BRIEF

A long-term seagrass monitoring program and strategy was developed for the Mackay-Hay Point region following a broad-scale baseline survey of the region in 2014. The program builds on seagrass monitoring that had been conducted at offshore areas around the Port of Hay Point since 2005, as well as coastal surveys conducted in 2010 and 2011.

The new annual monitoring strategy assesses five offshore monitoring areas between Mackay and Hay Point, an inshore region between Dudgeon Point and Hay Point, and two inshore subtidal meadows at the Keswick Island group. Seagrass meadows in these areas represent the range of different seagrass community types found in the Mackay-Hay Point region. These seagrass meadows are assessed for change in biomass, area and species composition. The offshore monitoring meadow in the Port of Hay Point has a long history of monitoring and a well-established baseline level of change for formal analysis and condition reporting. For the other meadows, 2015 was the first monitoring year since the 2014 baseline, and natural ranges of change are still being established.

Offshore seagrasses near Hay Point were in a satisfactory condition in 2015, with biomass increasing between 2014 and 2015, and at levels near to those found in 2012 (Figure 1 & 3). Seagrass density has not however, reached levels recorded in the 2005 baseline in the nine years since completion of capital dredging for the departure path in 2006. The relatively smaller inshore meadows at Dudgeon Point and Keswick/St Bees Islands also underwent increases in total area between 2014 and 2015 (Figure 3). There was however small declines in biomass in some of these meadows.

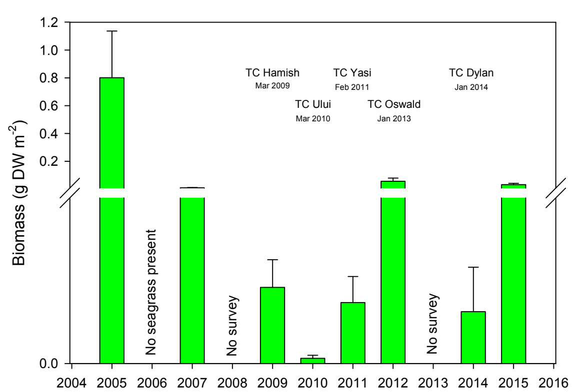

Figure 1. Mean seagrass biomass of Hay Point offshore monitoring sites from 2005 to 2015

Seagrass biomass and distribution are strongly influenced by local environmental conditions and for the last two years many of these environmental variables were at levels considered to be favourable for seagrass growth and survival, particularly for deep water seagrass. Below average rainfall and river flow and a prevailing El Niño climate pattern resulted in drier weather patterns with fewer episodic rainfall events (Figure 2). Benthic light data collected as part of a separate program TropWATER conducts in the Hay Point region also indicated that light levels were sufficient for *Halophila* growth during 2015. These favourable climate conditions likely explain the increase in offshore seagrass density around Hay Point, and also at the deeper edges of the meadows at Keswick/St Bees Islands.

Declines in biomass recorded for some shallow inshore seagrasses such as those at Dudgeon Point may be related to above average sea surface and air temperatures, combined with above average solar exposure and exposure to air that occurred during 2015. For intertidal meadows this combination can lead to high levels of stress associated with desiccation and high levels of light when exposed to air. Similar trends for intertidal seagrasses have been observed in other monitoring locations in Queensland including Weipa, Gladstone and Townsville during 2015.

The decline in biomass of the Keswick/St Bees Island meadows may be linked to a recent burst of flowering and fruiting activity at the site observed as part of another TropWATER research program. The plants were in a deteriorated state and the site was covered in seagrass fruits and flowers. Often during reproduction plants will divert most of their energy into producing fruits and flowers, sacrificing leaf/shoot condition, thus losing biomass. At this stage the nature of seagrass changes for this meadow are still being quantified.

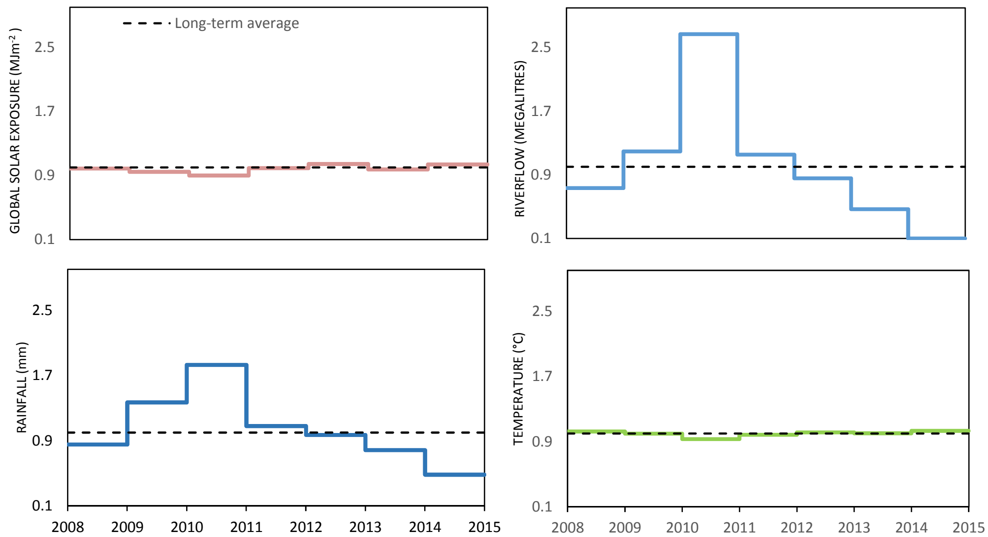

Figure 2. Recent climate trends in the Hay Point Area: change in climate variables as a proportion of the long-term average from 2008-2015. (See section 3.5 for detailed climate data).

It is likely that *Halophila* in the deep water areas around Hay Point and the Keswick/St Bees Islands are at the limits of light required to support seagrass growth. Their ability for rapid colonisation means they are capable of taking advantage of seasonal or infrequent favourable conditions of light to recruit into deep water areas, and they have the lowest light requirements of all tropical seagrass species. Many of these meadows may be annual, completely disappearing for large parts of the year and relying on a seed bank to recruit in the next growing season. Understanding the seed bank status and protecting flowering and fruiting is then critical for managing these meadows.

The Hay Point seagrass monitoring program forms part of a broader Queensland program that examines condition of seagrasses in the majority of Queensland commercial ports and areas where seagrasses face the highest levels of cumulative risk. It also forms 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.

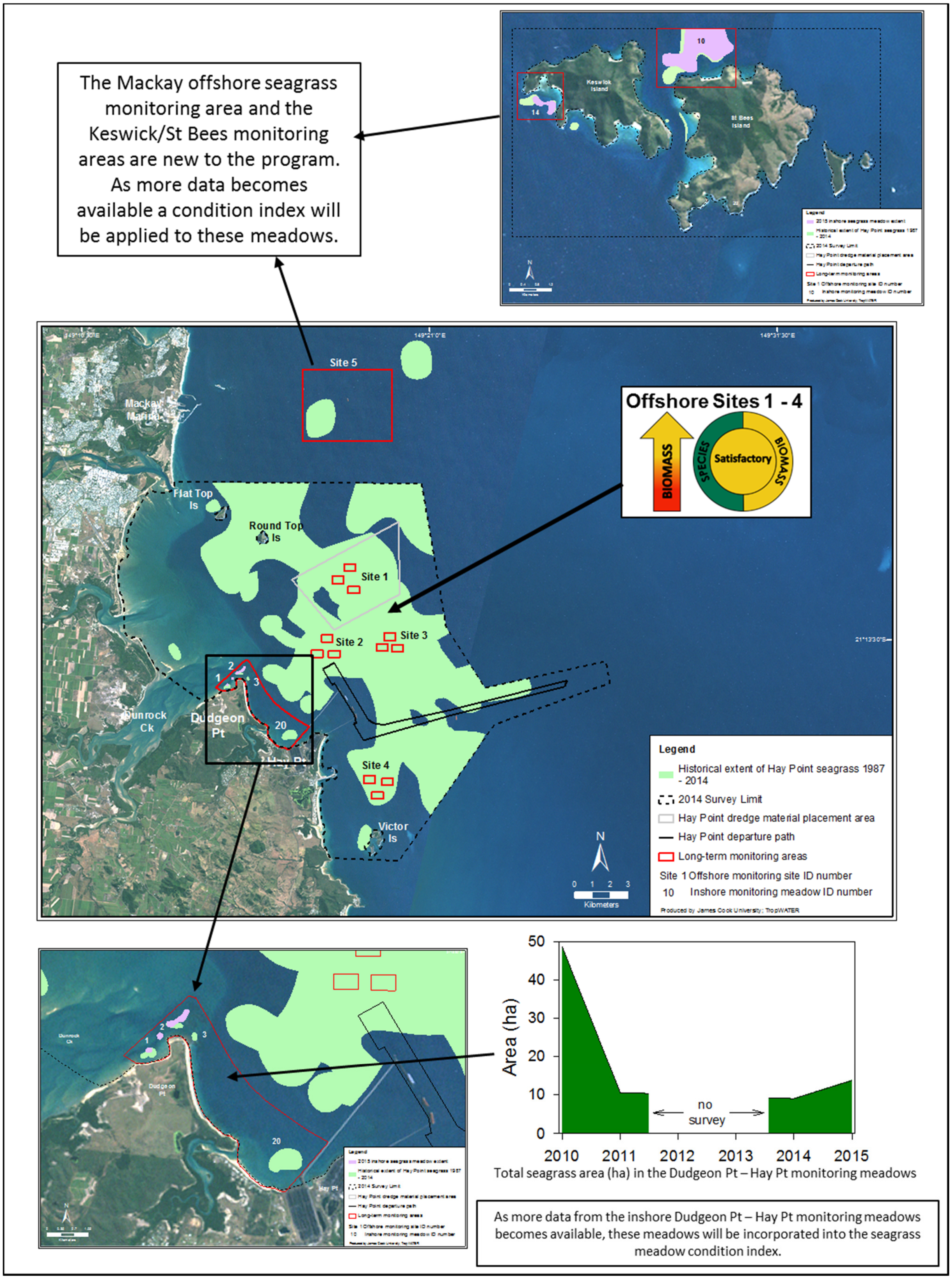

Figure 3. Seagrass meadow condition for the ports of Mackay and Hay Point, and Keswick/St Bees Island 2015

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1 INTRODUCTION

Seagrasses provide a range of critically important and economically valuable ecosystem services including coastal protection, support of fisheries production, nutrient cycling and particle trapping (Costanza et al. 1997; Hemminga and Duarte 2000). With globally developing carbon markets, the role that seagrasses play in sequestering carbon is also becoming more 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 marine environments (Dennison et al. 1993; Abal and Dennison 1996; Orth et al. 2006).

Globally, seagrasses have been declining at ever increasing rates due to both natural and anthropogenic causes (Waycott et al. 2009). Explanations for seagrass decline include natural disturbances such as storms, disease and overgrazing by herbivores, as well as 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). Locally in the Great Barrier Reef (GBR) coastal region the hot spots with highest threat exposure for seagrasses all occur in the southern two thirds of the GBR, 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 has been recognised and a strategic monitoring program of these high risk areas has been established to aid in their management and ensure impacts are minimised (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 the various 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 utilised to provide a network of seagrass monitoring locations throughout the state (Figure 4).

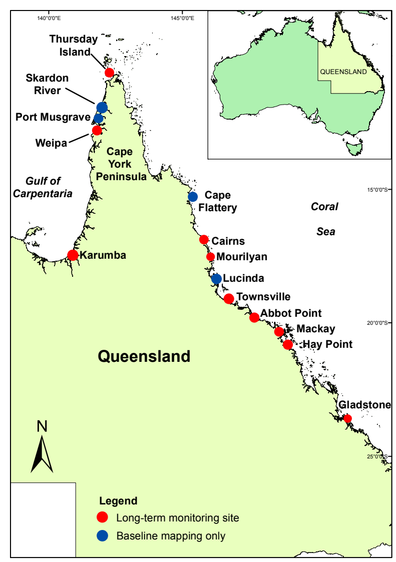


Figure 4. Location of Queensland Port Seagrass assessment sites

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 seagrasses 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 Mackay and Hay Point Seagrass Monitoring Program

North Queensland Bulk Ports (NQBP) is the port authority for the Port of Hay Point and Mackay situated on the central Queensland coast. The Port of Hay Point (approximately 38 km south of Mackay) is one of the world's largest coal exporting ports and comprises two coal export terminals; Dalrymple Bay Coal Terminal (DBCT) and the Hay Point Coal Terminal (HPCT).

TropWATER's Seagrass Ecology Group first mapped significant areas of deep water seagrass (>10m below mean sea level (MSL)) within the Port of Hay Point in a benthic survey conducted in July 2004 (Rasheed et al. 2004) and in Mackay in 2001 (Rasheed et al. 2001). The majority of this seagrass was low density (<5% cover of the substratum) although there were patches of higher density seagrass within the survey area. There were also large areas of low density macrophytic algae communities within the port limits. A subsequent monitoring program between 2005 and 2012 found that these seagrass meadows were highly dynamic within and between years, were susceptible to impacts associated with large-scale capital dredging operations, but recovered quickly once dredging was completed (Chartrand et al. 2008; York et al. 2015). York et al. found (2015) that deep water seagrasses at Hay Point, despite considerable inter annual variability, had a regular annual pattern of occurrence, low resistance to reduced water quality but a capacity for rapid colonisation on the cessation of impacts. Extensive and persistent turbid plumes from a large dredging program over an eight month period resulted in a failure of the seagrasses to establish in 2006, however recruitment occurred the following year and the regular annual cycle was re-established (York et al. 2015).

Since this monthly/quarterly monitoring program, three other broad-scale surveys re-mapping seagrasses in the Hay Point region have been conducted; October 2010, November 2011 and October/November 2014, all identifying some small coastal meadows near Dudgeon Point and Hay Point, and defining the natural variation in the deep water seagrass meadow off Hay Point (Thomas and Rasheed 2011; Thomas et al. 2012; McKenna and Rasheed 2015). The 2014 survey also included investigating seagrass habitat in the Keswick Island and St Bees Island areas, as well as exploring other inshore and offshore areas near Mackay that could be added to a long-term monitoring program as reference sites.

NQBP recognise that seagrasses form a key ecological habitat in the Mackay-Hay Point region and have commissioned TropWATER to re-establish the long-term seagrass monitoring program that was conducted between 2005 and 2012. The broad-scale survey conducted in 2014 was used as a platform to re-establish the program and add additional monitoring in the Keswick Island (southern Whitsunday Islands) and Mackay areas (Figure 5). The goals of the program are to minimise impacts of port activities on seagrass habitats and to periodically assess the health of Mackay and Hay Point's port environment. The seagrass monitoring program is used by management agencies to assess the status and condition of seagrass resources in the region. The monitoring program also forms part of Queensland's network of long-term monitoring sites of important fish habitats in high risk areas.

This report presents the findings of the annual seagrass habitat monitoring survey conducted in October 2015. The objectives of these studies were to:

- Map seagrass distribution and determine seagrass density and community type at the identified inshore monitoring locations between Dudgeon Point and Hay Point, and at Keswick and St Bees Islands;
- Determine seagrass density and community type in the offshore seagrass meadow at Hay Point;

- Compare results of monitoring surveys and assess any changes in seagrass distribution and abundance 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 Mackay-Hay Point REGION;
- Discuss the implications of monitoring results for overall health of the Mackay-Hay Point marine environment and provide advice to relevant management agencies.

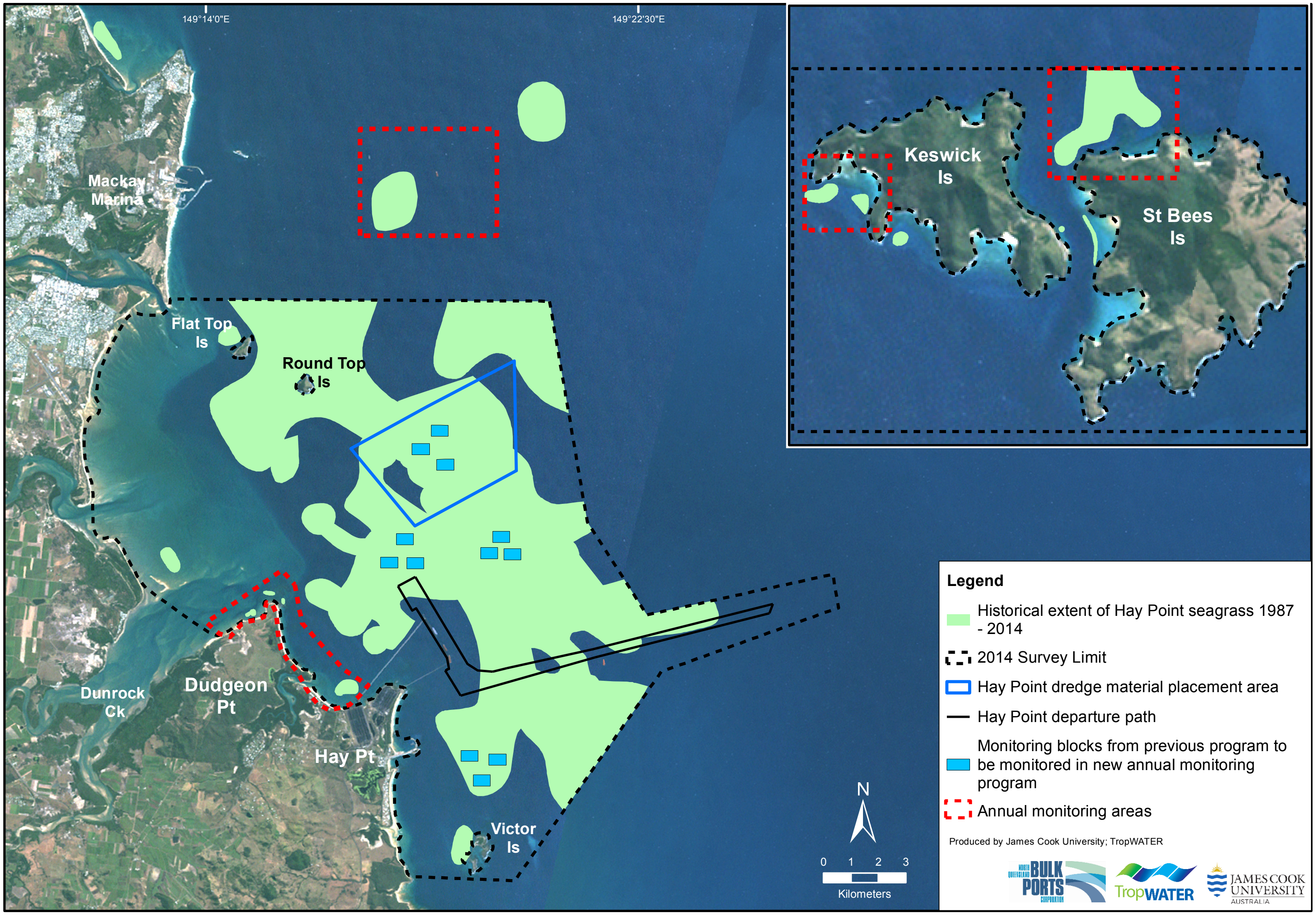


Figure 5. Location of annual seagrass monitoring areas around Mackay, Hay Point and the Keswick Island group.

2 METHODS

2.1 Survey Approach

The survey approach was focused on re-establishing an annual long-term seagrass monitoring program for the Port of Hay Point and adding new monitoring locations in the Mackay and Keswick Island areas. The long-term monitoring approach is based on periodic re-assessments of all seagrasses within the region (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 seagrass programs in the Ports of Weipa and Abbot Point, and elsewhere in other Queensland ports.

The current three year cycle began with the broad-scale survey in 2014. From the results of the 2014 survey and further investigations in 2015, two inshore meadows at Keswick/St Bees Islands, one inshore region from Dudgeon Point to Hay Point, four offshore areas around Hay Point (the same areas monitored between 2005 and 2012), and one offshore area off the Mackay Marina were identified as suitable for long term seagrass monitoring. Monitoring areas selected were representative of the range of seagrass communities in the Mackay-Hay Point region and were also located in areas considered ideal sensitive receptor sites for assessing seagrass condition in relation to port activity and any development.

The inshore monitoring meadows located at Keswick and St Bees Islands have a depth gradient that ranges from approximately 2.5m to 30m below MSL and are dominated by *Halophila* species. Neither of these meadows expose to air on spring low tides. The inshore monitoring region between Dudgeon Point and Hay Point ranges in depth from 0m to 9m below MSL. On a spring low tide Meadow 1 at Dudgeon Point exposes to air.

Annual surveys are conducted between September and December to capture seagrasses at their likely seasonal peak in distribution and abundance, and also facilitate comparisons with the previous surveys conducted in the area.

Methods for assessing inshore and offshore seagrasses were standard and extensively reviewed techniques developed and utilised by the TropWATER Seagrass Ecology Group for baseline assessment and monitoring of seagrasses and other benthic communities in Queensland; Hay Point, Gladstone, Cairns, Mackay, Abbot Point, Weipa, Torres Straits and Townsville. The application of standardised methods at Hay Point and throughout Queensland allows for direct comparison of local seagrass dynamics with the broader region.

Techniques ensure that a large area of seafloor is integrated at each site to take into account the spatial variability and patchiness common for many tropical benthic habitats, as well as logistical issues associated with naturally high water turbidity and the presence of dangerous marine animals including saltwater crocodiles. These standardised methods were used to ensure that new information collected would be directly comparable with existing and past programs.

2.2 Survey Methods

A variety of sampling methods were used to survey benthic habitats. Methods applied were based on existing knowledge of benthic habitats and physical characteristics of the area such as depth, visibility and logistical and safety constraints. Three sampling techniques were used:

1. Shallow subtidal areas <8m below MSL: Free diving;
2. Subtidal inshore areas >8m below MSL: Boat based underwater digital camera mounted on a drop frame;
3. Offshore subtidal areas >8m below MSL: Boat based digital camera sled tows.

At each survey site, seagrass habitat observations included seagrass species composition, above-ground 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.

At sites where seagrass presence was noted seagrass above-ground biomass was determined. Above-ground seagrass biomass was estimated using a "visual estimates of biomass" technique (Kirkman 1978; Mellors 1991). At free diving and camera drop 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. The video was paused at each of the ten time frames then advanced to the nearest point on the tape where the bottom was visible and sled was stable on the bottom. From this frame an observer ranked seagrass biomass and species composition. A $0.25m^2$ quadrat, scaled to the video camera lens used in the field, was superimposed on the screen to standardise biomass estimates.

Biomass ranks at all sites are made in reference to a series of quadrat photographs of similar seagrass habitats for which above-ground biomass has previously been measured. The relative proportion of the above-ground biomass (percentage) of each seagrass species within each survey quadrat was also recorded. Field biomass ranks were then converted into above-ground 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 were harvested and the actual biomass (separated by species) determined in the laboratory. A separate regression of ranks and biomass from these calibration quadrats was generated for each observer and applied to the field survey data to standardise the above-ground biomass estimates.

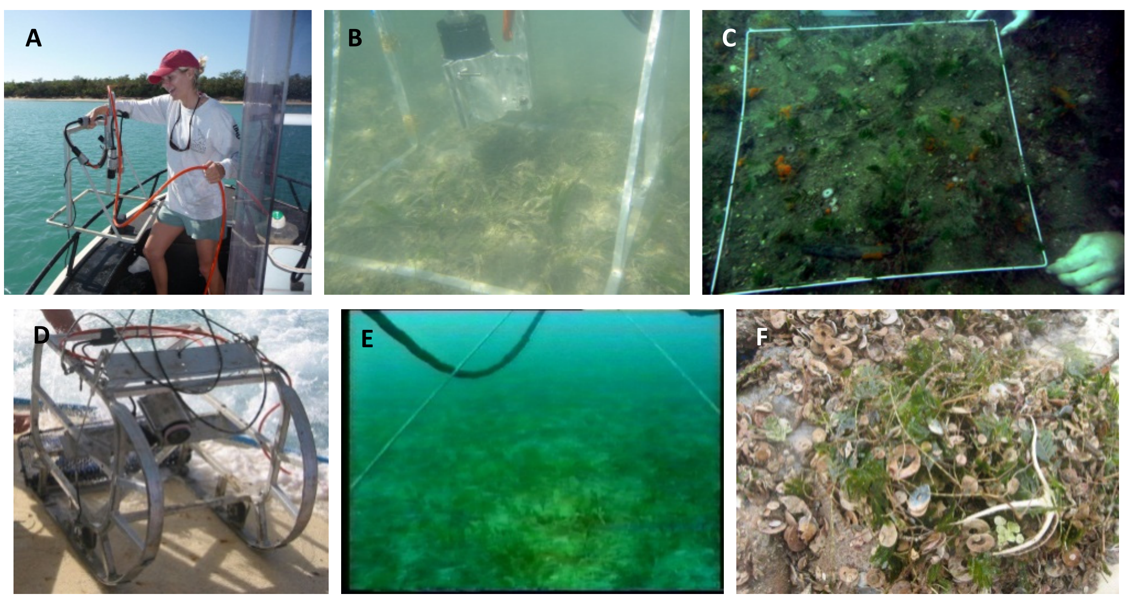


Figure 6. Shallow subtidal mapping of seagrass meadows using digital camera mounted on a $0.25m^2$ drop frame (A – B), freediving (C), and offshore underwater sled tows with digital camera(D-F).

All survey data was entered into a Geographic Information System (GIS) database for presentation of seagrass species distribution and density. Three GIS layers were created in ArcGIS to describe the seagrass habitat in the survey areas:

- **Habitat characterisation survey sites** - site data containing above-ground biomass (total and for each species), depth below mean sea level (MSL), sediment type (based on visual estimates), 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 overall species composition from nomenclature developed for seagrass meadows of Queensland (Table 1). This system was based on the percent composition of biomass contributed by each species within the meadow. This layer also included a measure of meadow density that was determined by the mean above-ground biomass of the dominant species within the community (Table 2).
- **Seagrass landscape category** - Area data for seagrass meadows showing the seagrass landscape category according to the below descriptions:

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)	*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 was mapped by free diving, underwater camera techniques and the distance between sites, and 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. This resulted in a range of meadow sizes which is expressed as error (±ha) around the total meadow area (ha).

Table 3. Mapping precision and methodology for boundary mapping in the Port of Hay Point and Keswick Island group.

Mapping precision	Mapping methodology
5m	Subtidal meadow boundaries determined from free diving surveys; Relatively high density of survey sites; Recent aerial photography aided in mapping.
50m	Subtidal meadow boundaries determined from free diving and underwater CCTV camera drops; Moderate to high density of survey sites; Recent aerial photography aided in mapping.

2.3 Seagrass meadow condition index

This is the first year of applying the seagrass condition index method that has been developed across the Queensland Ports Seagrass Monitoring Program, to Hay Point seagrass habitats. At this stage, a seagrass condition index will only be applied to the offshore monitoring sites at Hay Point, the dominant seagrass habitat in the area. Currently, there is insufficient data at the inshore sites to apply this method, however as the monitoring program progresses and more data is collected, this will be reviewed for the inshore monitoring sites.

A condition index was developed for the Hay Point offshore seagrass meadow based on changes in mean above-ground biomass and species composition, and follows the index that is applied across other long-term seagrass monitoring programs in ports throughout Queensland (Figure 7). Meadow condition was divided into one of five grades: A (very good), B (good), C (satisfactory), D (poor) and E (very poor) by comparing the condition of the current meadow against the baseline conditions.

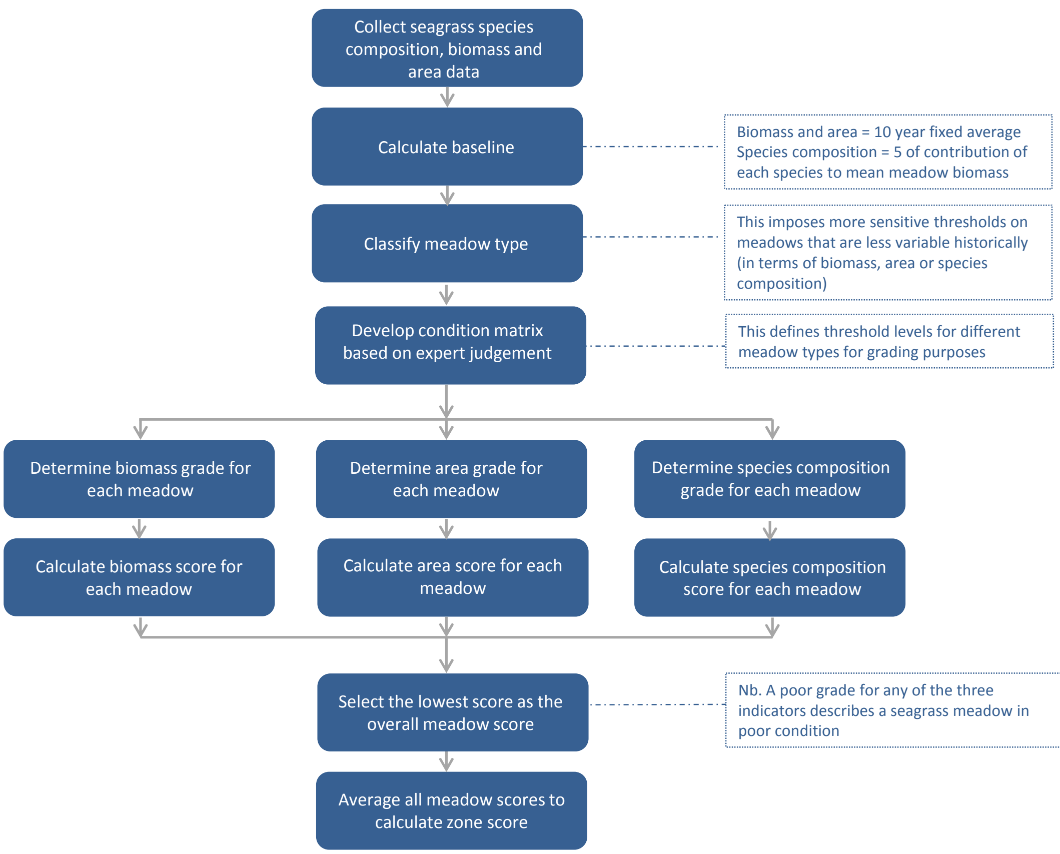


Figure 7. Flow chart to develop the TropWATER seagrass monitoring meadow condition index.

Baseline Conditions

Baseline conditions for seagrass biomass and species composition were established from annual means calculated from 2005-2014 (8 years) following the methods of Carter et al. (2015). Where possible, a long-term-average of 10 years is a more accurate representation of the baseline conditions, as a 10 year period incorporates a range of environmental conditions present including El Niño and La Niña periods. Once the monitoring program has collected over 10 years of data, the 10 year long-term average will be used for future assessments.

Meadow area was not calculated for offshore meadows as these are conducted using a transect method and transects are located within the meadow boundary; therefore a meadow area cannot be calculated every year. Offshore meadow area/distribution can only be determined when the broad-scale surveys are conducted every three years (the last being in 2014).

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 2005-2014 (only in the years where species were present; 6 years in total for the offshore Hay Point meadow). The baseline calculation was based only on the percent composition of what was considered to be the stable state species in the offshore meadow.

Meadow Classification

A meadow classification system was developed for the condition indicators (biomass, area, species composition) in recognition that for some seagrass meadows these measures are historically stable, while in other meadows they are relatively variable. The coefficient of variation (CV) for each baseline for each meadow was used to determine historical variability. Meadow biomass, area and species composition was classified as either stable or variable (Table 4). Two further classifications for meadow area were used: highly stable and highly variable, in recognition that some meadows are very stable while others have a naturally extreme level of variation (Table 4). The CV was calculated by dividing the standard deviation of the baseline years by the baseline for each of condition indicator.

Table 4. Coefficient of variation (CV) thresholds used to classify historical stability or variability of meadow biomass and species composition.

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

*Meadow area is not assessed for the Hay Point offshore monitoring sites

Threshold Levels for Grading Indicators

Seagrass condition was assigned one of five grades (very good, good, satisfactory, poor, very poor). Threshold levels for each grade were set relative to the baseline and were selected 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 5).

Table 5. Threshold levels for grading seagrass indicators for various meadow classes. 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	More than 20% above the baseline	Within 20% of the baseline (above or below)	Between 20% and 50% below the baseline	Between 50% and 80% below the baseline	More than 80% below the baseline
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
*Area	Highly stable	More than 5% above the baseline	Within 5% above and 10% below the baseline	Between 10% and 20% below the baseline	Between 20% and 40% below the baseline	More than 40% below the baseline
*Area	Stable	More than 10% above the baseline	Within 10% of the baseline (above or below)	Between 10% and 30% below the baseline	Between 30% and 50% below the baseline	More than 50% below the baseline
*Area	Variable	More than 20% above the baseline	Within 20% of the baseline (above or below)	Between 20% and 50% below the baseline	Between 50% and 80% below the baseline	More than 80% below the baseline
*Area	Highly 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 composition	Stable; Single species dominated	More than 0% above the baseline	<20% below the baseline	Between 20% and 50% below the baseline	Between 50% and 80% below the baseline	More than 80% below the baseline
Species composition	Stable; Mixed species	More than 20% above the baseline	<40% below the baseline	Between 40% and 70% below the baseline	Between 70% and 90% below the baseline	More than 90% below the baseline
Species composition	Variable; Single species dominated	More than 0% above the baseline	<20% below the baseline	Between 20% and 50% below the baseline	Between 50% and 80% below the baseline	More than 80% below the baseline
Species composition	Variable; Mixed species	More than 20% above the baseline	<40% below the baseline	Between 40% and 70% below the baseline	Between 70% and 90% below the baseline	More than 90% below the baseline
	Increase above threshold from previous year	↑ BIOMASS		Decrease below threshold from previous year	↓ BIOMASS	

*Meadow area is not assessed for the Hay Point offshore monitoring sites

Grades and Scores

A score system (0-1) was developed for each grade to enable comparisons of seagrass condition among meadows within a port, and among all the ports monitored by TropWATER (Table 6; see Carter et al. 2015 for a detailed description).

Calculating the score for each condition indicator required determining the 2015 grade for each indicator, then scaling the 2015 value for biomass, area (not calculated for the Hay Point offshore meadow) or species composition against the prescribed score range for that grade. Scaling was required because the score range in each grade was not equal (Table 6). This involved several steps. An example of calculating a meadow score for area in satisfactory condition is provided in Appendix 1.

Table 6. The score range for each grade used for TropWATER seagrass report cards.

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

Each overall meadow grade and score was determined by the lowest grade and score of the condition indicators (biomass, area, species composition: biomass and species composition only for the Hay Point offshore meadow) within that meadow. The lowest score was applied in recognition that a poor grade for any one of the indicators 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 enables the most conservative estimate of meadow condition to be made (Bryant et al. 2014).

Where species composition was determined to be anything less than in "perfect" condition (i.e. a score of 1.00), a decision tree was used to determine whether equivalent and/or more persistent species (based on Kilminster et al. 2015) were driving this grade/score (Figure 8). 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 8). This would occur when the stable state species is replaced by species considered to be earlier colonisers (Kilminster et al. 2015). 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).

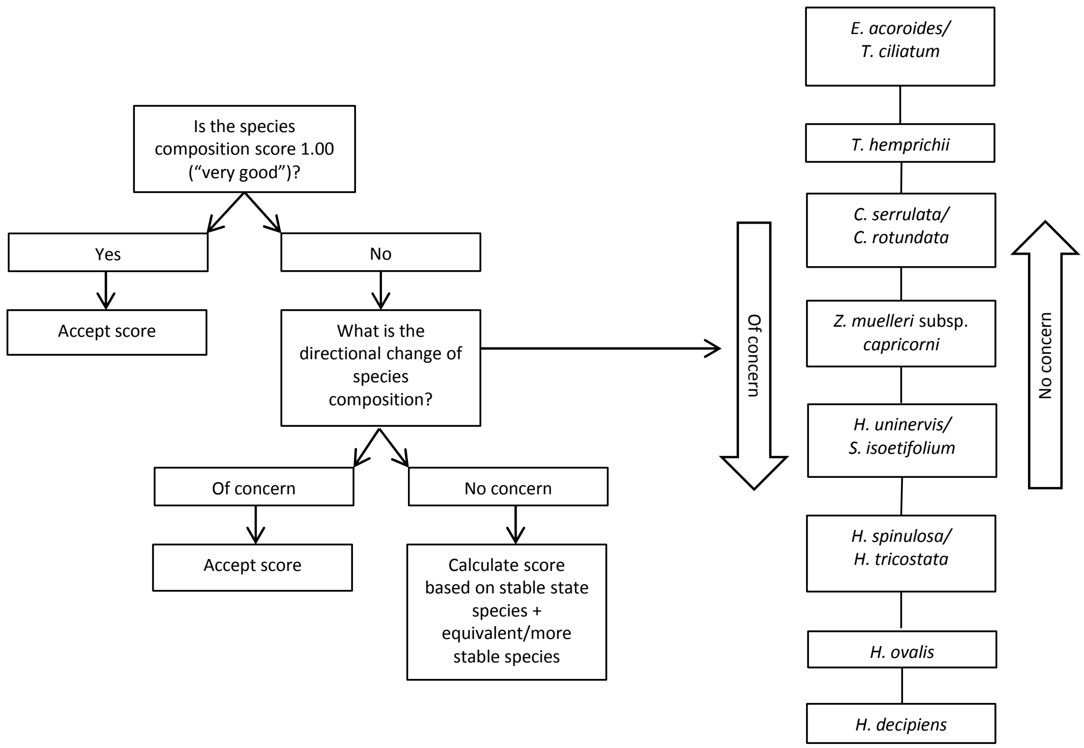


Figure 8. Decision tree and directional change assessment for grading and scoring seagrass species composition.

3 RESULTS

3.1 Seagrass in the Hay Point and Keswick Island areas

A total of 128 sites were surveyed in the Hay Point and Keswick Island area in October 2015 as part of the re-established long-term seagrass monitoring program (Figure 10). Seagrass was present at 24% of the inshore sites and at 42% of the offshore sites.

Five species of seagrass were recorded in 2015 in the monitoring areas (Figure 9). *Zostera muelleri* has previously been found at inshore meadows near Dudgeon Point but was not found in the 2015 annual survey. The *Halophila* species found were typical of deep water habitats in Queensland and in the Hay Point region, while *Halodule uninervis* is a typical coastal/shallow water species. *Halophila tricostata* is endemic to Australia and is known to have an annual habit (Kuo et al. 1993).

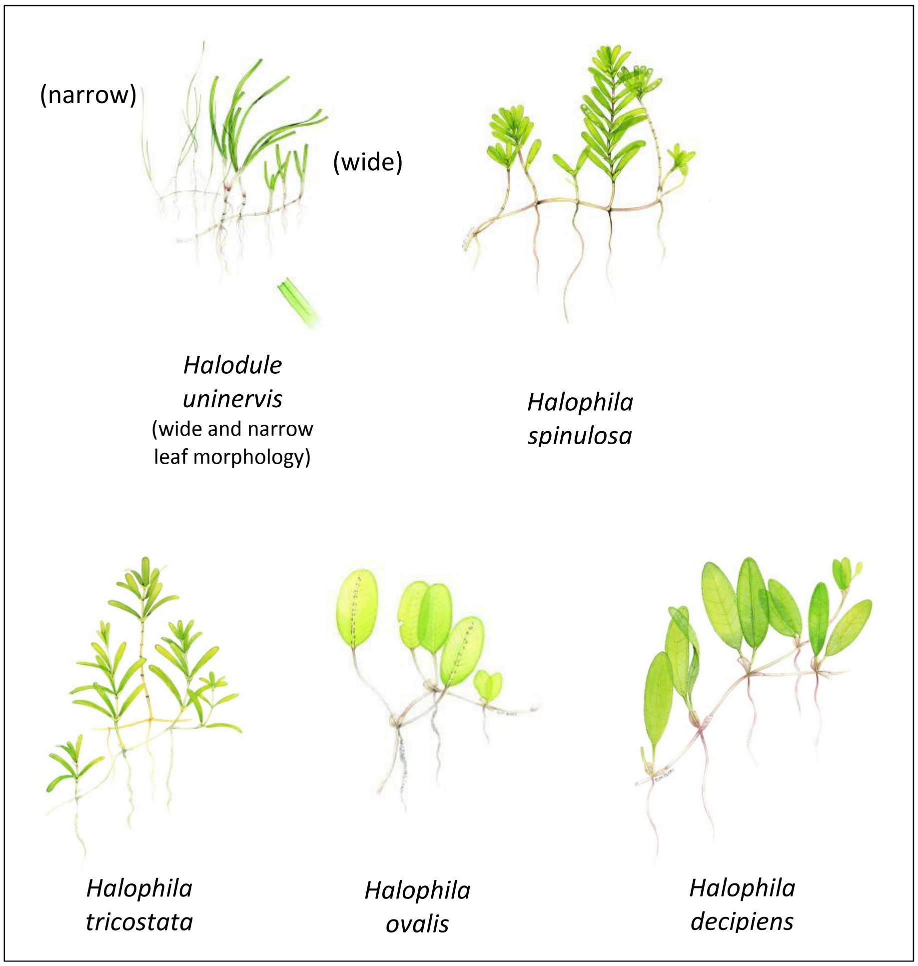


Figure 9. Seagrass species identified in the Hay point annual monitoring program in 2015.

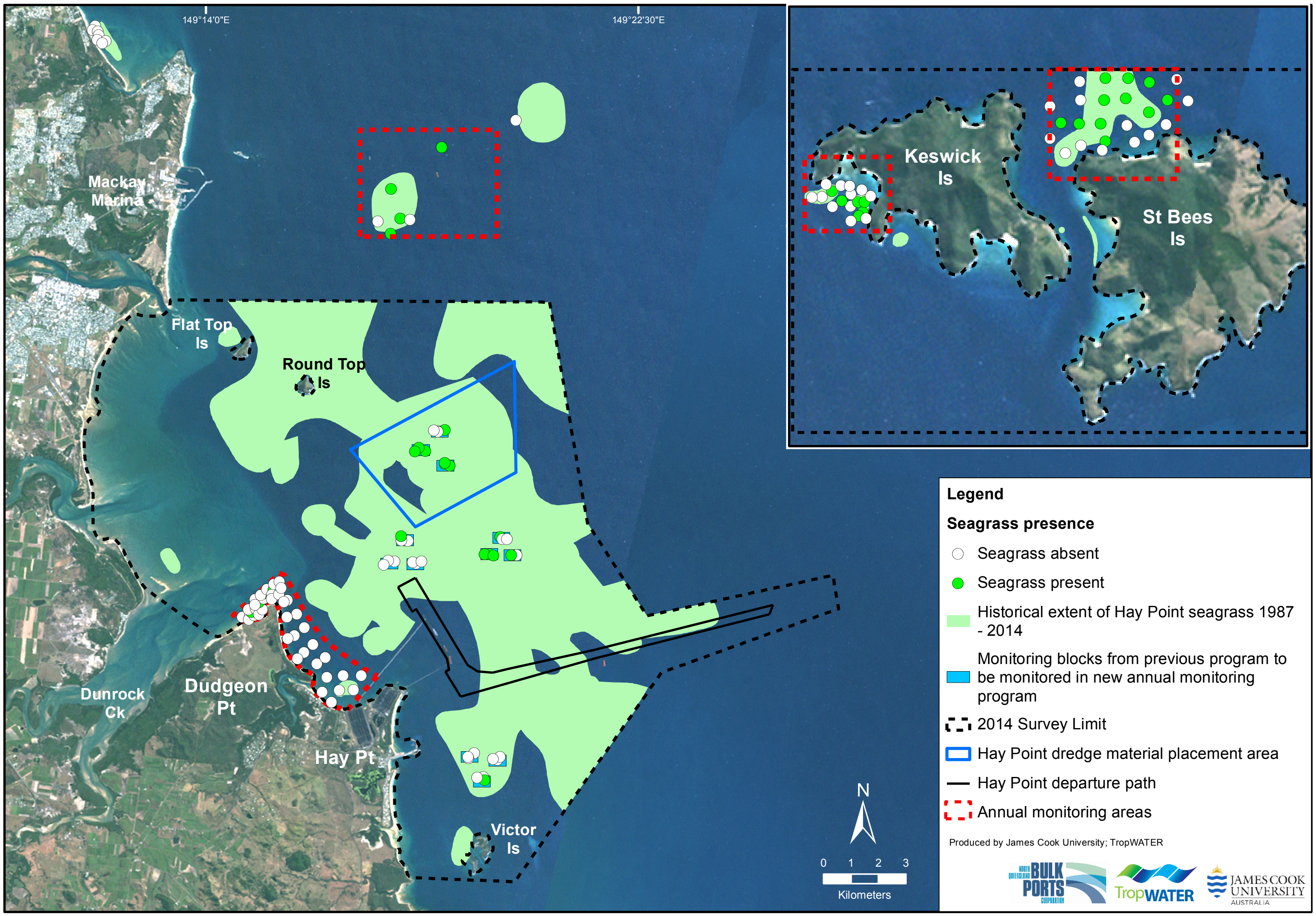


Figure 10. Location of 2015 annual monitoring survey sites in the Hay Point region

3.1.1 Seagrass condition in the Hay Point and Keswick Island monitoring areas

Two distinct types of seagrass habitat; inshore and offshore, were identified within the Hay Point section of the survey area, with two seagrass species observed: *H. uninervis* and *Halophila decipiens*.

Offshore seagrass at Hay Point

The overall condition of offshore seagrasses in the Hay Point area was classed as satisfactory and was an increase in grade from very poor in 2014 (Table 7; Figure 12). The species composition indicator was classed as very good while the biomass indicator was classed as satisfactory. It was the lower biomass indicator score that drove the overall offshore meadow score of satisfactory.

Seagrass meadows in the offshore monitoring areas were dominated by low biomass *H. decipiens* with an absence of previously recorded *H. ovalis* and *H. spinulosa* in this area (Appendix 2). Seagrass was found at eight of the twelve offshore monitoring blocks in 2015, including in the existing dredge material placement area (Figure 11). Seagrass biomass at monitoring blocks ranged from 0.02 ± 0 to 0.12 ± 0.05 gDWm^{-2}, the highest it has been since the 2012 survey.

The maximum depth that seagrass was recorded in the Hay Point offshore monitoring blocks was 18.86m below mean sea level (MSL).

Table 7. Grades and scores for seagrass indicators (biomass, area and species composition) for the Port of Weipa.

Meadow	Biomass	Species Composition	Overall Meadow Score
Offshore monitoring areas	0.501	1.0	0.501
Overall Score for the Port of Hay Point			0.501

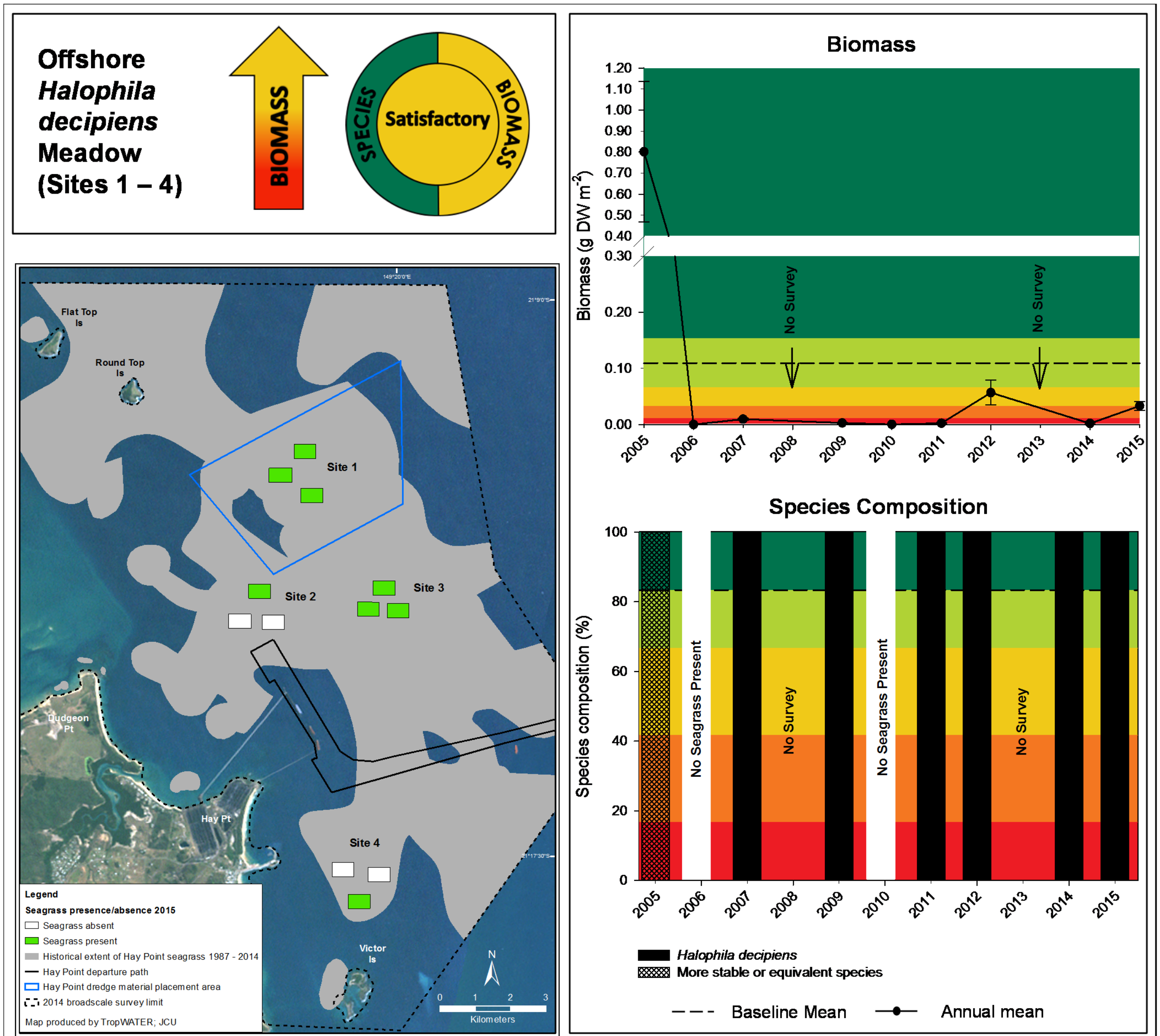
*****Meadow area is not assessed for the Hay Point offshore monitoring meadow

As part of the 2014 broad-scale survey we investigated inshore and offshore areas around the Port of Mackay that could potentially become part of the long-term monitoring program. These sites were re-surveyed in 2015 (Figure 10).

A deep water *H. spinulosa/H. decipiens* meadow off the Mackay Marina was identified and surveyed in 2015, and is now part of the annual long-term monitoring program (Figure 10). As it is the first data point for this meadow, and it is a separate meadow from the Hay Point deep water seagrass meadow, the Mackay offshore meadow did not contribute to determining the above meadow condition indicators. This monitoring site will be treated as an independent site from the Hay Point offshore sites and will be integrated into the seagrass condition index once at least 5 years of data has been collected.

Seagrass above-ground biomass in this area ranged from 0.06 ± 0 to 0.76 ± 0.53 gDWm^{-2}, similar to biomass' in 2005 when larger densities of *H. spinulosa* were found in the Hay Point deep water meadow (Figure 11 and 12). Seagrass in this Mackay monitoring area was found to a maximum depth of 19.82m below MSL.

Figure 11. *Halophila spinulosa* collected at the Mackay offshore monitoring site October 2015.



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 (variable single sp.)	More than 0% above the baseline	<20% 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 12. Changes in meadow biomass and species composition for seagrass in the offshore area around Hay Point, 2005 – 2015 (biomass error bars = SE).

Inshore seagrass at Dudgeon Point-Hay Point & Keswick Island group

At inshore monitoring areas between Dudgeon Point and Hay Point, seagrass occurred at 12% of the sites and formed three small meadows confined to Dudgeon Point with a total area of 13.74 ± 1.33 ha (Table 10; Figure 13). These meadows were located in similar areas to previous surveys.

Seagrass within the mapped area around Dudgeon Point consisted of aggregated patches of *H. decipiens* and *H. uninervis* (wide form) with the above-ground biomass of seagrass at sites ranging between 1.32 ± 0.74 and 2.63 ± 0.60 $gDWm^{-2}$. The last time inshore seagrass was found near the Hay Point terminal was in 2011 (Thomas et al. 2012).

Two seagrass meadows (Meadow 14 at Keswick Island and Meadow 10 at St Bees Island) were identified in the 2014 broad-scale survey as being suitable to monitor as part of the annual Mackay-Hay Point region long-term seagrass monitoring program (Figure 14). Four seagrass species were observed in these monitoring areas in 2015: *H. decipiens, H. ovalis, H. spinulosa* and *H. tricostata*, with *H. tricostata* being the dominant species present (Appendix 2).

Seagrass occurred at 40% of the sites and formed two different meadows according to their community type (Meadow 10 and 14) with a total combined area of 151.94 ± 41.75 ha; a 15.4 ha increase from 2014 (Table 8; Appendix 2). Seagrass within the mapped area consisted of aggregated patches of seagrass, and biomass at individual survey sites ranged in density from 0.24 ± 0 to 2.73 ± 0.07 $gDWm^{-2}$. Mean meadow biomass for the two meadows were 1.22 ± 0.19 $gDWm^{-2}$ (Meadow 10) and 1.13 ± 0.35 $gDWm^{-2}$ (Meadow 14) and were both lower in biomass than what was reported for the meadows in 2014 (Table 8).

Seagrass in the meadows ranged from intertidal to deep subtidal sites and was found between 2.6m and 28.69 m below MSL.

No seagrass was found at the McCready's Creek or Black Beach area at Mackay in 2015 (Figure 10). This area was identified in the 2014 survey as an area we could potentially include as part of the annual monitoring program. After two years (2014 and 2015) with no seagrass this area has been excluded from the annual monitoring program.

Table 8. Inshore seagrass community type, mean above-ground biomass and meadow area in the Dudgeon Point – Hay Point, and Keswick Island annual survey areas, October 2015

Hay Point – Dudgeon Point inshore survey area				
Meadow ID	**Meadow location**	**Seagrass meadow community type**	**Mean meadow biomass ($gDWm^{-2}$ ± SE)**	**Area ± R (ha)**
October 2010				
1	Inshore	Light *Halophila ovalis*	na	4.5 ± 1.6
2	Inshore	Light *Halophila ovalis/Halodule uninervis* (wide & narrow)	na	5.1 ± 2.0
3	Inshore	Light *Halodule uninervis* (wide)	na	2.6 ± 1.3
20	Inshore	Light *Halodule uninervis* (narrow)	na	36.5 ± 12.2
			Total	**48.7 ± 17.1**
November 2011				
1	Inshore	Not present	np	np
2	Inshore	Light *Halodule uninervis* (wide)	na	4.3 ± 1.9
3	Inshore	Not present	np	np
20	Inshore	Light *Halodule uninervis* (narrow)	na	6.3 ± 1.9
			Total	**10.6 ± 3.8**
October/November 2014				
1	Inshore	Light *Zostera muelleri/Halophila ovalis*	1.18 ± 0	4.3 ± 1.8
2	Inshore	Light *Halodule uninervis* (wide)	2.74 ± 0	4.7 ± 1.8
3	Inshore	Not present	np	np
20	Inshore	Not present	np	np
			Total	**9.0 ± 3.6**
October 2015				
1	Inshore	Moderate *Halophila decipiens*	1.42 ± 0	1.8 ± 0.3
2	Inshore	Light *Halodule uninervis* (wide)	1.79 ± 0.23	11.9 ± 1.1
3	Inshore	Not present	np	np
20	Inshore	Not present	np	np
			Total	**13.7 ± 1.4**
Keswick/St Bees Islands inshore survey areas				
October/November 2014				
10	Inshore	Light *Halophila tricostata* with *Halophila decipiens*	2.34 ± 0.38	118.6 ± 60.0
14	Inshore	Moderate *Halophila decipiens* with mixed species	2.6 ± 0.71	17.9 ± 13.3
			Total	**136.5 ± 73.3**
October 2015				
10	Inshore	Light *Halophila tricostata*	1.23 ± 0.19	137.2 ± 30.5
14	Inshore	Light *Halophila spinulosa* with mixed species	1.13 ± 0.35	14.7 ± 11.3
			Total	**151.9 ± 41.8**

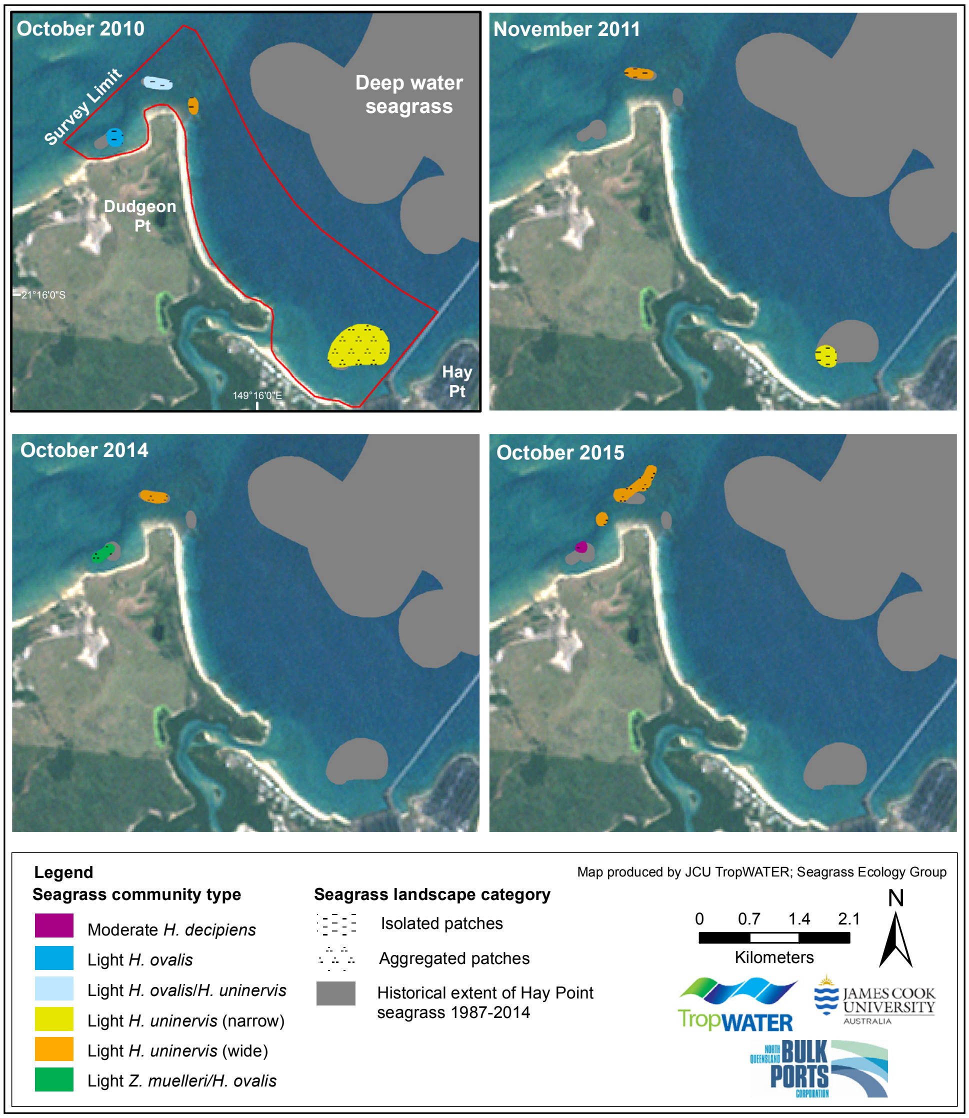


Figure 13. Seagrass community type in the Dudgeon Point to Hay Point annual monitoring area; 2010, 2011, 2014 and 2015.

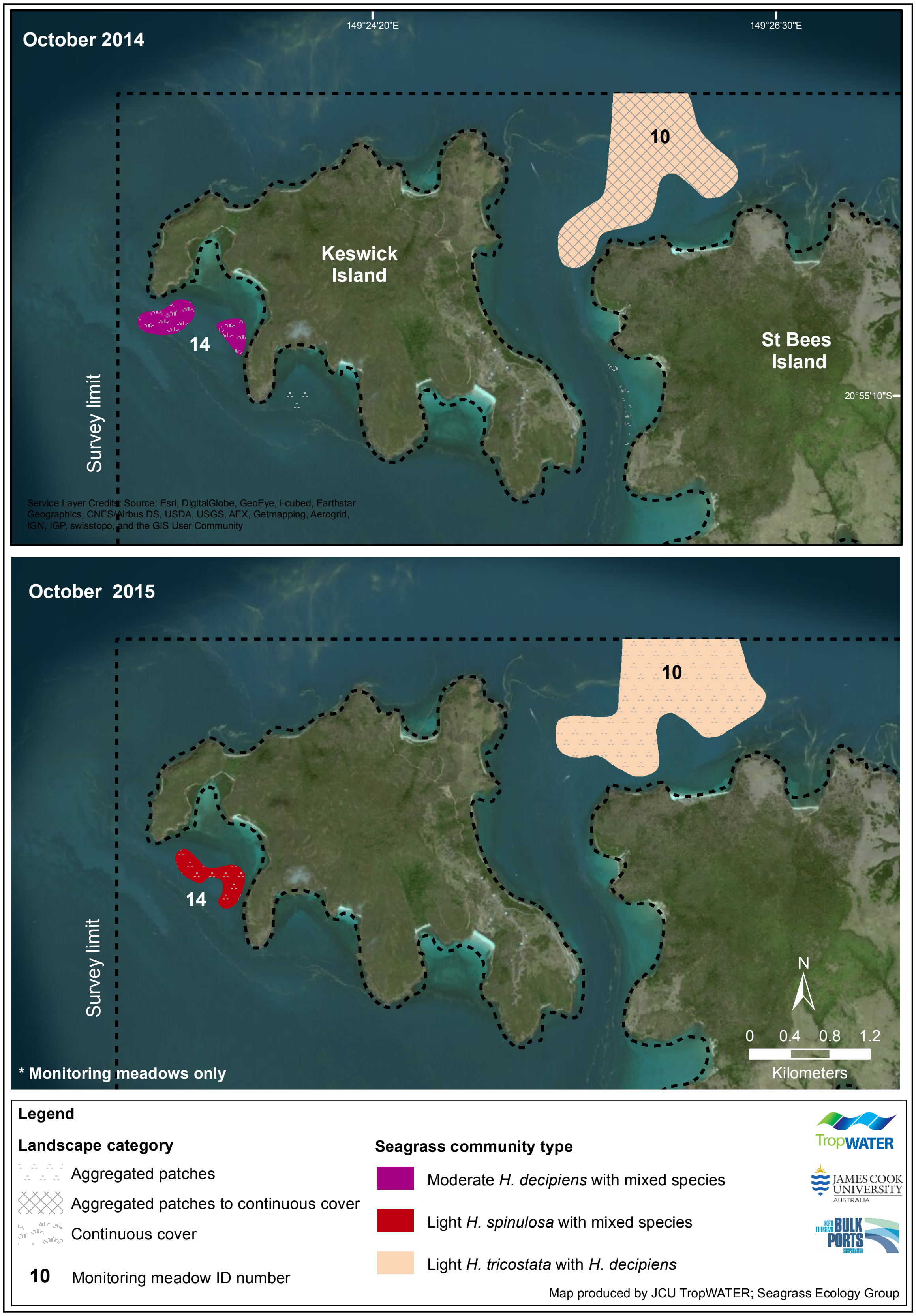


Figure 14. Seagrass community type in the annual monitoring meadows at Keswick and St Bees Islands 2014 – 2015.

3.5 Hay Point Climate Data

Rainfall

Annual rainfall has been below the long term average for the past two years, with 2014/15 recording the lowest annual rainfall (754 mm) in at least the past 11 years (Figure 14a). Rainfall was above the long term average three times in the twelve months preceeding the survey (January, June and October (survey month) 2015) (Figure 14b).

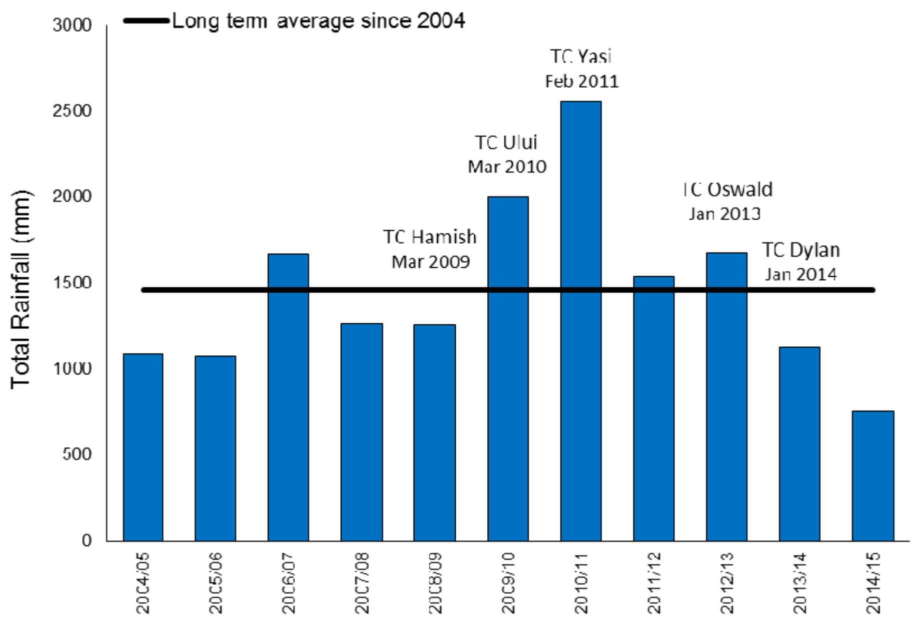


Figure 15a. Total annual rainfall (mm) recorded at Mackay Aero, 2004/05-2014/15. Twelve month year is twelve months prior to the survey. Source: Bureau of Meteorology (BOM), Station number 033045.

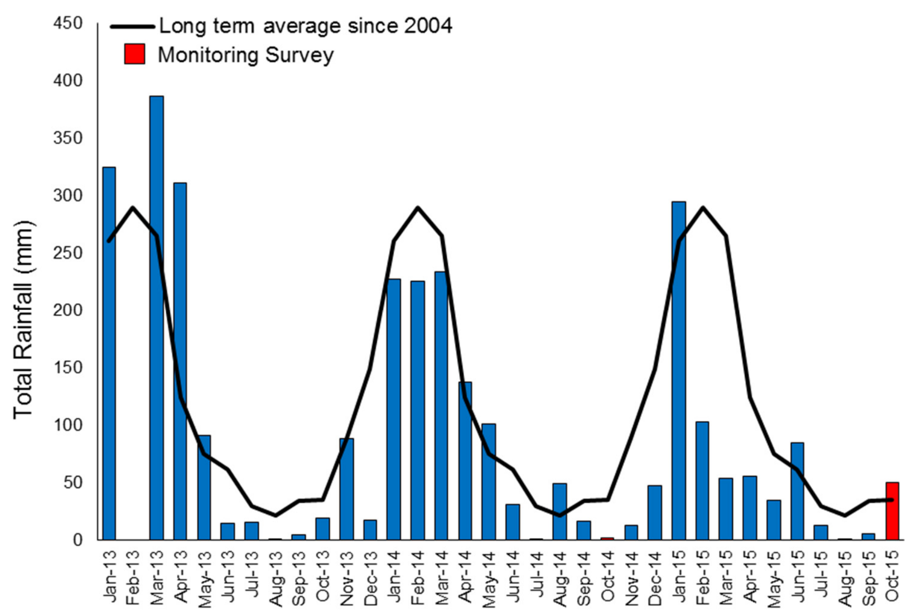


Figure 15b. Total monthly rainfall (mm) recorded at Mackay Aero, January 2013- October 2015. Source: BOM, Station number 033045.

River flow

Annual river flow of the Pioneer River has also been below the long-term average for the past three years, with 2014/15 recording the lowest river flow for the past nine years (Figure 16a). Monthly river discharge was well below the long term average for the twelve months preceding the 2015 survey (October 2015). The largest discharge in this time period was in January 2015: 66, 818 Mega litres (Figure 16b). No peak floods have been recorded since 2010/11.

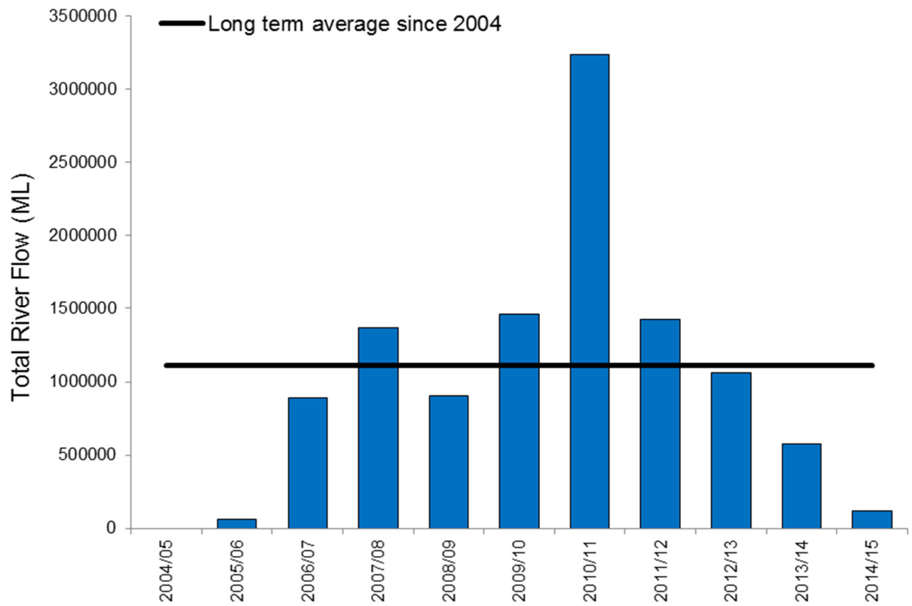


Figure 16a. Annual river flow (Mega litres) for the Pioneer River, 2004/5-2014/5. Twelve month year is twelve months prior to the survey. Source: Queensland Department of Environment and Resource Management, Station number 125016A.

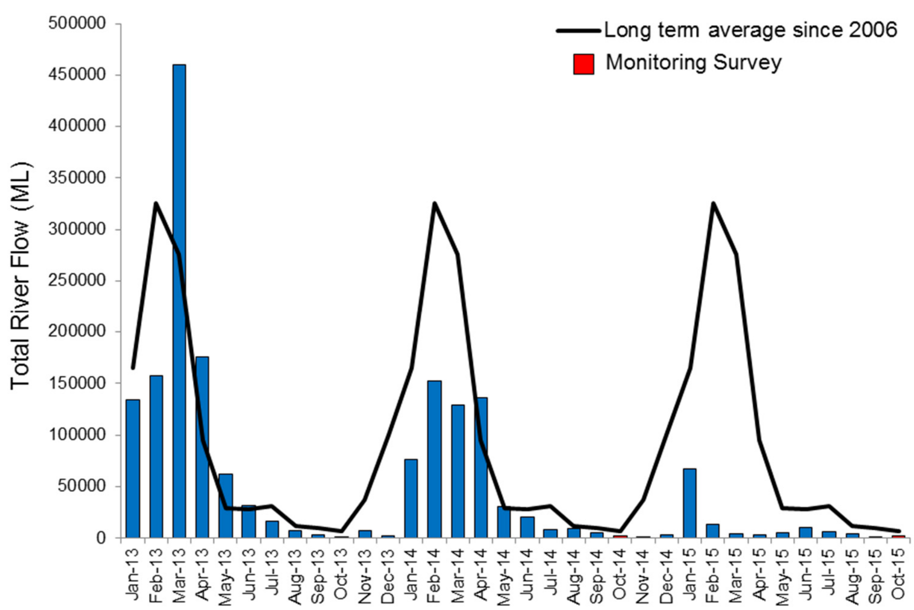


Figure 16b. Monthly river flow (Mega litres) for the Pioneer River January 2013- December 2015. Source: Queensland Department of Environment and Resource Management, Station number 125016A.

Sea Surface Temperature

Sea surface temperature has been collected half hourly at Hay Point since 2008 (QLD Department of Science, Information Technology and Innovation 2015). Mean annual maximum daily sea surface temperature has been above the long term average 24.66 °C for the last two years (Figure 17a). Monthly data shows that sea surface temperatures has been above the long term average by at least two or three degrees for the last two years (Figure 17b). April 2015 for example was 5.4 °C higher than the long term April maximum average.

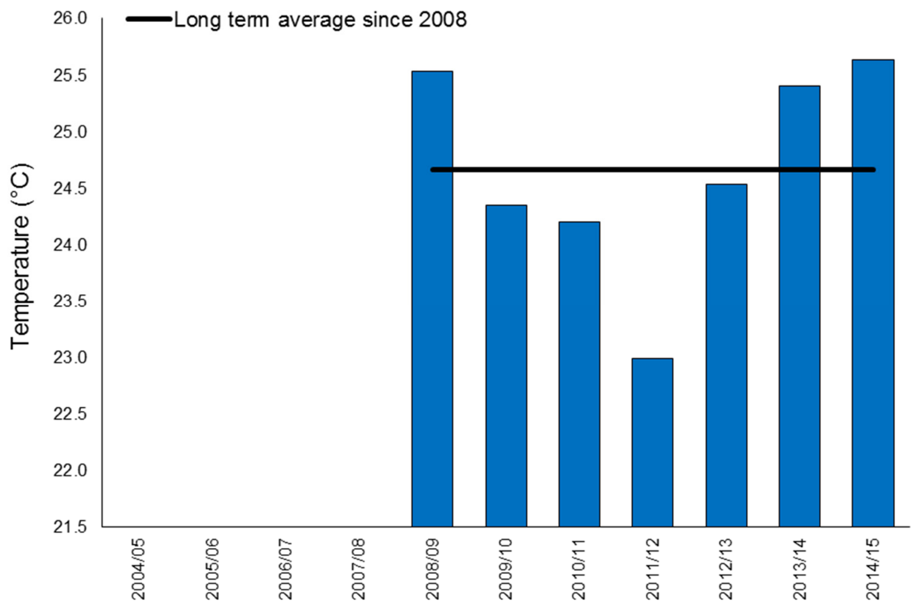


Figure 17a. Mean annual maximum sea surface temperature (°C) recorded at Hay Point 2008/09-2014/15. Twelve month year is twelve month prior to the survey. Source: QLD Department of Science, Information technology and Innovation

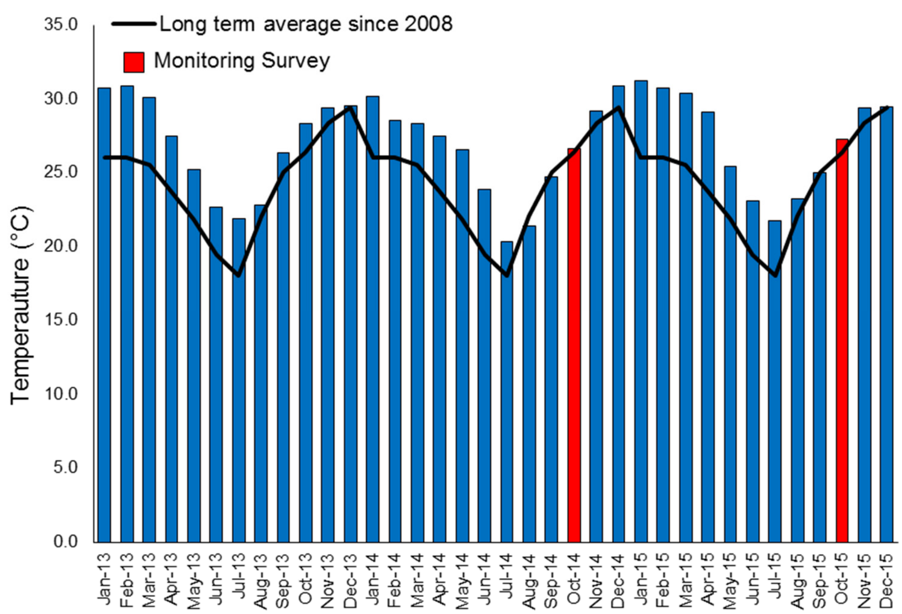


Figure 17b. Monthly maximum sea surface temperature (°C) recorded at Hay Point; January 2013 to December 2015. Source: QLD Department of Science, Information technology and Innovation

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 sun conditions during spring/summer and lowest during winter. Solar exposure in the Hay Point area was above the long term average in 2014/15 with a measure of 20.88 MJ m^{-2} (Figure 18a). Exposure was generally above average each month in the first half of 2015, with levels returning to average for the second half of the year (Figure 18b).

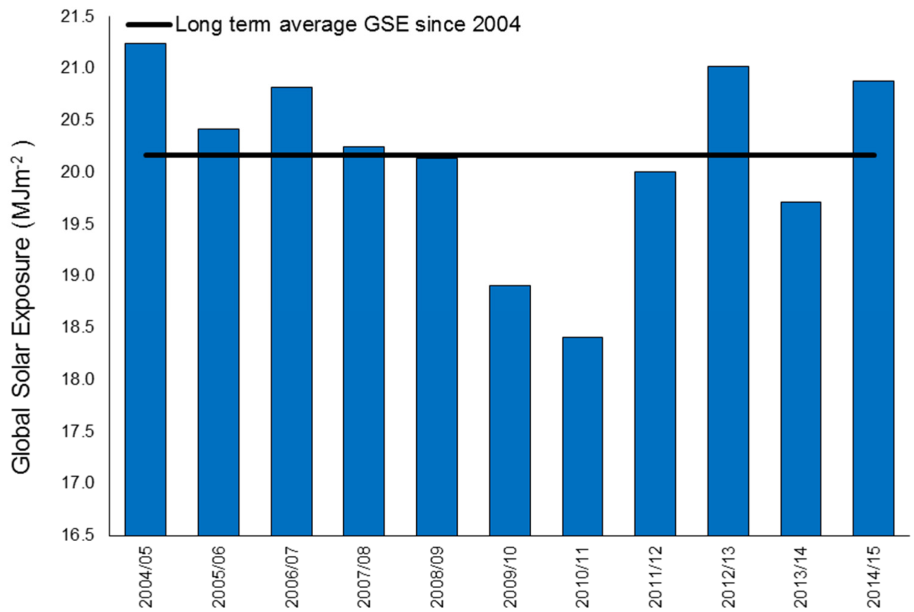


Figure 18a. Mean annual solar radiation (MJm^{-2}) recorded at Hay Point (Station 033317) and Mackay Aero (Station 033045) 2004/05 -2014/15. Twelve month year is twelve months prior to the survey. Source: BOM.

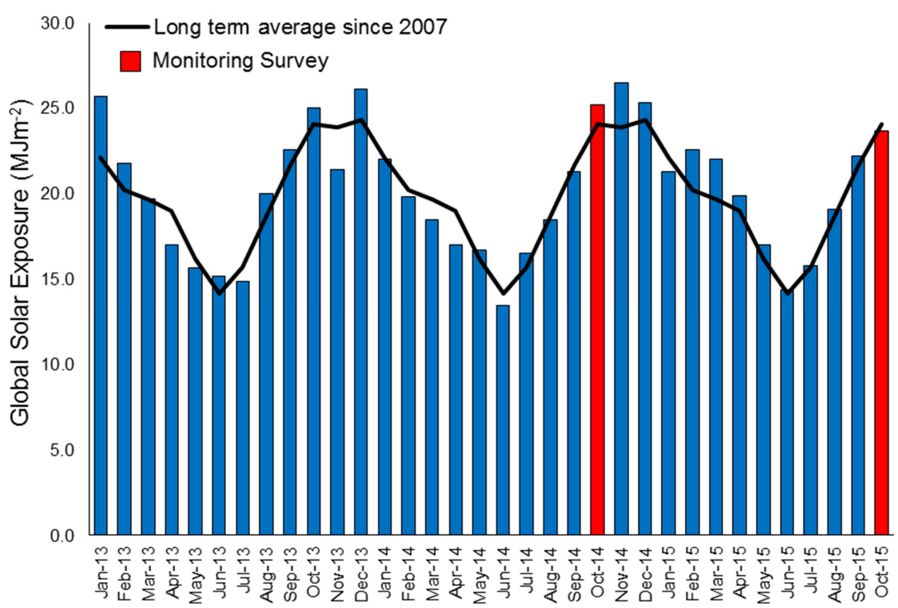


Figure 18b. Mean monthly daily global solar exposure (MJ m^{-2}) recorded at Hay Point (Station 033317) and Mackay Aero (Station 033045) January 2013-October 2015. Source: BOM.

4 DISCUSSION

This report presents the results of the first year of annual seagrass monitoring as part of the re-established Mackay-Hay Point annual seagrass monitoring program. This program now also includes monitoring seagrass habitats at Keswick and St Bees Islands, coastal meadows around Dudgeon Point and at an additional offshore monitoring area near Mackay. The 2015 survey documented an increase in biomass in offshore meadows compared to 2014, with an overall condition index score of 'satisfactory'. The relatively smaller inshore seagrass meadows underwent an increase in total area between 2014 and 2015, but there were some small declines in biomass (density) in some of these meadows.

There have been five (2004, 2005, 2010, 2011, 2014) surveys examining seagrass in the broader Hay Point area. There was a marked decline in seagrass area between 2010 and 2011 most likely a result of the well documented flooding and high rainfall that occurred across Queensland between 2010 and 2011 as a result of TC Yasi (Figures 15a & 16a; Rasheed et al. 2014; BOM 2015). The 2014 survey saw the recovery of much of this lost area of seagrass in the Hay Point region albeit at a lower biomass, and 2015 saw some further recovery of seagrass biomass in offshore meadows. However, offshore seagrass biomass has still not returned to pre-capital dredging (dredging occurred in 2006) densities (see York et al. 2015).

The spatial extent of deep water *Halophila* seagrasses around Hay Point is naturally highly variable with an annual cycle of occurrence, being present only from July to December each year (York et al. 2015). The driver of this natural seasonal cycle of senescence and subsequent recruitment is unclear but likely to be driven by seasonal differences in climate including rainfall, high river flow from proximal catchments, wind patterns, and ensuing chronic turbidity impacting on light availability. In particular, peak rainfall during the wet season (December/January–April) leads to reduced water quality and irradiances, and reduced wind from July to November enhances the deep-water light environment through a reduction in sediment resuspension. Both *H. decipiens* and *H. spinulosa* are considered to be physiologically suited to low light environments; a light requirement threshold of 1.5 mol photons $m^{-2}d^{-1}$ over a seven day rolling average was found to best describe the light condition at which offshore *Halophila* at Abbot Point was able to maintain biomass (McKenna et al. 2015). Chartrand et al. (2014) also found that *H. decipiens* shoot density significantly declined after 2 weeks under low light treatments (1.1 mol photons $m^{-2}d^{-1}$), whereas *H. spinulosa* was not affected until 4 weeks.

For the last two years conditions for offshore seagrass growth have generally been favourable with below average rainfall and river flow, and the prevailing El Nińo climate pattern resulting in drier weather patterns with fewer episodic rainfall events. Benthic light data collected as part of a separate program TropWATER conducts in the Hay Point region indicated that between July and October 2015 light levels only fell below 1.5 mol photons $m^{-2}d^{-1}$ four times, and the longest period was for seven consecutive days. Light was above this threshold for three straight weeks just prior to the survey. These favourable climate conditions have likely facilitated the increase in offshore seagrass density around Hay Point, and also at the deeper edges of the inshore meadows at Keswick/St Bees Islands; for example depth range increased from 18.42m to 20.61m in meadow 10 at St Bees Island.

It is likely however, that *Halophila* in the deep water areas around Hay Point and the Keswick/St Bees Islands are at the limits of light required to support seagrass growth. Their ability for rapid colonisation means they are capable of taking advantage of seasonal or infrequent favourable conditions of light to recruit into deep water areas (Longstaff et al. 1999; Dean and Durako 2007; Ralph et al. 2007) and they have the lowest light requirements of all tropical seagrass species. However this combined with an annual life cycle means they are highly reliant on their seedbank for long term survival and resilience.

The decline in biomass between 2014 and 2015 of the Keswick/St Bees Island meadows may be linked to a flowering and fruiting event that occurred prior to the survey. A separate research program investigating deep water seagrasses conducted by TropWATER found that seagrass in Meadow 14 was covered in flowers and fruits, with the plants appearing in a deteriorated state in October 2015. Often during reproduction plants will divert most of their energy into producing fruits and flowers, sacrificing leaf/shoot condition, thus losing biomass (Davies and Gan 2011; Chartrand et al. 2014a). Only minimal amounts of fruits were noted at the experimental site in the previous year (November 2014). At this stage it is unclear if this is a regular cycle for this meadow as 2015 was only the second year of sampling.

Only two seagrass species were found in the coastal areas of Dudgeon Point/Hay Point (*H. uninervis* and *H. decipiens*). The species shift at the Dudgeon Point inshore Site 1 meadow from *Z. muelleri/H. ovalis* to an earlier coloniser; *H. decipiens*, indicated that there has been a decline in meadow condition. While climate conditions have been favourable for deep water seagrasses during 2015, environmental conditions for shallow inshore seagrass meadows, such as those at Site 1 are likely to have created stress associated with high temperatures and exposure. Sea surface and air temperatures, and daily global exposure were all above the long-term averages in 2015. These conditions can create high levels of stress for intertidal/inshore seagrasses and may lead to declines through extreme temperatures (both in the air and water), high light intensity, and desiccation or heat stress caused by exposure to air (Collier and Waycott 2009; Unsworth et al. 2012). However the same conditions can be beneficial to sub-tidal seagrasses that are protected from exposure related stresses while benefiting from improved light conditions. Site 1 at Dudgeon Point in particular would be most susceptible to these conditions as the site exposes to air during spring low tides. Similar trends have been seen across North Queensland in 2015, where declines in biomass of intertidal/inshore seagrass have been recorded at numerous monitoring locations including Weipa, Gladstone and Townsville (McKenna et al. 2016; Davies et al. 2016a & b).

The Hay Point and Keswick Island seagrass meadows may provide a seasonally important food source for dugong. The species found in the survey occurred well within the depth range suitable for dugong feeding (Lanyon 1991; Preen 1995; Gredzens et al. 2014). The Mackay-Hay Point region is not known to contain a large resident dugong population but dugong are likely to pass through the area as several declared Dugong Protection Areas (DPA) are located in the region, with the Newry and Sand Bay DPA's to the north and the Ince and Llewellyn DPA's to the south of Hay Point (Coles et al. 2002). The value of these types of low biomass and low cover seagrass meadows for services such as fish habitat and nursery grounds, and their ability to store and sequester carbon, is likely to be lower than for denser coastal seagrass meadows on a per hectare basis (Chartrand et al. 2008). However, their large area and rapid turnover and growth rates of the species mean that they potentially play an important regional role in marine primary productivity, diversity and ecosystem services (Rasheed et al. 2014).

The Mackay-Hay Point long-term monitoring program has been incorporated into the broader Queensland Ports seagrass monitoring program using the consistent state-wide monitoring methodology. This enables direct comparisons with regional and state-wide trends to put local changes into a regional context. 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.

In summary, results of the 2015 seagrass monitoring found:

1. The overall condition of offshore seagrass in the Hay Point area was classed as satisfactory; biomass increased from very poor to satisfactory between 2014 and 2015 and species composition remained good.
2. Deep water seagrass biomass in the Hay Point area was the highest it has been since 2012, but has still not returned to the baseline levels recorded in 2004.
3. A deep water *H. spinulosa/H. decipiens* meadow off the Mackay Marina was identified and is now part of the annual long-term monitoring program.
4. Inshore seagrasses formed three small meadows in the Dudgeon Point to Hay Point monitoring area and increased in total area between 2014 and 2015. The Keswick and St Bees Island inshore meadows also increased in area.
5. Favourable climate conditions for deep water seagrasses are likely to have facilitated the increases in biomass and distribution of deep water seagrass meadows.

6. Shallow inshore seagrasses were exposed to higher levels of temperature and exposure stresses in 2015 which likely contributed to declines in biomass at the smaller Dudgeon Point meadows.
7. Declines in biomass in the Keswick and St Bees meadows were likely due to plant deterioration from a recent flowering and fruiting event diverting effort into sexual reproduction rather than shoot growth and maintenance.
8. It is likely that *Halophila* in the deep water areas around Hay Point and the Keswick Island group are at the limits of light required to support seagrass growth.

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6 APPENDICES

Appendix 1.

An example of calculating a meadow score for biomass in satisfactory condition.

1. Determine the grade for the 2015 (current) biomass value (i.e. satisfactory).

2. Calculate the difference in biomass (B_{diff}) between the 2015 biomass value (B_{2015}) and the area value of the lower threshold boundary for the satisfactory grade ($B_{satisfactory}$):

$$B_{diff} = B_{2015} - B_{satisfactory}$$

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:

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

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_{2015} takes up:

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

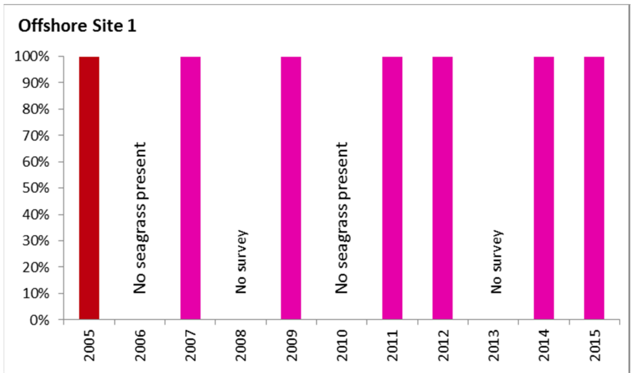
5. Determine the biomass score for 2015 ($Score_{2015}$) by scaling B_{prop} against the score range (SR) for the satisfactory grade ($SR_{satisfactory}$), i.e. 0.15 units:

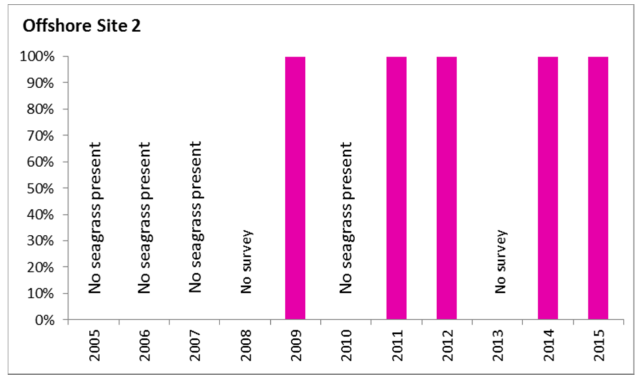
$$Score_{2015} = LB_{satisfactory} + \left(B_{prop} \times SR_{satisfactory}\right)$$

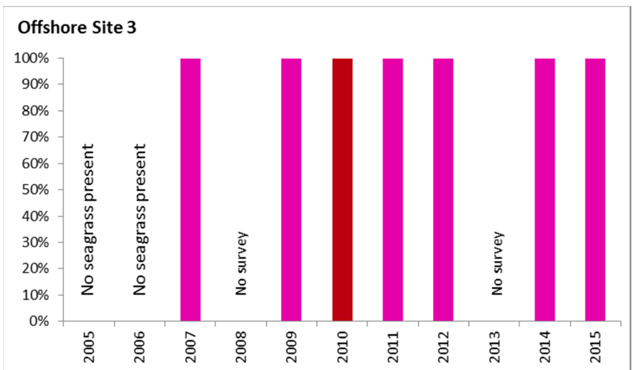
Where $LB_{satisfactory}$ is the defined lower bound (LB) score threshold for the satisfactory grade, i.e. 0.50 units.

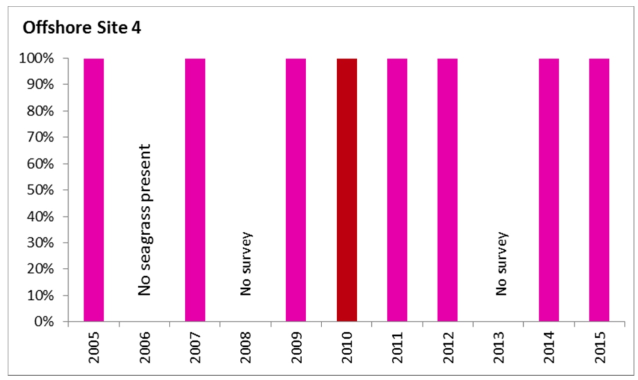
Appendix 2.

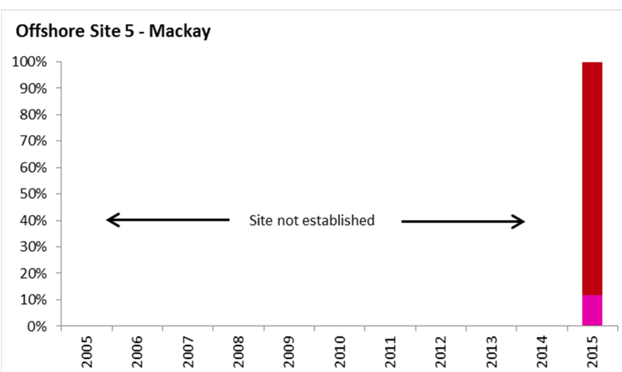
Species composition of monitoring meadows in the Hay Point/Mackay region, and the Keswick Island group.

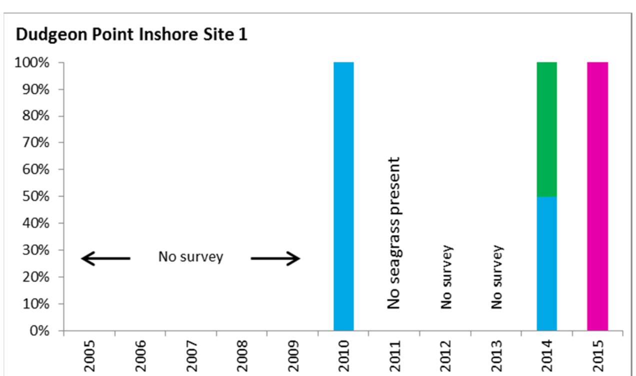


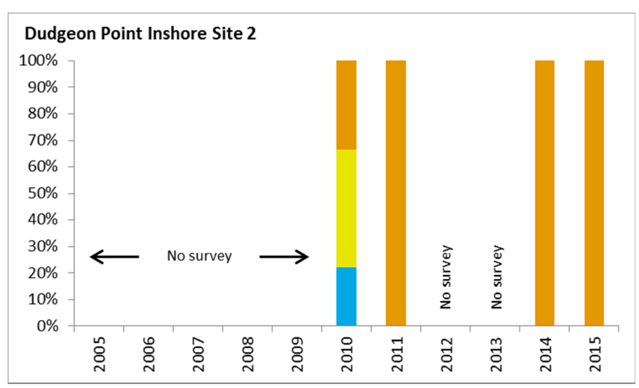


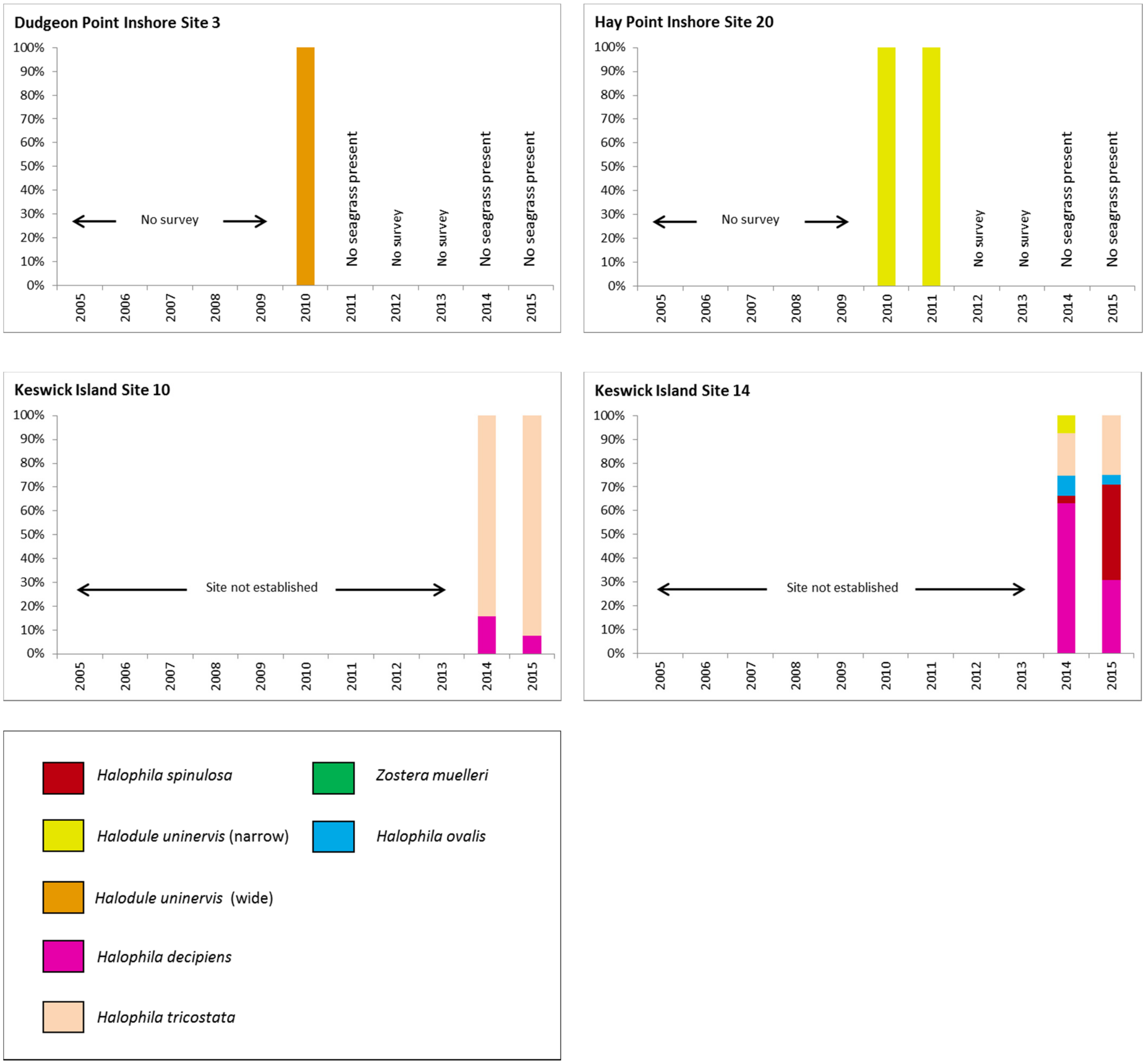











Dudgeon Point Inshore Site 3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
No survey
No seagrass present
No survey
No survey
No seagrass present
No seagrass present
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Hay Point Inshore Site 20
No survey
No survey
No survey
No seagrass present
No seagrass present
Keswick Island Site 10
Site not established
Keswick Island Site 14
Site not established
Halophila spinulosa
Zostera muelleri
Halodule uninervis (narrow)
Halophila ovalis
Halodule uninervis (wide)
Halophila decipiens
Halophila tricostata