HAY POINT SEAGRASS AND BENTHIC HABITAT SURVEY – 2014

McKenna SA and Rasheed MA

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A report for BHP Billiton Mitsubishi Alliance (BMA)

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SUMMARY

This report presents the results of a survey of seagrass, algae and habitat forming benthic macro-invertebrates in the Hay Point area conducted in October/November 2014. The survey provides an updated baseline (last assessed in 2010) on habitat forming benthic communities including seagrass in the vicinity of the port of Hay Point.

- There have been four previous mapping surveys conducted of the Hay Point seagrass habitat (2004, 2005, 2010 & 2011). Overall the locations and species composition of coastal and offshore seagrass meadows in the Hay Point area have been similar between surveys. The 2014 and 2004 surveys had the largest extent of seagrass.

- In 2014 seagrass distribution was the largest recorded since the initial baseline assessments conducted in 2004. Seagrass was present at 24% of survey sites and was found to a depth of 19.9m (depth below mean sea level (dbMSL)).

- Five species of seagrass were recorded in the Hay Point area. The 2014 survey was the first recorded occurrence of *Zostera muelleri* in the coastal meadows around Dudgeon Point, and *Halophila ovalis* in the offshore meadows around Hay Point. *Halophila decipiens* dominated the offshore meadows.

- The benthic macro-invertebrate and algal communities within the survey area were typical of communities found in offshore and nearshore subtidal areas elsewhere in Queensland and similar to previous assessments at the site.

- The dominant habitat feature within the survey area was open substrate with a low to medium density of benthic community life. There were no benthic macro-invertebrate communities that were classified as 'high density', however there were macro-algae communities classified as 'high density' in offshore and nearshore areas of Hay Point.

- Medium and high density algae communities coincided with regions of medium density benthic macro-invertebrate communities, and tended to be concentrated around habitat-forming 'live' and dead rock/rubble and reef. This association led to the observed pattern of higher biodiversity patches within the survey area.

- There have been two previous surveys of benthic macro-invertebrates and macro-algae in the Hay Point area; 2004 and 2010. Moderate density benthic macro-invertebrate communities occurred across a greater area in 2004 and 2014 compared to 2010.

- The density and distribution of macro-algae across surveys changed considerably. The distribution of macro-algae was highest in 2004 and lowest in 2010. The only functional group identified in 2010 was erect macrophytic algae. While 2014 was the only survey to record 'high density' areas of algae these areas were dominated by filamentous algae rather than the more structurally complex macro-algae groups.

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1 INTRODUCTION

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) leased from the State Government by DBCT Management Pty Ltd and the Hay Point Coal Terminal (HPCT) owned by BHP Billiton Mitsubishi Alliance (BMA). BMA's HPX3 expansion at the port has increased the Port's capacity from 44 million tonnes per annum (mtpa) to 55 mtpa (BMA 2015). The HPX3 project involved the addition of a new berth and shiploader, and replacing the existing jetty, trestle conveyors and surge bins (BMA 2015).

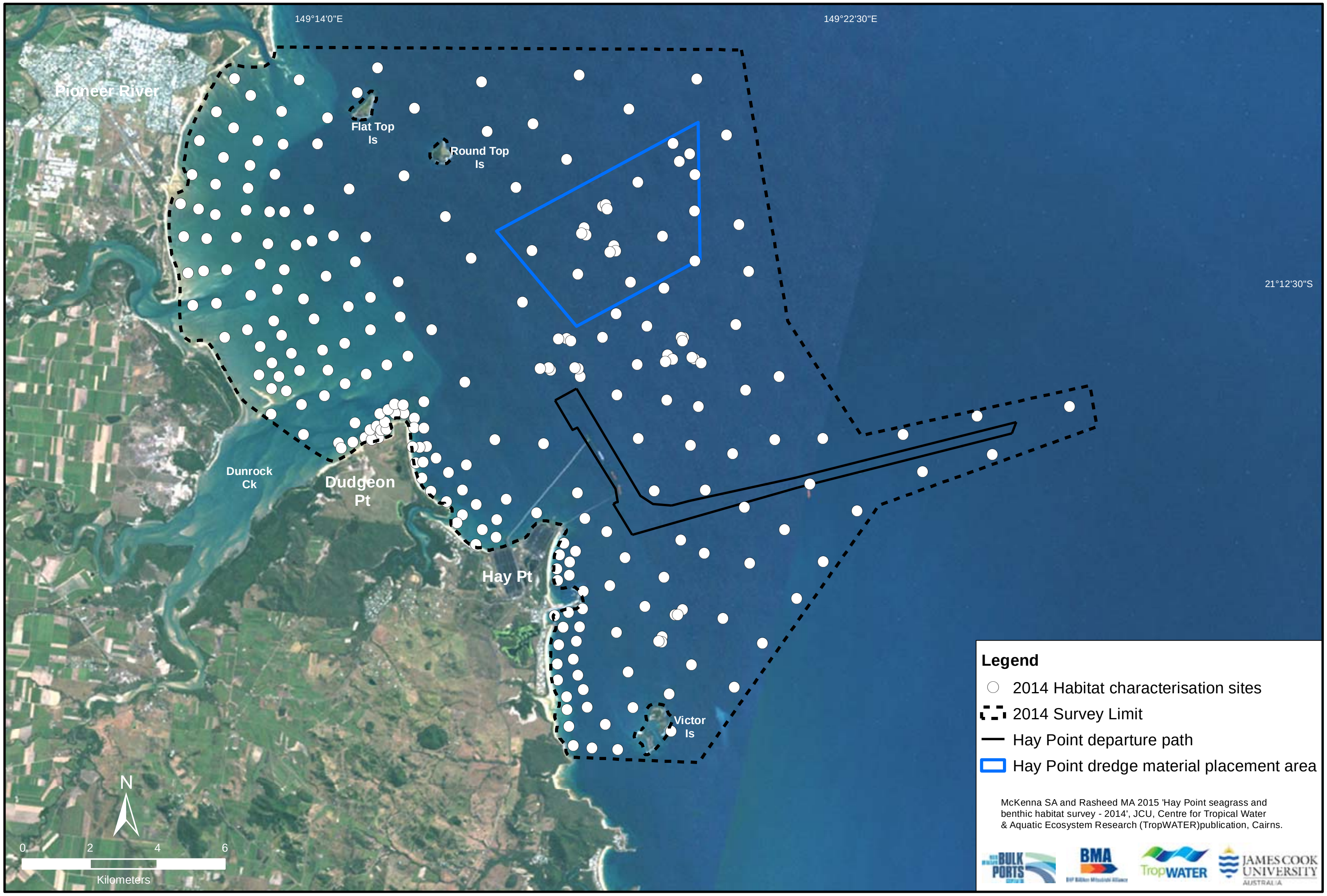
BHP Billiton Mitsubishi Alliance and NQBP recognise the importance of existing benthic habitats in the Port of Hay Point and surrounding areas, including seagrasses, benthic macro-invertebrates and macro-algae. BMA and NQBP have supported numerous programs that have been involved in researching and monitoring these habitats to gain a better understanding of these communities in preparation for planned port maintenance works and any future developments. To keep this benthic habitat information current, in partnership with the James Cook University - Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Seagrass Ecology Group, NQBP commissioned studies to update information on the benthic habitats; seagrass, benthic macro-invertebrates and macro-algae, within and surrounding the Port of Hay Point (Map 1).

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 also 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). The TropWATER 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 2008 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). Two additional surveys re-mapping all of the seagrasses in the Hay Point region were conducted in October 2010 and 2011 which also identified some small coastal meadows near Dudgeon Point and a much reduced area of deep water seagrasses (Thomas and Rasheed 2011; Thomas et al. 2012).

The objective of these studies was to:

- Provide an update on the distribution and density of seagrasses within and surrounding the Port of Hay Point;
- Provide an update on the distribution and density of benthic macro-invertebrates and macro-algae within and surrounding the Port of Hay Point;
- Build on historical data sets to provide insight into temporal changes in area and biomass.

Map 1. Location of Hay Point benthic habitat sites October/November 2014



2 METHODOLOGY

2.1 Survey Approach

The survey approach of these studies was focused on the need to update information on the benthic habitats within and surrounding the Port of Hay Point and re-establish an annual long-term seagrass monitoring program. Annual surveys would be conducted between September and December to capture seagrasses at their likely seasonal peak in distribution and abundance and would also facilitate comparison with the previous surveys conducted in the area in 2004, 2010 and 2011.

Seagrass, algae and benthic macro-invertebrate communities within the area outlined in Map 1 were surveyed between October and November 2014. Offshore survey sites were scattered throughout the survey area with a sampling intensity approximately 1-2.5km apart, while coastal/nearshore survey sites ranged between 50m and 700m apart. The survey methods implemented 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 such as those used by the team previously in Hay Point (Thomas and Rasheed 2011; Thomas et al. 2012) and in other Queensland locations, including Gladstone, Cairns, Mackay, Abbot Point and Townsville (see Rasheed et al. 2001; Rasheed and Taylor 2008; McKenna et al. 2013; McKenna and Rasheed 2014). 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 communities as well as logistical issues associated with naturally high water turbidity and the presence of dangerous marine animals including saltwater crocodiles. These standardised methodologies 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 and benthic macro-invertebrates. 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 reef/rocky areas >8m below MSL: Boat based underwater CCTV drop camera;
3. Offshore subtidal areas >8m below MSL: Boat based CCTV camera sled tows.

2.2.1 Boat based underwater CCTV drop camera and free diving

Assessments of shallow subtidal areas were conducted from a small research vessel. An underwater CCTV camera system with real-time monitor was mounted to a 0.25m^2 quadrat which provided live images allowing researchers to record presence, density and composition of seagrass, algae, benthic macro-invertebrates and sediment type from three random placements of the quadrat (Figure 1). Where free diving was suitable divers swam to the seafloor with a 0.25 m^2 quadrat and gathered the same information as above.

Figure 1 Shallow subtidal mapping of seagrass meadows using CCTV system, Van Veen sediment grab and free divers.

2.2.2 Boat based CCTV camera sled tows

Offshore benthic habitat sites around Hay Point were surveyed from a research vessel with stern winching capability. At each sampling site the real-time underwater camera system was towed for approximately 100m at drift speed (approx. one knot). Footage was observed on a TV monitor and recorded. The CCTV camera was mounted on a sled that incorporates a sled net 1.5m long, 600mm wide and 250mm deep, with a net of 10mm mesh aperture (Figure 2). Surface benthos was captured in the net (semi-quantitative bottom sample) and used to confirm benthic habitat characteristics observed on the monitor. Benthic macro-invertebrates collected in the sled net were identified into taxa groups and counts were made of individuals.

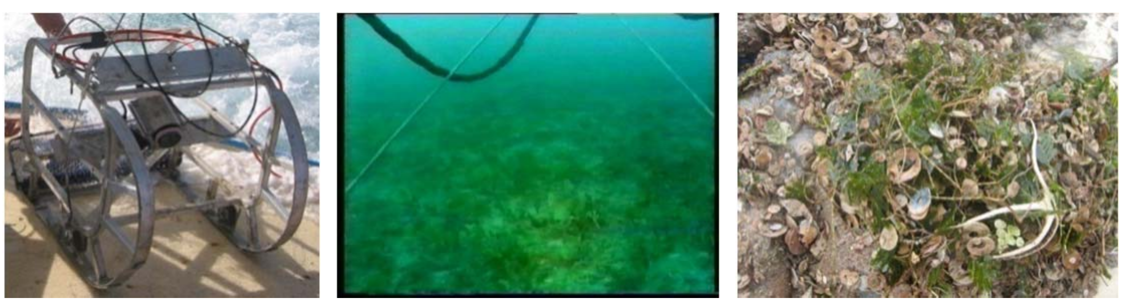


Figure 2 Deep water sled tows using CCTV system and sled net.

At sites where the camera system was used a Van Veen grab (grab area $0.0625m^2$) was used in conjunction with the camera system to confirm species viewed on the video screen and sediment type (identified as shell grit, rock, gravel (>2000µm), coarse sand (>500µm), sand (>250µm), fine sand (>63µm) and mud (<63µm)).

2.3 Habitat Characterisation

2.3.1 Seagrass

At sites where seagrass presence was noted in the field, seagrass species composition and seagrass above-ground biomass was determined. Above-ground seagrass biomass was estimated using a "visual estimates of biomass" technique (Kirkman 1978; Mellors 1991). At drop camera and free diving sites this technique involved an observer ranking seagrass biomass within three randomly placed 0.25m^2 quadrats at each site. At CCTV 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 recorded an estimated rank of 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.

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 was harvested and the actual biomass 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.

Two GIS layers were created in ArcGIS to describe the seagrasses around the Hay Point area:

- **Survey sites** - GPS sites containing all seagrass data collected at habitat characterisation sites.

- **Seagrass meadow biomass and community types** - Area data for seagrass meadows and information on community characteristics. Community types were determined according to overall species composition. A standard nomenclature system was used to name each of the meadows in the survey area. This system was based on the percent composition of biomass contributed by each species within the meadow (Table 1). 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).

Table 1 Nomenclature for seagrass community types in the Hay Point area

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 the Hay Point area

Density	Mean above-ground biomass (g DW m^{-2})				
	H. uninervis (narrow)	*H. ovalis* *H. decipiens*	*H. uninervis* (wide)	*H. spinulosa*	*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

2.3.2 Benthic macro-invertebrates

Benthic macro-invertebrates identified while free diving, collected in the sled net and visible on the monitor were identified into broad taxonomic groups. Where the sled net was used at habitat sites, counts were made of the number of taxa and individuals found in the sled net. For each site a benthic macro-invertebrate community density category was determined. Four community density categories were used and are similar to that previously used for Hay Point (Thomas & Rasheed 2011):

- ***Open substrate*** - dominant feature was bare substrate with occasional isolated benthic macro-invertebrate individuals covering <1% of the substratum (free diving and camera drop sites) or present for <1% of the video record at each site (sled tow sites).
- ***Low density*** - benthic macro-invertebrates covering 1-10% of the substratum (free diving and camera drop sites) or present for 1-10% of the video record at each site (sled tow sites).
- ***Moderate density*** - benthic macro-invertebrates covering 10-80% of the substratum (free diving and camera drop sites) or present for 10-80% of the video record at each site (sled tow sites).
- ***High density*** - benthic macro-invertebrates covering >80% of the substratum (free diving and camera drop sites) or present for >80% of the video record at each site (sled tow sites).

Two GIS layers were created in ArcGIS to describe the benthic macro-invertebrate communities around the Hay Point area:

- **Survey sites -** GPS sites containing all benthic macro-invertebrate community data collected at benthic survey sites.
- **Benthic community type and density category -** area data for benthic macro-invertebrate community regions. Community types within this layer were determined according to overall taxa composition within each region. Density was determined by the mean percent benthic macro-invertebrates covered the substratum or were present in the video record for sites within regions.

2.3.3 Benthic macro-algae

At all sites where macro-algae were present, they were identified into the following five functional groups:

- ***Erect macrophytes -*** Macrophytic algae with an erect growth form and high level of cellular differentiation e.g. *Sargassum*, *Caulerpa* and *Galaxaura* species.
- ***Erect calcareous -*** Algae with erect growth form and high level of cellular differentiation containing calcified segments e.g. *Halimeda* species.
- ***Filamentous -*** Thin thread-like algae with little cellular differentiation.
- ***Encrusting -*** Algae growing in sheet like form attached to substrate or benthos e.g. coralline algae.
- ***Turf Mat -*** Algae that forms a dense mat or "turf" on the substrate.

For each site a macro-algae density category was determined. Density categories were defined by the overall percent cover of algae for each site. The relative proportion of the total cover made up of each of the algal functional groups for each site defined the community type. Four community density categories were used:

- ***Open substrate*** - dominant feature was bare substrate with no algae present.
- ***Low density -*** algae covered 1-10% of the substratum (free diving and camera drop sites) or present for 1-10% of the video record at each site (sled tow sites).
- ***Medium density -*** algae covered between 10-80% of the substratum (free diving and camera drop sites) or present for 10-80% of the video record at each site (sled tow sites).
- ***High density -*** algae covered >80% of the substratum (free diving and camera drop sites) or present for >80% of the video record at each site (sled tow sites).

Two GIS layers were created in ArcGIS to describe the macro-algae communities around the Hay Point area:

- **Survey sites** - GPS sites containing all algae data collected at benthic survey sites.
- **Macro Algae community types and density category** - area data for benthic macro-algae community regions. Community types within this layer were determined according to overall taxa composition within each region. Density was determined by the mean percent benthic macro-algae covered the substratum or were present in the video record for sites within regions.

2.4 Habitat Boundary Mapping and Geographic Information System

All survey data was entered into a Geographic Information System (GIS) for presentation of benthic habitat community distribution and abundance. Maps were generated in ArcGIS utilising recent aerial and satellite imagery. Other information including depth below MSL, substrate type and the shape of existing geographical features such as banks and channels were used to assist in mapping.

The boundary of seagrass meadows, macro-invertebrate regions and macro-algae regions were mapped by free diving and underwater camera techniques and then assigned a mapping precision estimate (±ha) (Table 3). The precision of the boundary as mapped was determined using an estimate of mapping reliability (R) based on the distance between sampling sites (McKenzie et al. 2001). This resulted in a range of meadow and region sizes which is expressed as error (±ha) around the total meadow/region area (ha) (McKenna et al. in press). Additional sources of mapping error associated with digitising aerial photographs onto base maps and with GPS fixes for survey sites were embedded within the meadow reliability estimates.

Table 3 Mapping precision and methodology for boundary mapping in the Hay Point area

Mapping precision	**Mapping methodology**
10-50m	Subtidal meadow boundaries determined from free diving surveys; Relatively high density of survey sites; Recent aerial photography aided in mapping.
50-200m	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.
200-500m	Larger subtidal meadows with boundaries determined from underwater CCTV and sled tows; All meadows subtidal; Relatively low density of survey sites.

3 RESULTS

A total of 264 sites were surveyed around the Hay Point area (Map 1). The dominant habitat feature was open substrate with a low to moderate density of benthic habitats and benthic communities. Three areas of macro-algae were classified as having a 'high' density of algae present. These areas were dominated by filamentous algae.

3.1 Seagrass in the Hay Point area

Seagrass was present at 24% of survey sites and covered approximately 8,937.7 ± 5,433.6 ha (Map 2; Table 4). Two distinct types of seagrass habitat (coastal and offshore) were identified within the Hay Point survey area with five seagrass species observed: *Zostera muelleri, Halodule uninervis, Halophila decipiens, Halophila ovalis* and *Halophila spinulosa* (Figure 3). This was the first record of *Halophila ovalis* occurring in the deep water meadows and *Zostera muelleri* occurring in the coastal meadows in the Hay Point area. In addition 2014 was the first time *Halophila spinulosa* had been recorded since capital dredging of the Port of Hay Point departure path in 2006. The *Halophila* species found were typical of deep water habitats in Queensland and in the Hay Point region, while *Halodule uninervis* and *Zostera muelleri* are typical coastal/shallow water species. Seagrass within the mapped area consisted of aggregated to isolated patches of seagrass with above-ground biomass of seagrass at sites ranging between 0.0003 and 5.29 gDWm^{-2} (Map 2).

Seagrass meadows in the offshore areas were dominated by low biomass *Halophila decipiens* with *Halophila ovalis* and *Halophila spinulosa* only occurring at one site to the north east of Round Top Island. Seagrass was found in the existing spoil ground, the departure channel and near to the existing wharf infrastructure. The maximum depth that seagrass was recorded was 19.9m below MSL.

Seagrass meadows in the coastal areas were confined to the Dudgeon Point area and were characterised as three individual meadows ranging in size from 4.3 ha to 41.5 ha. On the northern side of Dunrock Creek a moderate cover of *Halodule uninervis* (narrow) was present. At Dudgeon Point two small seagrass meadows were identified and characterised as a light *Z. muelleri/H. ovalis* meadow (Meadow 1) and a light *H. uninervis* (wide) meadow (Meadow 2).

Table 4 Seagrass community types, mean above-ground biomass and meadow area in the Hay Point survey area, October/November 2014

Meadow ID	Meadow location	Community type	Mean meadow biomass (gDWm^{-2} ± SE)	Area ± R (ha)	No. of sites
1	Coastal	Light *Zostera muelleri/Halophila ovalis*	1.18 ± 0	4.3 ± 1.8	2
2	Coastal	Light *Halodule uninervis* (wide)	2.74 ± 0	4.7 ± 1.8	2
9	Coastal	Moderate *Halodule uninervis* (narrow)	2.7 ± 0.4	41.5 ± 28	2
3	Offshore	Light *Halophila decipiens*	0.003 ± 0.001	8887.2 ± 5402	57
Total				**8937.7 ± 5433.6**	**63**

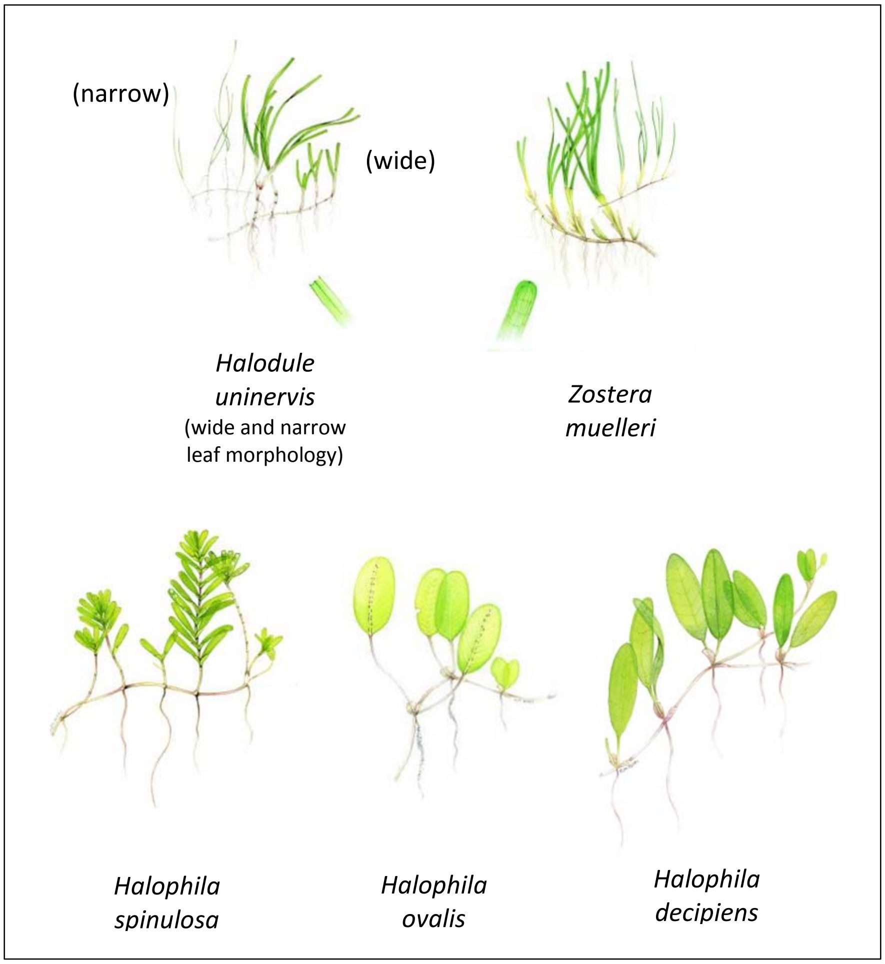
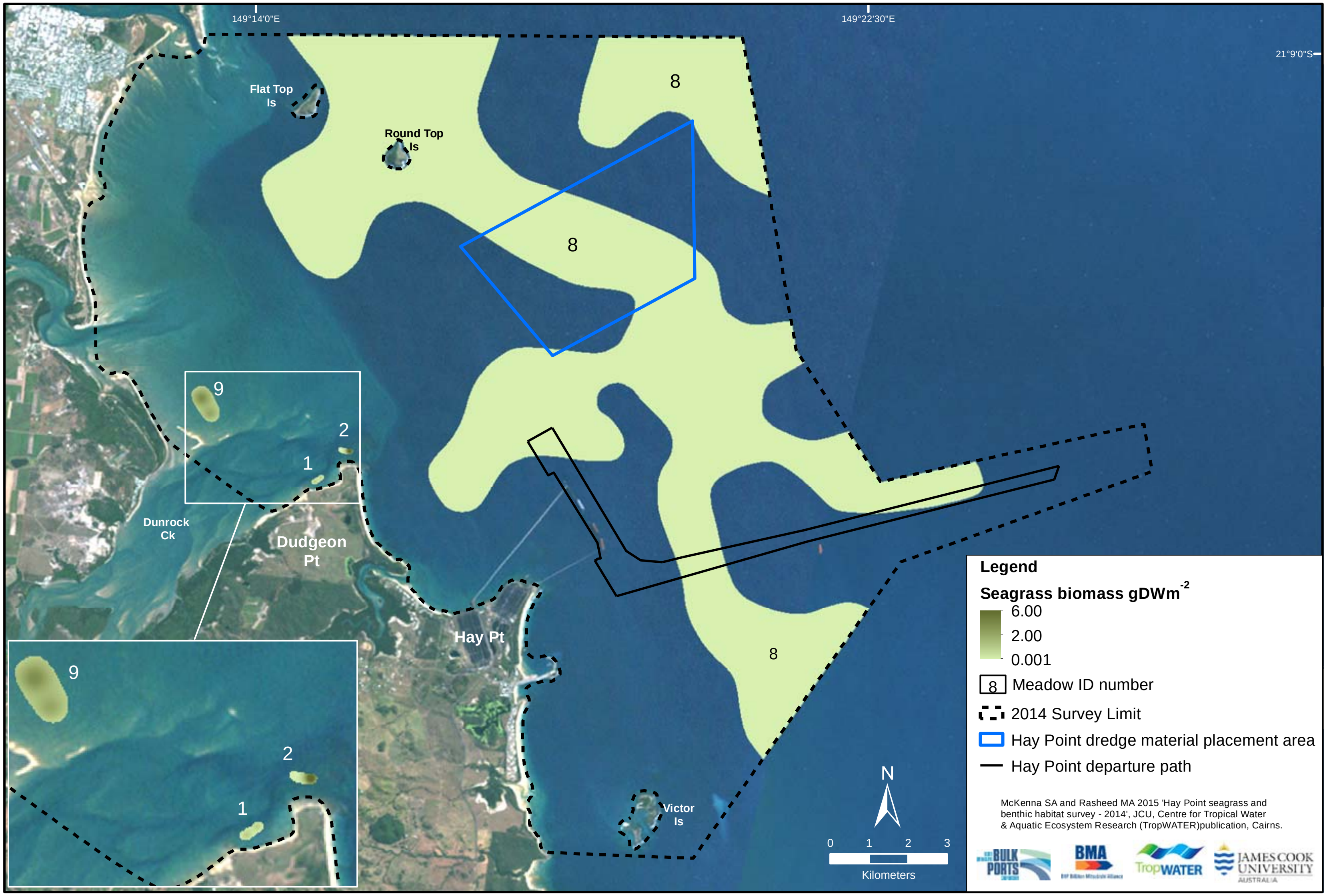


Figure 3 Seagrass species identified in the Hay Point survey area 2014

Map 2. Location, density and distribution of seagrass in the Hay Point area October/November 2014



3.2 Comparison with previous seagrass surveys in the Hay Point area

There have been four (2004, 2005, 2010, 2011) previous surveys examining seagrass in the broader Hay Point area (Table 5; Map 3). The 2004 and 2005 surveys only focused on offshore seagrass while the 2010, 2011 and 2014 surveys also encompassed coastal seagrass around the Dudgeon Point/Hay Point area (Map 3). The 2014 survey incorporated a larger offshore area than all other surveys extending south to Victor Island and north to the Pioneer River.

In general the locations and species composition of coastal and offshore seagrass meadows were similar between surveys (Table 5; Map 3). *Halophila decipiens* has been the dominant species at offshore meadows, and *Halodule uninervis* and *Halophila ovalis* has dominated the small coastal meadows (Table 5). Of note was the presence of *Halophila ovalis* in the offshore meadow and *Zostera muelleri* in the coastal meadows for the first time in the 2014 survey (Table 5; Map 3).

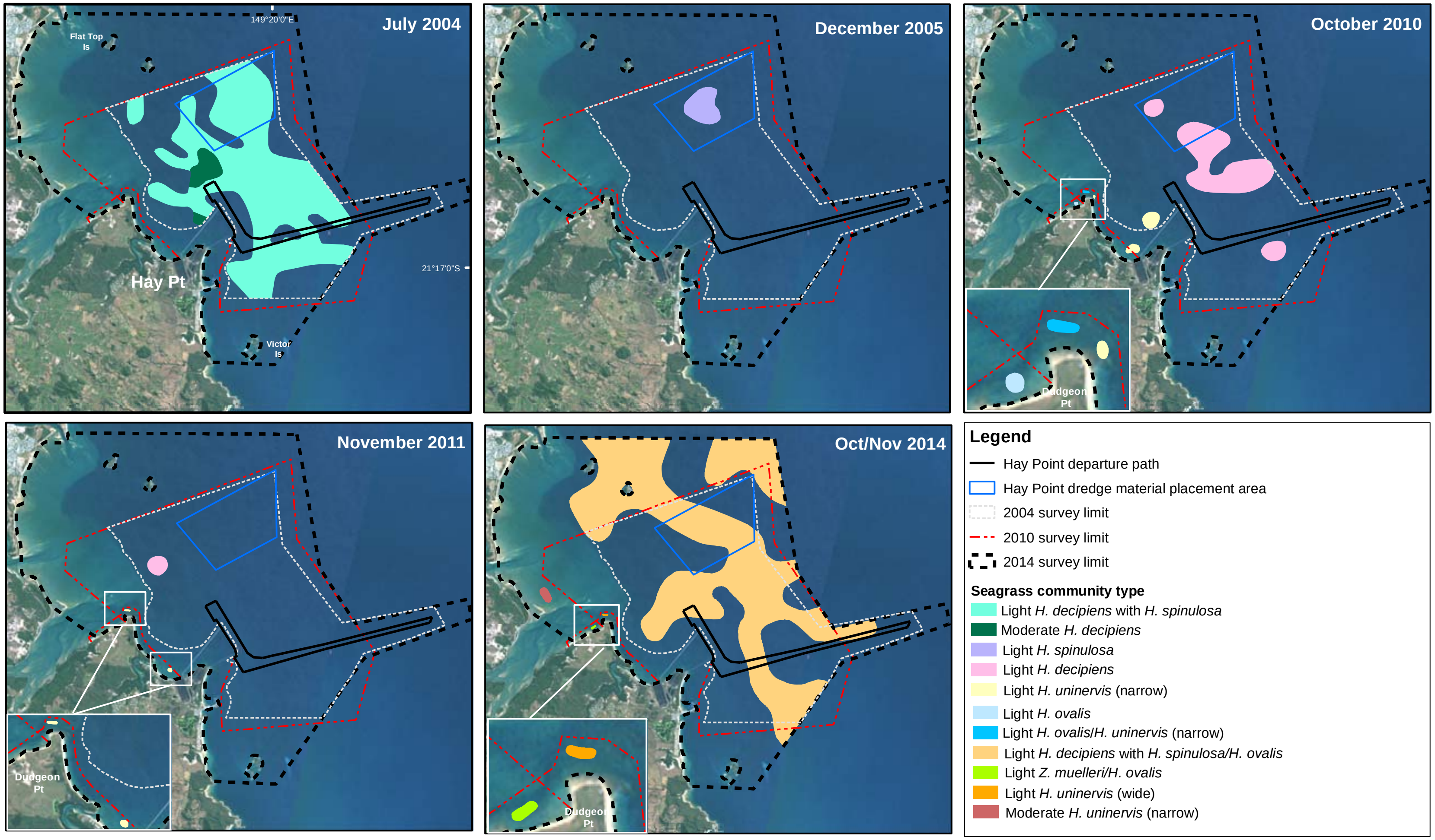
The biomass of the offshore meadows ranged from a low of 0.003 ± 0.001 gDWm^{-2} in 2014 to a high of 2.8 ± 0 g DW m^{-2} in the 2004 survey (Table 5). The area of the offshore meadow has also changed between years with 2011 recording the smallest meadow area (105.1 ± 19.1 ha) within the comparable survey area (Table 5; Map 3). The biomass of coastal meadows was not previously recorded due to poor visibility during the 2010 and 2011 survey. The total area of coastal meadows that can be compared between the 2010, 2011 and 2014 surveys has remained similar; 12.2 ± 4.9 ha in 2010, 10.6 ± 3.8 ha in 2011, and 9 ± 3.6 in 2014 (Table 5; Map 3).

Previous long-term monitoring program between 2004 and 2008 at four representative offshore sites found that the deep water seagrasses around Hay Point were naturally highly variable with peak abundance and distribution occurring in winter and spring before seasonal declines over summer.

Table 5 Seagrass community types, mean above-ground biomass and meadow area in the Hay Point area 2004, 2005, 2010, 2011 and 2014 **(note: survey extent for each year is slightly different see Map 3).**

Meadow ID	Meadow location	Community type	Mean meadow biomass ($gDWm^{-2}$ ± SE)	Area ± R (ha)	No. of sites
July 2004					
1	Offshore	Light *Halophila decipiens* with *Halophila spinulosa*	0.2 ± 0.03	6397.2 ± 2371.0	68
2	Offshore	Moderate *Halophila decipiens*	1.4 ± 0.2	278.1 ± 238.5	5
3	Offshore	Light *Halophila decipiens* with *Halophila spinulosa*	0.03	133.9 ± 76.0	1
4	Offshore	Moderate *Halophila decipiens*	2.8	42.7 ± 30.1	1
Total				**6851.9 ± 2715.6**	**75**
December 2005					
1	Offshore	Light *Halophila spinulosa*	2.7 ± 0.7	338.6 ± 155.5	na
Total				**338.6 ± 155.5**	**na**
October 2010					
1	Coastal	Light *Halophila ovalis*	na	4.5 ± 1.6	2
2	Coastal	Light *Halophila ovalis/ Halodule uninervis* (narrow)	na	5.1 ± 2.0	2
3	Coastal	Light *Halodule uninervis* (narrow)	na	2.6 ± 1.3	1
4	Offshore	Light *Halodule uninervis* (narrow)	na	36.5 ± 12.2	2
5	Offshore	Light *Halodule uninervis* (narrow)	na	78.4 ± 16.7	1
6	Offshore	Light *Halophila decipiens*	0.01 ± 0.003	95.7 ± 38.3	1
7	Offshore	Light *Halophila decipiens*	0.01 ± 0.003	132.6 ± 44.6	1
8	Offshore	Light *Halophila decipiens*	0.01 ± 0.003	1221.9 ± 202.9	9
Total				**1577.3 ± 319.6**	**19**
November 2011					
1	Coastal	Light *Halodule uninervis* (wide)	na	4.3 ± 1.9	1
2	Coastal	Light *Halodule uninervis* (narrow)	na	6.3 ± 1.9	2
3	Offshore	Light *Halophila decipiens*	0.01 ± 0.003	105.1 ± 19.1	1
Total				**115.7 ± 22.9**	**4**
October/November 2014					
1	Coastal	Light *Zostera muelleri/Halophila ovalis*	1.18 ± 0	4.3 ± 1.8	2
2	Coastal	Light *Halodule uninervis* (wide)	2.74 ± 0	4.7 ± 1.8	2
9	Coastal	Moderate *Halodule uninervis* (narrow)	2.7 ± 0.4	41.5 ± 28	2
3	Offshore	Light *Halophila decipiens*	0.003 ± 0.001	8887.2 ± 5402	57
Total				**8937.7 ± 5433.6**	**63**

Map 4. Seagrass distribution and community types at the Port of Hay Point in 2004, 2005, 2010, 2011 and 2014



McKenna SA & Rasheed MA 2015 'Port of Hay Point & Keswick Island seagrass and benthic habitat survey: Baseline Survey - 2014', JCU, Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER)publication, Cairns.

3.3 Benthic macro-invertebrates

Benthic macro-invertebrates occurred throughout the survey area and were comprised of a diverse suite of taxa (Tables 6 & 7; Map 4). While there was a diversity of taxonomic groups identified in the survey, the dominant community type in the area were those that had a low density of macro-invertebrates, with open substrate comprising the majority of the area (Table 6; Map 4). Some moderate density areas of habitat forming benthic macro-invertebrates were found in both offshore and coastal areas within the survey area (Map 4). Organisms in these regions were concentrated around habitat forming 'live' and dead rock/rubble in offshore areas, or rock and reef in coastal areas. This association led to patches of higher biodiversity and density.

Benthic macro-invertebrate communities were divided into regions based on community composition from video analysis and free diving, and density of individuals found in the sled net and video analysis. There were three density categories identified; open substrate, low density communities and moderate density communities. Within these density categories a range of different community types were identified, with various combinations resulting in nine different benthic macro-invertebrate region types (Tables 6 & 7; Map 4).

Mostly open substrate with occasional isolated individuals

This was the lowest density category used to describe benthic macro-invertebrate communities and was the most extensive community type covering approximately 17,730.5ha of the survey area; Region 1 (Table 6; Map 4; Figure 4). There was one community type in this category (Table 6 & 7). Although the density of individuals within this region was low, macro-invertebrate isolates within this region were from a wide range of taxonomic groups (Table 7).

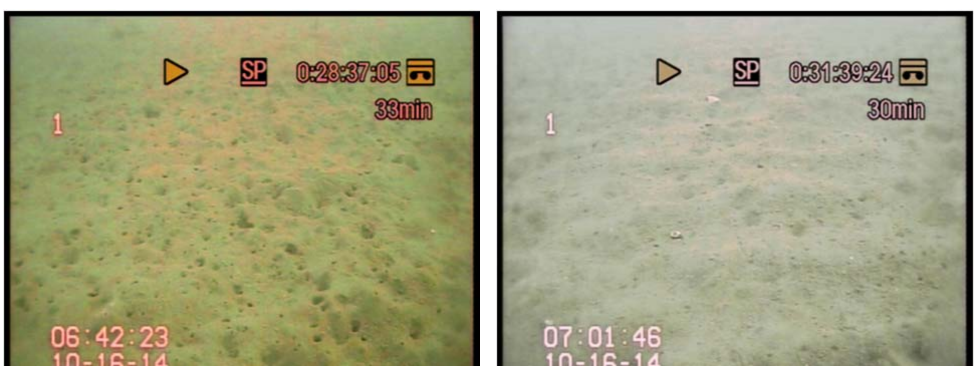


Figure 4 Examples of open substrate/Region 1 (frame taken from video footage in the north eastern corner of the survey area: 16 Oct 2014)

Low density benthic communities

Community types in this density category were extensive and collectively covered approximately 6,330.9ha of the total survey area. There were five community types in this density category (Tables 6 & 7; Map 4; Figure 5):

Region 2: Mostly open substrate with reef/rubble patches containing a low cover of hard coral.
This region covered 260.6ha and occurred in small pockets along the coast from Hay Point to Victor Island.

Region 3: Mostly open substrate with rubble patches containing high/medium numbers of barnacles and brachyurans and patches of erect bryozoans, echinoids and solitary corals.
This low density community was the smallest offshore community and covered 128.3ha. Region 3 occurred just south of the wharves and departure channel. This region had a notably high number of barnacles which occurred in large clumps attached to rock rubble.

Region 4: Mostly open substrate with high/medium numbers of polychaetes, bryozoans and brachyurans with patches of sea pens and ascidians.
This low density region occurred as two separate communities in the survey area and covered 2945.9ha. The two communities occurred across a significant amount of the current spoil ground as well as the departure channel (Figure 5).

Region 5: Mostly open substrate with medium numbers of bryozoans and patches of ascidians and hydroids.
This region was one of the smaller offshore regions to the south east of the spoil ground.

Region 6: Mostly open substrate with medium numbers of bryozoans and brachyurans with patches of soft coral.
This low density community covered 2,832.4ha and occurred towards the middle of the survey area. Region 6 contained a notable presence of soft coral, albeit in low densities, and was the only low density community in the offshore area that had soft coral.

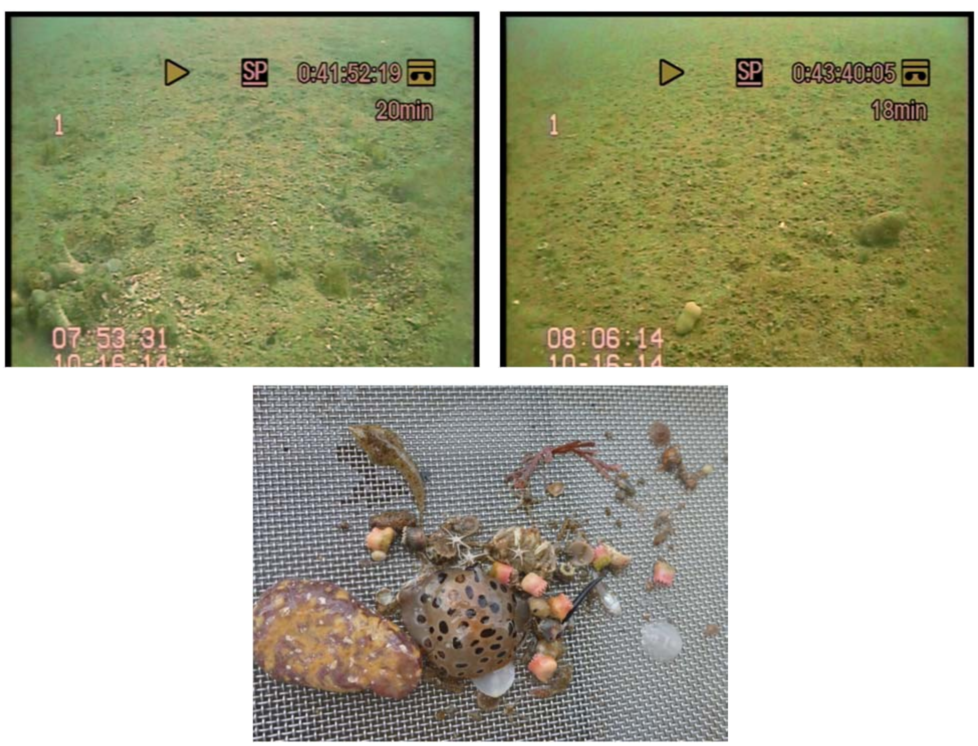


Figure 5 Examples of low density communities (frame taken from video footage at Hay Point 16 Oct 2014)

Moderate density benthic communities

There were three community types in this density category that collectively covered approximately 2,898ha. The benthic communities in these regions consistently covered 20-80% of the total bottom area in either the video transect or the free diving assessments (Tables 6 & 7; Map 4; Figure 6). The substratum within this density category varied significantly from sand to reef (Table 6).

Region 7: Reef/rubble areas containing high numbers of polychaetes, bryozoans, hydroids, ascidians and brachyurans with patches of soft coral, sponges and anemones.
This moderate density region featured a diverse variety of polychaetes, erect and encrusting bryozoans, hydroids and ascidians, and covered 2158.4ha. The region was split into two areas that were located at the northern and southern borders of the survey area.

Region 8: Rock areas containing bivalves.
Region 8 was the only coastal area that contained a moderate density of macro-invertebrates, specifically bivalves. These bivalves were found over rock and reef in the Dudgeon Point area.

Region 9: Sandy areas containing high/medium numbers of bryozoans and brachyurans with patches of hydroids.
This moderate density region covered 732.6ha and was located within and on the south eastern border of the spoil ground. The substrate in this region was mainly sand.

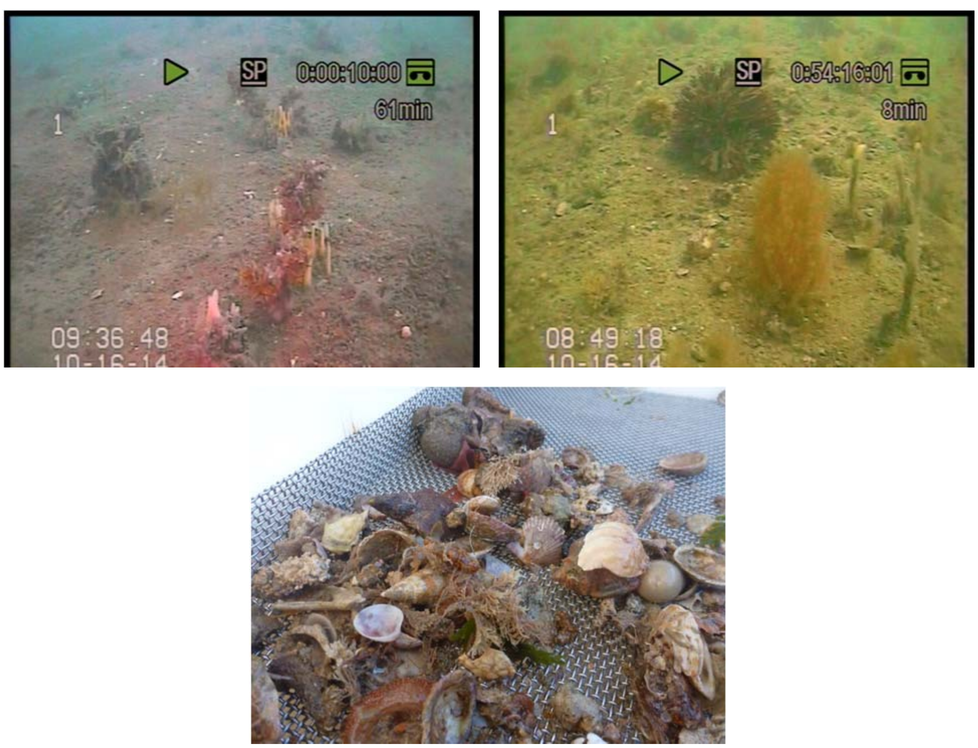


Figure 6 Examples of low density communities (frame taken from video footage at Hay Point 16 Oct 2014)

Map 4. Location, density and distribution of benthic macro-invertebrates in the Hay Point area October/November 2014

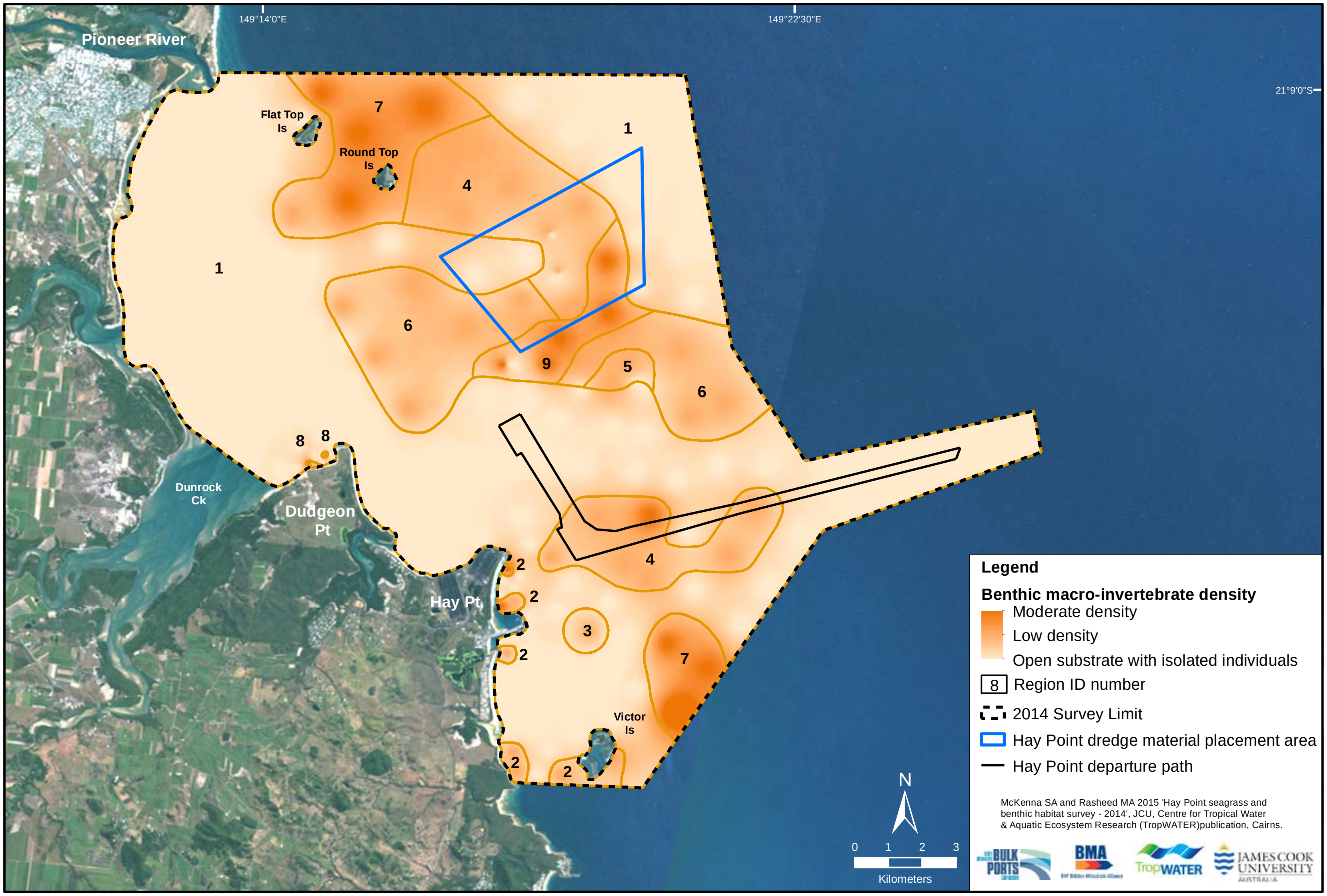


Table 6 Benthic macro-invertebrate regions at the Port of Hay Point - density, region description, number of sites and total area, October/November 2014

Density category	Benthic macro-invertebrate region description	Region ID (see map 4)	No. of sites	Area ± R (ha)
Open substrate, occasional benthic individuals	Open substrate with occasional isolated benthic individuals	1	202	17730.5 ± 8245.7
Low density benthic community	Mostly open substrate with reef/rubble patches containing a low cover of hard coral	2	8	260.6 ± 166.3
	Mostly open substrate with high/medium numbers of barnacles and brachyurans and patches of erect bryozoans, echinoids and solitary corals	3	1	128.3 ± 43.3
	Mostly open substrate with rubble patches containing high/medium numbers of barnacles and brachyurans and patches of erect bryozoans, echinoids and solitary corals	4	19	2945.9 ± 2072.2
	Mostly open substrate with medium numbers of bryozoans and patches of ascidians and hydroids	5	6	163.7 ± 60
	Mostly open substrate with medium numbers of bryozoans and brachyurans with patches of soft coral	6	10	2832.4 ± 1929.4
Moderate density benthic community	Reef/rubble areas containing high numbers of polychaetes, bryozoans, hydroids, ascidians and brachyurans with patches of soft coral, sponges and anemones	7	8	2158.4 ± 1674.9
	Rock areas containing bivalves	8	3	7.2 ± 1.6
	Sandy areas containing high/medium numbers of bryozoans and brachyurans with patches of hydroids	9	7	732.6 ± 514.6
Total		**9**	**264**	**26958.9 ± 14708**

Table 7 Benthic macro-invertebrate communities in offshore regions in the Hay Point area - density and types of taxa present for each community region, October/November 2014.
(L = low, average of <4 individuals per site; M = medium, 4-10 individuals per site; H = high, average of >10 individuals per site)

Taxonomic Group		Benthic Community Region						
		1	**3**	**4**	**5**	**6**	**7**	**9**
Annelidia	Polychaete worm	L	L	M		L	H	
Sipuncula	Unsegmented worm				L			
Ectoprocta	Encrusting bryozoan	L		H	M	M	H	H
	Erect bryozoan	L		L	L	L	M	M
	Motile bryozoan	L		L	L	L	L	L
Cnidaria								
Anthozoa								
Zoantharia	Zoanthid	L	L	L	L	L	L	
	Anemone							
	Hard Coral						L	
	Solitary coral	L		L		L	L	L
Alcyonaria	Gorgonian	L		L			L	
	Sea pen	L						
	Soft coral					L		
Hydrozoa	Hydroid	L	L	L		L	H	
Echinodermata	Asteroid	L		L		L	L	
	Crinoid	L		L	L	L	L	
	Echinoid	L		L	L	L	L	L
	Holothuroid	L		L			L	
	Ophiuroid	L		L	L	L	L	L
Ctenophora	Jelly fish	L						
Urochordata	Ascidian	L		L	L	L	H	L
Porifera	Sponge	L		L			L	
Foraminiferida	Foram							
Arthropoda								
Crustacea	Brachyuran	L	M	M	L	M	M	M
	Penaeid prawn	L		L		L	L	
	Carid shrimp	L		L	L	L	L	L
	Stomatopod	L						
	Barnacle	L	H	L				L
	Elegant squat lobster			L			L	
	Other decapod							
Isopoda	Isopod (sea lice)	L			L	L		
Mollusca	Bivalve	L	L	L	L	L	L	L
	Gastropod	L		L	L	L	L	L
	Cephalopod	L	L	L		L		L
	Nudibranch	L						
	Chiton							
	Scaphopod							
	Sea hare							L
Vertebrata	Fish	L		L		L	L	L
	Seahorse	L		L			L	
Other	Shelless mollusc	L		L	L	L	L	L
	Egg Mass							

3.4 Macro-algae

Where present macro-algae communities occurred in aggregated patches and covered approximately 10,949.4 ha of the survey area (Table 8; Map 5). Large areas (medium and high density cover) of habitat-forming algae communities occurred in both offshore and nearshore areas. Medium density algae communities coincided with regions of medium density benthic macro-invertebrates, and tended to be concentrated around habitat-forming 'live' and dead rock/rubble and reef.

Four of the five functional groups of macro-algae were identified in the Hay Point survey area (Table 8). While not all macro-algae were identified to species level the most common types of erect macrophytes present were from the genus *Udotea, Caulerpa, Sargassum* and other mixed red and brown macrophytes.

Algal communities were divided into regions based on the density of functional algae groups present in the video analysis, collected in the sled net or identified in free diving surveys. Algal habitats in the survey area fell into four density categories; open (algae absent), low, moderate and high density, with fourteen different community types identified within these categories (Table 8; Map 5).

Open substrate

This region (Region 1) was used to describe areas where no algae were found and covered approximately 16,009.6ha of the survey area.

Low density macro-algae communities

This was the lowest density category used to describe the algae regions within the survey area and covered 5104.9ha of the survey area (Table 8; Map 5; Figure 7). There were six community types in this category;

Region 2: Mostly open substrate with a low cover of filamentous algae.
This community was the smallest (8.1ha) coastal algae community and occurred at Dudgeon Point. The region consisted of filamentous algae growing in small isolated patches in sandy areas of Dunrock Creek.

Region 3: Mostly open substrate with a low cover of erect macrophytes with erect calcareous algae.
This region coincided with the small *Halodule uninervis* meadow at Dudgeon Point and covered 111.6ha. The algae in this area were a mix of erect macrophytic algae and erect calcareous algae.

Region 4: Mostly open substrate with a low cover of turf mat algae.
This community type was found in a small area in the coastal part of the survey in approximately 7.2m (below MSL). The turf mat in this region occurred on the shell and rubble found at this site.

Region 5: Mostly open substrate with a low cover of erect macrophytes with erect calcareous and filamentous algae.
Region 5 was one of the small coastal algae communities that occurred near Hay Point and covered 89ha. This community type was different to Region 4 due to the presence of filamentous algae in the area (33.3% of the species composition).

Region 6: Mostly open substrate with a low cover of erect macrophytes.

The only functional group of algae found in this region of the survey area was erect macrophytic algae, specifically of the *Sargassum* species. This community type occurred in both the offshore and coastal parts of the survey area and was split into four separate areas. The offshore areas were found on the northern side of Flat Top Island and as a large area encompassing both the spoil ground and departure channel. The dominant sediment type in this region was mud in the offshore areas and sand in the coastal regions.

Region 8: Mostly open substrate with a low cover of erect macrophytes with filamentous algae.

This low density community type occurred as a large offshore area (1846.5ha) encompassing the spoil ground. The region was made of 93.75% erect macrophytes and 3.84% filamentous algae.

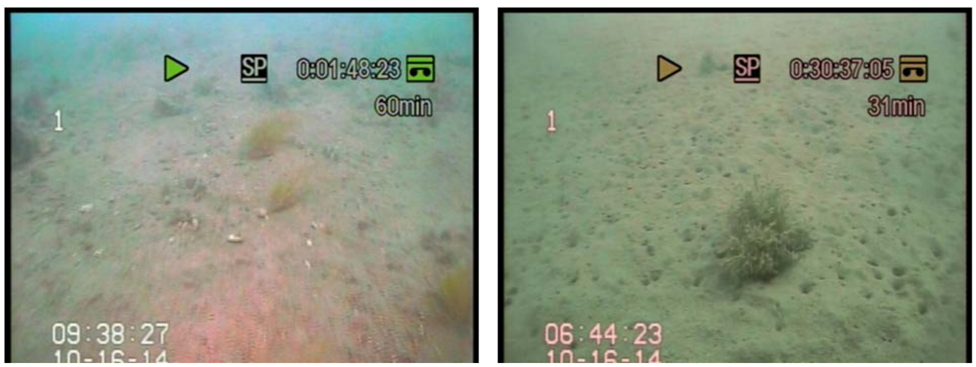


Figure 7 Examples of low density algae communities (frame taken from video footage at Hay Point 16 Oct 2014)

Moderate density macro-algae communities

There were five community types in this density category that collectively covered approximately 2901ha of the survey area. The algal habitat in these regions consistently covered 20-80% of the total bottom area (Table 8; Map 5; Figure 8). In the coastal areas algae from this density category occurred on rock and rubble, while in the offshore areas, mud was the dominant substrate structure for these moderate density macro-algae communities.

Region 9: Areas of moderate cover erect macrophytes.

The habitat type in Region 9 occurred in both coastal and offshore areas and covered 1650.9ha. This habitat type was found in the spoil ground and in large areas around Victor Island.

Region 11: Areas of moderate cover turf mat algae.

This moderate density algae community occurred as a small area at the mouth of the Pioneer River and consisted of 90% turf mat algae. The turf mat algae in this region were found on large areas of rock.

Region 13: Areas of moderate cover filamentous algae.
This region covered 284.1ha of the survey area and consisted entirely of filamentous algae. The offshore section of this region was on the far eastern boundary of the survey area while the coastal section of this region was found around Dudgeon Point.

Region 14: Areas of moderate cover erect macrophytes with filamentous algae.
Region 14 was found to the west of the spoil ground. The algae composition of this region was made up of 75% erect macrophytic algae and 25% filamentous algae.

Region 23: Areas of moderate cover erect macrophytes with turf mat algae.
The algae habitat in this region was found primarily on rock and reef. The region encompassed the area between the trestle wharves where Hay Reef is located. There was a mix of red and brown erect macrophytes in this area.

Figure 8 Examples of moderate density algae communities (frame taken from video footage at Hay Point 16 Oct 2014)

High density macro-algae communities

There were two community types in this density category that collectively covered approximately 2944.3ha of the survey area. The algal habitat in these regions consistently covered greater than 80% of the total bottom area (Table 8; Map 5; Figure 9). Both community types were found offshore and primarily occurred on a mud/sand/shell substratum.

Region 16: Areas of high cover filamentous algae.
This high density algae community occurred as a large (873.8ha) area on the northern side of the existing wharves at Hay Point. Algae in this region were comprised entirely of filamentous algae.

Region 17: Areas of high cover filamentous algae with erect macrophytes and erect calcareous algae.
This high density algae community occurred around Flat Top and Round Top Islands and extended to the northern boundary of the survey area. The algae composition of this region was made up of 35.71% erect macrophytes, 50% filamentous algae and 14.28% calcareous algae of *Udotea* sp and *Halimeda* sp.

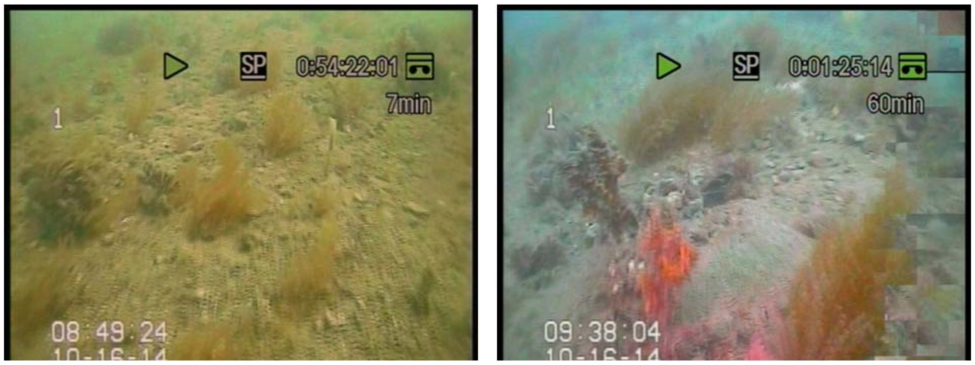


Figure 9 Examples of high density algae communities (frame taken from video footage at Hay Point 16 Oct 2014)

Map 5. Location, density and distribution of benthic macro-algae in the Hay Point area October/November 2014

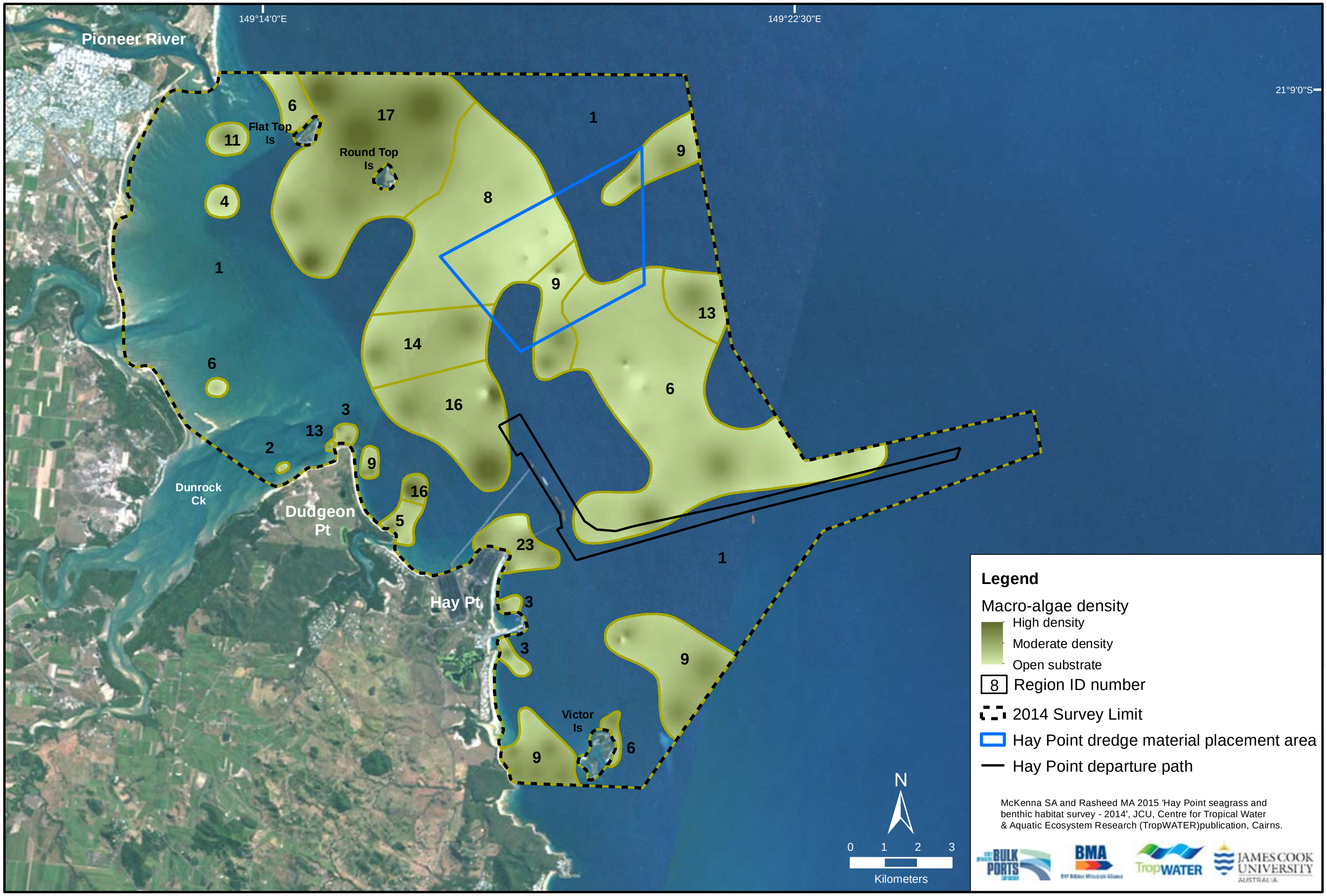


Table 8 Algae community types at the Port of Hay Point - density, region description, number of sites, total area and functional groups October/November 2014

Density category	Algae region description	Region ID (see map 5)	No. of sites	Area ± R (ha)	% Algae type				
					Erect Macrophyte	Turf mat	Filamentous	Erect calcareous	Encrusting
Open substrate	Open substrate with no algae present	1	164	16009.6 ± 9141.9	-	-	-	-	-
Low density algae community	Mostly open substrate with a low cover of filamentous algae	2	1	8.1 ± 1.1		100			
	Mostly open substrate with a low cover of erect macrophytes with erect calcareous algae	3	11	111.6 ± 15.3	78.18			21.81	
	Mostly open substrate with a low cover of turf mat algae	4	1	70.7 ± 6.1		100			
	Mostly open substrate with a low cover of erect macrophytes with erect calcareous and filamentous algae	5	3	89 ± 21.9	53.33		33.33	13.33	
	Mostly open substrate with a low cover of erect macrophytes	6	26	2979 ± 1790.7	100				
	Mostly open substrate with a low cover of erect macrophytes with filamentous algae	8	11	1846.5 ± 1025.6	93.75		6.25		
Moderate density algae community	Areas of moderate cover erect macrophytes	9	24	1650.9 ± 682.1	96.16		3.84		
	Areas of moderate cover turf mat algae	11	1	88.4 ± 17.6	10	90			
	Areas of moderate cover filamentous algae	13	2	284.1 ± 146.7			100		
	Areas of moderate erect macrophytes with filamentous algae	14	2	651.5 ± 21.4	75		25		
	Areas of moderate erect macrophytes with turf mat algae	23	5	226.1 ± 37.1	87.5	12.5			
High density algae community	Areas of high cover filamentous algae	16	6	873.8 ± 322.9			100		
	Areas of high cover filamentous algae with erect macrophytes and erect calcareous algae	17	7	2070.5 ± 443	35.71		50	14.28	
Total			**264**	**26959.9 ± 13692.9**					

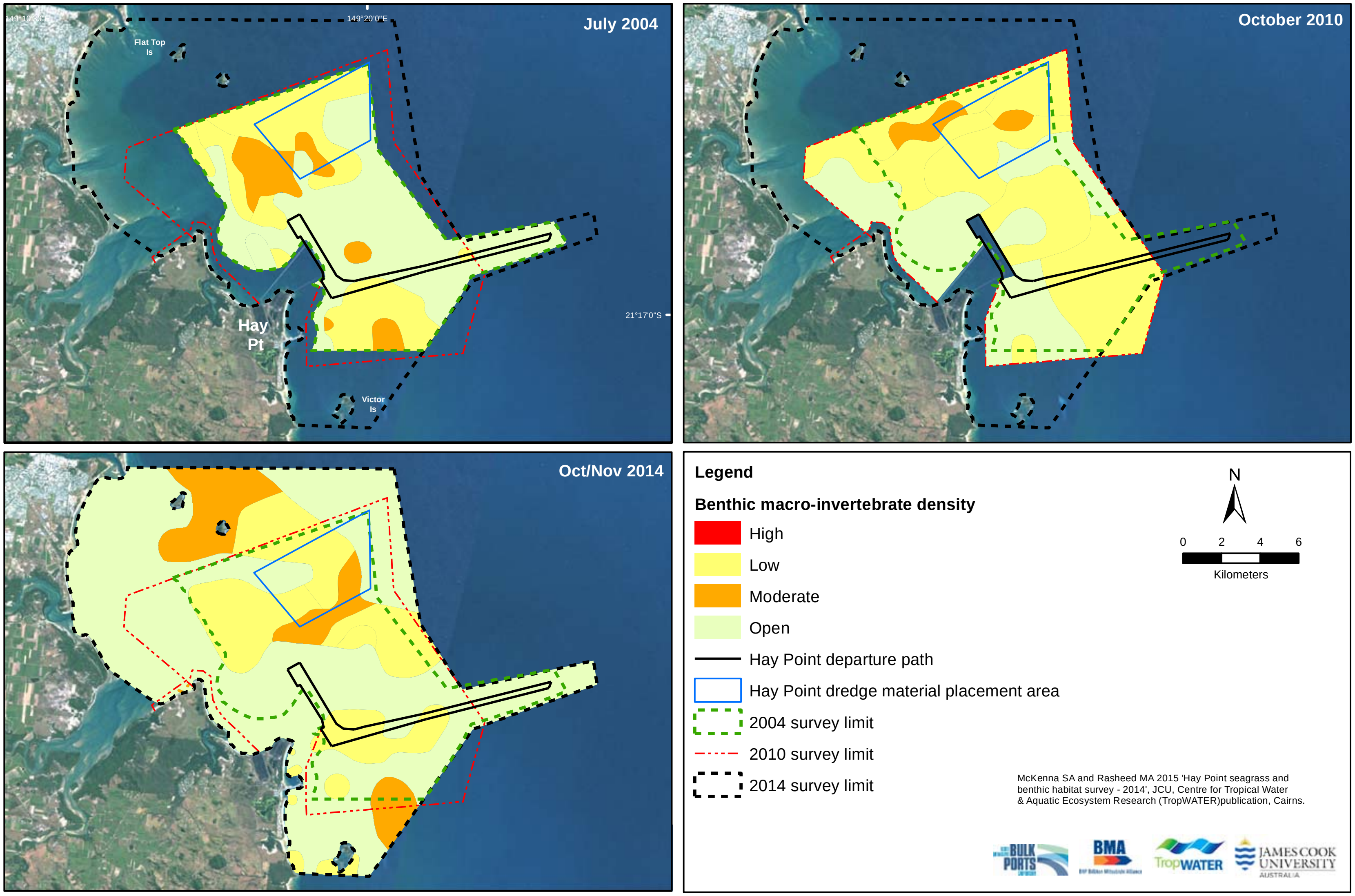
3.5 Comparison with previous benthic macro-invertebrate and macro-algae surveys in the Hay Point area

There have been two previous surveys of benthic macro-invertebrates and macro-algae in the Hay Point area; 2004 and 2010. The 2014 survey was the first survey to extensively investigate benthic habitats in the coastal areas of the Hay Point region. Coastal habitats can therefore not be compared to previous surveys.

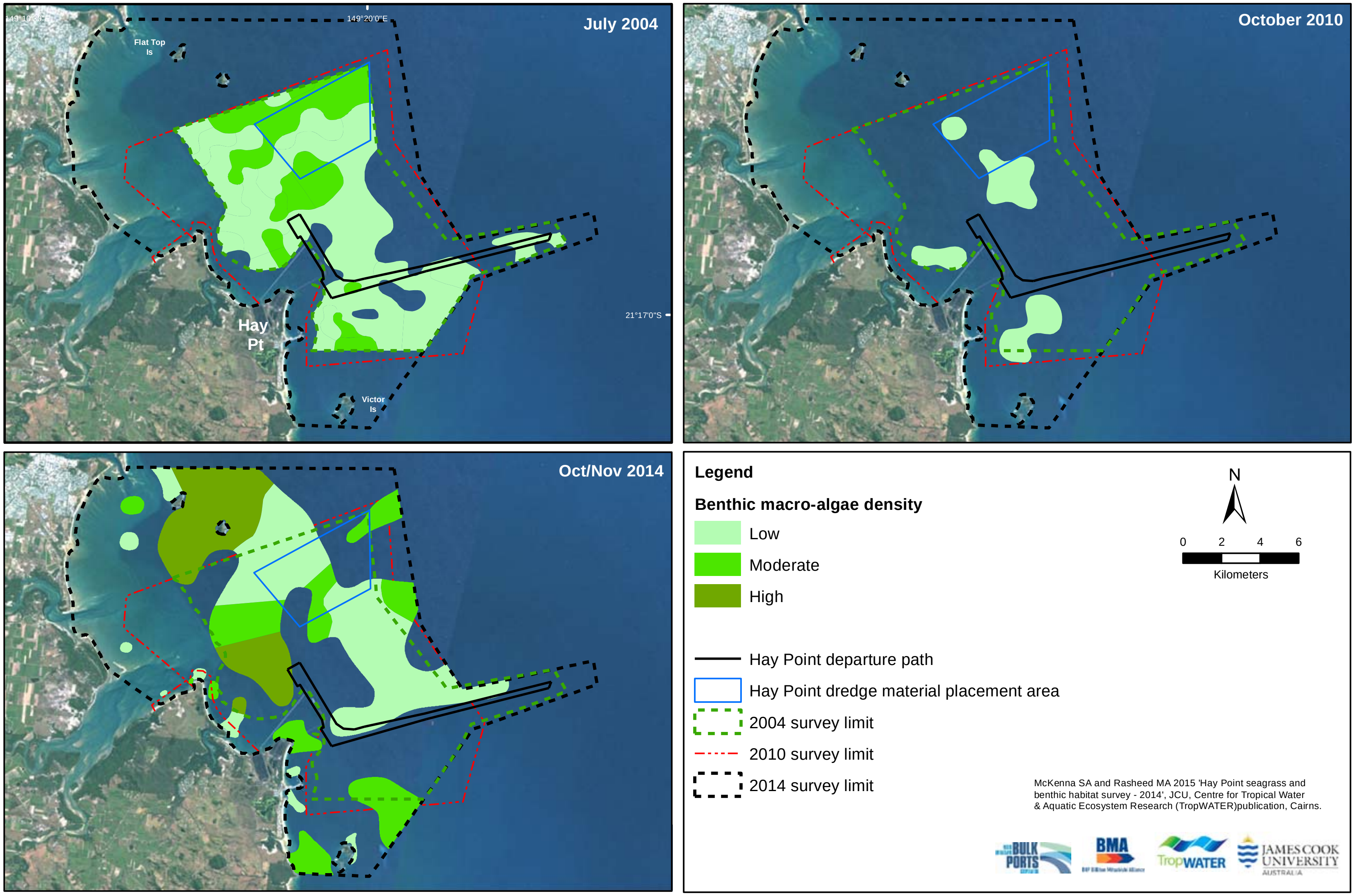
In all years the dominant benthic habitat community type was open substrate with a low density of macro-invertebrates (Map 6). Comparing the area in common between all three surveys (2004 survey limit), moderate density benthic macro-invertebrate communities occurred across a greater proportion of the total area in 2004 and 2014 compared to 2010 (Map 6). There have been no “high density” macro-invertebrate communities mapped in any of the surveys.

In contrast to benthic macro-invertebrates, the density and distribution of macro-algae has changed considerably across surveys (Map 7). The distribution of macro-algae was highest in 2004 and lowest in 2010. In 2010 the algae habitat was fragmented into four separate regions (Map 7). The only functional group identified in the 2010 survey area was erect macrophytic algae. The survey in 2014 was the only survey to record regions of high density (consistently covered greater than 80% of the substrate) algae habitat but these were dominated by the fast growing and colonising group of filamentous algae (Map 7).

Map 6. Benthic macro-invertebrate distribution and density at the Port of Hay Point in 2004, 2010 and 2014



Map 7. Benthic macro-algae distribution and density at the Port of Hay Point in 2004, 2010 and 2014



4 DISCUSSION

This survey examined the seagrass habitats and the macro-invertebrate and macro-algae habitats around Hay Point. Seagrass distribution was the largest recorded since the initial baseline of Hay Point in 2004. The majority of seagrasses occurred in deeper offshore areas although some shallow coastal meadows were also described around the Dudgeon Point area. The dominant feature of deeper survey areas was open substrate, although this was interspersed with a diverse range of benthic habitats and community types that were typical of those found in offshore and nearshore subtidal areas elsewhere in Queensland such as Gladstone (McKenna et al. 2014), Abbot Point (Rasheed et al. 2005; McKenna and Rasheed 2014) and Cairns (McKenna et al. 2013).

4.1 Seagrass in the Hay Point survey area

Seagrass occurred across a large extent of the offshore region around Hay Point in 2014, as well as coastally around Dudgeon Point. There have been four (2004, 2005, 2010, 2011) previous 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 (Thomas et al. 2012; BOM 2015). This loss of seagrass was reflected throughout much of the urbanised east coast of Queensland (McKenna et al. 2015; McKenzie et al. 2014; Rasheed et al. 2014). The 2014 survey has seen the recovery of much of this lost area in the Hay Point region albeit at low biomass.

The spatial extent of deep water seagrasses around Hay Point is naturally highly variable with peak abundance and distribution in winter and spring with a seasonal decline over summer (Chartrand et al. 2008). The seagrass distribution mapped in this survey between October and November is therefore likely to represent seagrass near its annual maximum. A study conducted at the site between 2004 and 2009 found that seagrasses were absent between December and June each year indicating an annual growth habit (York et al. In review). The driver of this natural seasonal cycle of senescence and subsequent recruitment were unclear but likely to be associated with changes to the availability of light. Also of note during that program was a lack of light during the year of capital dredging (2006), likely preventing the normal annual recruitment of deep water seagrasses. Seagrass re-established in the year following dredging indicating that they were susceptible to impacts but capable of rapid recovery (York et al. In review).

The diversity of seagrass species found in the offshore survey areas (*Halophila decipiens, Halophila ovalis, Halophila spinulosa* and *Halophila tricostata*) were typical of deep water seagrasses occurring in waters between the mainland and the Great Barrier Reef (Coles et al. 2009). Species of the *Halophila* genus in Queensland are considered highly ephemeral and seasonal in their occurrence particularly in deep water locations (Carruthers et al. 2002; Chartrand et al. 2014a). *Halophila* species are rapid colonisers and are often the first species to occur following a disturbance, having the ability to rapidly spread through sexual and asexual reproduction (Birch & Birch 1984; Rasheed 2004; Chartrand et al. 2008; Unsworth et al. 2010). *Halophila decipiens* tends to thrive in environments where disturbances are frequent and/or environmental conditions are regularly shifting, making conditions unsuitable for maintaining the larger, long-lived seagrass species (Josselyn et al. 1986; Kenworthy et al. 1989; Preen et al. 1995; Kenworthy 2000).

The presence of *Halophila* species around Hay Point does not necessarily reflect disturbance as they may be the only species capable of growing in these deep water areas, persisting 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 & Durako 2007; Ralph et al. 2007) and they have the lowest light requirements of all tropical seagrass species. The presence of *Halophila decipiens* in the existing Hay Point spoil ground is a good indication of its ability to colonise disturbed areas and co-exist with this type of disturbance. *Halophila decipiens* has commonly been found in disturbed areas of other Queensland ports such as the dredge spoil grounds in Gladstone and Townsville (Rasheed et al. 2003; Rasheed & Taylor 2008) and dredged channels and apron areas in the ports of Weipa, Cairns and Abbot Point (Neil et al. 2003; Roelofs et al. 2004; McKenna & Rasheed 2014).

Only three seagrass species were found in the coastal areas of Hay Point (*Halodule uninervis, Halophila ovalis* and *Zostera muelleri*), and these were also typical of coastal estuarine and inshore reef habitats in this area of Queensland. The Reef Rescue Marine Monitoring site on Hamilton Island to the north of Keswick Island has similarly only ever recorded *Halodule uninervis*, *Zostera muelleri* and *Halophila ovalis* (McKenzie et al. 2014). Of note was the presence of *Zostera muelleri* at Dudgeon Point. This species has not previously been found in the Hay Point area. On Queensland's east coast *Zostera muelleri* dominates many intertidal and shallow subtidal areas (Carruthers et al. 2002). *Zostera* is also seen as genera that can survive moderate levels of disturbance (Carruthers et al. 2002).

The presence of *Zostera muelleri*, *Halodule uninervis* and *Halophila spinulosa* at Hay Point in 2014, combined with the increase in seagrass distribution and macro-algae density is a good indication that light conditions have improved to be more favourable for marine plant growth in recent times. Rainfall in the 19 months before the 2014 surveys was below the mean monthly average (BOM 2015), which may have allowed for favourable light conditions due to a reduction in runoff related turbidity. These seagrass species have higher light requirements than other species that were present in those meadow areas in previous years. In Gladstone *Zostera muelleri* required between 5 and 8 mol photons m^{-2} d^{-1} of light over at least two weeks to survive (Chartrand et al. 2012), and in the deeper offshore areas a critical light threshold in the range of 1-2 mol photons m^{-2} d^{-1} was required for *Halophila decipiens* and *Halophila spinulosa* survival (Chartrand et al. 2014). In laboratory studies Chartrand et al. (2014) found that *Halophila decipiens* shoot density significantly declined after 2 weeks under low light treatments, whereas *Halophila spinulosa* was not affected until 4 weeks.

Preliminary PAR results from the Port of Mackay/Hay Point Water Quality Monitoring program indicates that light at the deeper Hay Point spoil ground site ranged between 0 and 2.75 mol photons m^{-2} d^{-1} and did not fall below 1 mol photons m^{-2} d^{-1} for longer than 8 days in the 4 weeks leading up to the October 2014 seagrass survey. At the shallow Dudgeon Point light monitoring site near to where *Zostera muelleri* was found, light ranged between 0.15 and 9.05 mol $m^{-2}d^{-1}$. Unfortunately the light loggers at the Dudgeon Point site did not record any readings in the 4 weeks prior to the seagrass baseline survey. These preliminary light results combined with the presence of seagrass indicate that light levels were in the range required to support seagrass presence for shallow and deep-water areas in 2014.

The Hay Point seagrass meadows may provide a seasonally important food source for dugong. The species found in the survey were of those preferred by dugong and occurred well within the depth range suitable for dugong feeding (Lanyon 1991; Preen 1995). The Hay Point area 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 and ecosystem services (Rasheed et al. 2014).

4.2 Benthic macro-invertebrates and macro-algae in the Hay Point survey area

The benthic macro-invertebrate communities found at Hay Point have been similar across all surveys and in 2014 were dominated by open substrate interspersed with a low to moderate density of filter feeding and suspension feeding species such as bryozoans, hydroids, ascidians, bivalves, polychaetes and brachyurans. Algal communities across all surveys tended to be dominated by erect macrophytic algae and in 2014 large areas of filamentous algae were observed. The invertebrate communities at Hay Point typify pioneering and opportunistic assemblages, represented by large numbers of comparatively small, short-lived individuals (Bolam and Rees 2003). The absence of any high-density benthic macro-invertebrate communities in any of the Hay Point surveys may be a reflection of the exposed nature of the area. In other locations where similar surveys have been conducted that have bays, inlets and large islands to provide protection from winds and high wave energy, higher density benthic macro-invertebrate communities are more common (e.g. Gladstone - Rasheed et al. 2003; McKenna et al. 2014).

Many of the macro-algal and benthic macro-invertebrate communities described in this and previous Hay Point surveys occur within or in proximity to maintained channels, port facilities and the existing dredge material placement areas (DMPA). This indicates that benthic macro-invertebrates and macro-algae communities in the area are resilient to some level of disturbance. In addition due to its exposed nature, the survey area is likely to be colonised by naturally resilient species that can cope with high levels of wind and wave action, and tidal movement (Dauer 1984; Bolam and Rees 2003; Bolam 2011).

Elevated suspended material can result in the death of benthic fauna through congestion of feeding mechanisms and smothering, especially in filter-feeding organisms like those found in this survey (Cruz-Motta and Collins 2004; Erftemeijer and Lewis 2006). Some species tend to be more sensitive than others to burial and increases in turbidity (Cruz-Motta and Collins 2004). During the long-term monitoring program at Hay Point; during the 2006 capital dredging campaign, macro-invertebrate analyses found that the number of sessile individuals was lower at the spoil ground site compared to other sites up to three months after the cessation of dredging, while motile macro-invertebrates did not appear to be affected by dredging (Chartrand et al. 2008). A study at an offshore DMPA in Townsville also found that macro-benthic assemblages inside the offshore DMPA were not different from assemblages outside the DMPA within three months after dredge material placement, suggesting that some benthic macro assemblages may respond quickly to the disturbance (Cruz-Motta and Collins 2004). Rapid rates of recolonisation (between one week and three months) of benthic assemblages inside offshore DMPA's have also been reported in other studies (McCauley et al. 1977; Jones 1986).

In 2010, macro-algae did not form a significant habitat within the survey area. While small amounts of macro-algae were found, the distribution and the diversity of species was substantially reduced compared to the baseline survey conducted in 2004 and in this survey. In 2004 macro-algae communities were represented by species from five functional groups; erect macrophytes, encrusting, erect calcareous, turf mat and filamentous (Rasheed et al. 2004) and four functional groups in this study. In 2010, macro-algae only formed 10% of the survey area and were represented by species from only one functional group; erect macrophytes. This reduction in macro-algae in 2010 is consistent with that noted for seagrasses and was a strong indicator of unfavourable growing conditions for benthic primary producers during that period. As with seagrasses, the reduction in density and diversity was likely a reflection of an unfavourable light climate for deep water plant growth (Thomas et al. 2012). The presence of 'high' cover/density macro-algae communities in the 2014 survey was driven by an increase in filamentous algae rather than the more structurally complex erect macrophytes. Filamentous algae are typically colonisers that can increase and decline rapidly with changing environmental conditions.

Although the dominant density category of benthic macro-invertebrates and macro-algae was low to moderate density communities, they are still likely to have some value in supporting fisheries and biodiversity values. Benthic fauna and algae are a source of food for many consumers (Miller et al. 2002). Benthic fauna also form a link between habitat substrata, detritus-based food chains and larger carnivores (Posey et al. 1997). Similarly, although the value of sparse algal communities to fisheries productivity and the marine environment in general is poorly quantified, algae provide food, habitat and shelter for benthic animals and other larger carnivores (Kulczycki et al. 1981). Denser algae beds in the Gulf of Carpentaria are known to be important nursery grounds for juvenile prawns (Hayward et al. 1995). In addition macro-algae also provide food for some species of marine turtles in Queensland (Limpus 1998) and globally algae have been considered as important as seagrasses for their ecosystem services role (Costanza et al. 1997). While the sparse beds that typified Hay Point may not be providing the same level of ecosystem services as denser algae communities, it is likely that they do contribute some value to fisheries and the overall marine ecosystem for the area.

4.3 Benthic Habitats and Port Management

The management of seagrass and other benthic habitats and fauna in the Hay Point area should remain focused on ensuring the resilience of these habitats remains high enough to withstand expected anthropogenic impacts and risks. Previous studies by the group at Hay Point have shown that seagrasses were susceptible to impacts associated with dredging (in 2006) but were capable of rapid recovery (York et al. in review). The loss of seagrass in the Hay Point area has also been associated with climatic events that occurred across Queensland in 2010/2011 (Thomas et al. 2012). The 2014 survey has seen the recovery of much of this lost area in the Hay Point region albeit at low biomass. It is likely however, that the resilience of seagrass in the Hay Point area is still at low levels, much like the seagrasses monitored in other parts of east coast of Queensland including Cairns (Jarvis et al. 2014), Mourilyan (York et al. 2014) and Abbot Point (McKenna and Rasheed 2014) where climate impacts have led to major declines in seagrasses that have yet to fully recover (Rasheed et al. 2014). Under these circumstances seagrasses may struggle to withstand stresses they have previously been able to cope with.

Results of this survey have provided the foundation for re-establishing the seagrass long-term monitoring program for Hay Point, and expanding the scope to include areas in Mackay and reference sites in the Southern Whitsundays (Keswick Island group). NQBP is considering implementing a long-term monitoring approach based on periodic re-assessments of all seagrasses within the region (ideally every three years) with a subset of representative areas monitored annually in the intervening years. Long-term monitoring programs will enhance our understanding of seagrass dynamics and enable more effective management of valuable marine habitats and marine port environments. Information collected in these programs aims to assist in planning and managing future developments in coastal areas, particularly new and expanding marine port projects.

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