Department of Employment, Economic Development and Innovation

Port Musgrave Seagrass and Benthic Habitat Baseline Assessment

April and September 2009

CapeAlumina

Toward Q2 Tomorrow's Queensland

Queensland Government

Port Musgrave Seagrass and Benthic Habitat Baseline Assessment – April and September 2009

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EXECUTIVE SUMMARY

This report details the results of flora and fauna benthic habitat assessments in Port Musgrave and the design of a long-term seagrass monitoring strategy for the area. Two baseline surveys were conducted during the seasonal extremes for tropical seagrass abundance, the wet season (April 2009) and the dry season (September 2009). The surveys were commissioned by Cape Alumina Pty Ltd (CAPL) as a joint project with the Fisheries Queensland Marine Ecology Group (MEG) to aid in planning and management of future port activities and to monitor potential impacts to sensitive fisheries and seagrass habitats.

The 2009 baseline surveys were the first fine-scale assessment of seagrass distribution and abundance that have been conducted for the Port Musgrave area. The naturally protected waters of Port Musgrave provide shelter for a diverse and productive marine environment. Seagrass covered a substantial portion of the embayment with 689 ha and 1296 ha mapped in the 2009 wet and dry season respectively.

There was a diversity of seagrass species and meadow types in the area with five species and 11 meadow types identified over the two surveys. Meadows ranged from very low density, highly patchy *Halophila spp.* in the subtidal, to more dense, continuous, *Halodule uninervis* along the shoreline of the Mapoon community. Seagrass covered many of the intertidal mudbanks, and while the distribution was broadly similar between the wet and dry season surveys there were substantial additions of seagrass during the dry season with increases in both intertidal and subtidal *Halophila*. These changes were typical of seasonal fluctuations for tropical seagrass communities.

No seagrass, algae or habitat forming benthic invertebrate communities were found directly within the proposed shipping channel or development site footprint. However, seagrass, algae and oyster banks were located in proximity to the channel and may be vulnerable to the effects of turbidity associated with dredging. While these communities are likely adapted to natural pulsed turbidity events, further increases associated with dredging could potentially push communities beyond their tolerance. Effective dredge planning to mitigate these potential impacts would be an important consideration. Factors such as the length of dredging windows, type of dredge and timing in which dredging occurs (i.e. state of tide) could potentially be manipulated to avoid significant impacts.

The value of seagrasses as nursery habitat for juvenile prawns and commercial fish is well recognized (see Watson *et al*. 1993). Seagrasses in Queensland are also an important food resource for dugong and sea turtles. Dugong feeding trails were observed in high densities in many of the intertidal meadows in both the wet and dry surveys, indicating the value of Port Musgrave seagrasses to local dugong populations on the coastline.

Seagrasses can also be used as a tool to monitor the environmental health of ports and coastal areas as they show measurable responses to changes in water quality (Dennison *et al*. 1993). MEG has established seagrass monitoring programs in a number of Queensland ports. Mapping and monitoring programs have aided in the planning of dredging programs and port developments that have a minimal effect on the marine environment as well as assisting in the assessment of effects of port maintenance and development operations. A bi-annual monitoring program beginning in April 2010 was developed from the results of the baseline surveys. A subset of 5 meadows representing the range of meadow types and capturing areas of interest and potential impact were selected. Monitoring meadows include both intertidal and subtidal seagrasses as well as meadows preferred as food by dugong and those likely to support fisheries productivity.

The information collected in the initial baseline surveys will feed directly into the formulation of impact assessment on marine flora and habitat forming benthos and can be used in the formation of appropriate mitigation strategies when planning for the proposed port and long term viability of shipping channels and capital works in the Port Musgrave area.

INTRODUCTION

Cape Alumina Pty Ltd (CAPL) is investigating options for establishing a port facility in Port Musgrave to service a proposed bauxite mining operation north of Weipa. As part of the preliminary investigations for the project CAPL have commissioned studies to identify, assess and track changes in Port Musgrave's aquatic environment. Port Musgrave is likely to contain benthic marine communities with a high value to fisheries and endangered species. Surveys and monitoring by Fisheries Queensland in the nearby Ports of Weipa and Skardon River have found large areas of seagrass and algae (Roelofs *et al.* 2004; Chartrand and Rasheed 2009) and broadscale surveys of the Queensland coast in the early 1980's also identified areas of seagrass within Port Musgrave (Coles *et al.* in prep). These types of habitat provide feeding grounds for dugong and turtle and are also important nursery grounds for juvenile commercial fisheries species. Benthic marine habitats, especially seagrass meadows, have the potential to be impacted by many of the activities associated with port development, including dredging and establishing new infrastructure. Despite this potential there are several examples on the Queensland coast where well managed port activities and productive seagrass communities can co-exist.

The Marine Ecology Group, a working group of Fisheries Queensland, was engaged by CAPL to conduct two baseline surveys on seagrass, macro-algae and other habitat forming benthos in Port Musgrave; a wet season baseline in April 2009 and a dry season baseline in September 2009. The sampling approach was based on a need to establish baseline data on seagrass characteristics and other significant habitat forming benthic macro-invertebrate (BMI) communities. Conducting assessments at the seasonal extremes was considered important as seagrass distribution and density has been shown to vary seasonally, typically expanding and contracting following seasonal rainfall and temperature patterns (McKenzie 1994, Rasheed *et al*. 2001).

Fisheries Queensland and CAPL are also assisting the Mapoon community to establish a community seagrass monitoring program which is currently underway. Together, the bi-annual surveys and community program initiatives will form the basis of a long-term seagrass monitoring strategy to ensure the health of seagrass meadows during any dredging and port development operations and to form strategies to mitigate potential impacts to seagrasses.

METHODS

Sampling and mapping techniques applied were standard methodologies developed by the Fisheries Queensland Marine Ecology Group for assessing seagrass and benthic marine habitats in tropical environments. Techniques 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 creatures including saltwater crocodiles. The mapping and monitoring approach developed by Fisheries Queensland has been highlighted as an example of world best practice for assessing seagrasses in dredging programs (Erftemeijer and Lewis 2006). The methods are also used as part of baseline and long term monitoring programs throughout Queensland including Weipa, Karumba, Thursday Island, Cairns, Townsville, Mourilyan Harbour, Gladstone, Upstart Bay and Mackay (see Rasheed *et al*. 2001, 2002; Campbell *et al.* 2003; Rasheed and Taylor 2007; Chartrand and Rasheed 2009; Chartrand *et al*. 2009; Sankey *et al*. 2009;). This enables direct comparisons of the results collected in Port Musgrave with other Queensland locations.

The survey area encompassed intertidal and subtidal areas with a focus on benthic marine flora and fauna (Maps 1-5). Therefore, the baseline assessments did not characterise the mangrove fringe found at the edges of the survey extent or productive reef habitats located just outside of the survey area at the mouth of Port Musgrave.

Three mapping and sampling techniques were used to collect marine habitat data:

1. Helicopter aerial surveys
2. Subtidal underwater camera surveys
3. Subtidal sled tow surveys

1. Helicopter Aerial Surveys

Intertidal habitat boundaries, characteristics and species composition were determined using a helicopter around spring low tides when habitats were exposed. Habitat boundaries were flown directly over at low speed at a height between 10 and 100m while the position of the meadow edge was fixed using a Global Positioning System (GPS). Habitat characteristics and composition were determined by observers in a helicopter hovering over the habitat at a height of <2.0m while the position was fixed using a GPS, accurate to ± 5.0m. The position of submerged areas likely to contain seagrass and other benthic communities was also noted to help focus efforts during subtidal surveys. Habitat characteristics were determined at sites located approximately every 100 to 500m on transects with transects spaced from 150m to 1 km apart (Map 1). A higher density of transects and sites within transects were used in areas of high habitat complexity to ensure accurate community characterisation and to determine habitat area boundaries. Additional sites were sampled between transects to check for habitat continuity.

2. Subtidal underwater camera surveys

In subtidal areas, an underwater CCTV camera system was used to assess habitat characteristics. The camera was deployed to the seabed and provided real-time footage to a monitor observed on the vessel. A Van Veen grab (grab area 0.0625 m^2) was used at sites to confirm seagrass and benthic species and surface sediment characteristics. Habitat characterisation sites were spaced along transects as performed during helicopter-based surveys. Subtidal characterisation sites were located 300m to 1km apart. A lower density of sites was used in deeper parts of the embayment characterised by uniform open mud substrate in order to focus efforts in areas dominated by more complex benthic communities. To ensure accurate subtidal habitat boundaries, characterisation sites were located on either side of a site where a particular community type is present (i.e. seagrass). This technique ensures sites are identified just outside of a habitat boundary as well as inside to define subtidal habitat boundaries more precisely.

3. *Subtidal sled tow surveys*

   The underwater CCTV camera system was mounted on a sled that incorporated a sled net and towed behind the research vessel to verify benthic community composition at low visibility sites and throughout the survey area to corroborate vertical drop underwater camera survey results. Towing the camera and sled over the seafloor integrates a larger area of the bottom than the vertical drop method, to ensure that very patchily distributed benthic life was not missed. The sled net is 600mm in width and 250mm deep with a 10mm mesh-aperture. Surface benthos collected in the net can include seagrass, algae and BMI communities present. For each transect, the camera was towed for 50 meters at drift speed (less than 1 knot). Footage was observed on board the vessel and recorded to digital tape for analysis in the lab. The sled net was further checked for benthic flora and fauna collected on each tow to compare with observations on video. When visibility was too poor to obtain video footage, the sled net was used to take a semi-quantitative sample to describe benthic habitat characteristics.

Habitat Characterisation

Habitat characterisation sites assessed as part of the helicopter and subtidal camera surveys encompassed a circular area of the substratum of approximately 10m^2. The position of each site was recorded using a GPS accurate to ±5.0m. Survey details including time, depth below mean sea level (MSL; boat-based surveys only), the observer and sediment type were recorded at each site. While methods of observing habitat characterisation sites varied (i.e. helicopter or observer/camera), information collected at each site was consistent. The site was characterised by assessments of three random deployments of a 0.25m^2 quadrat.

Seagrass

At sites where seagrass was present the seagrass species composition, seagrass above ground biomass, and percent cover were recorded. Seagrass above ground biomass was determined using a modified “visual estimates of biomass” technique (Mellors 1991; Rasheed 1999; 2004; Rasheed *et al.* 2008). This technique involves an observer ranking seagrass biomass in the field in three random placements of a 0.25m^2 quadrat at each site. Ranks were made in reference to a series of quadrat photographs of similar seagrass habitats for which the above ground biomass has previously been measured. Three separate biomass ranges were used: low biomass, high biomass and an *Enhalus* range for sites dominated by the largest species, *Enhalus acoroides*. 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 photo calibration quadrats that represented the range of seagrass biomass in the survey for each of the three biomass ranges. The photographs of calibration quadrats were previously 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 determine above ground biomass estimates (see Appendix).

The presence or absence of seagrass at each site was defined by the above ground biomass. Survey sites with no seagrass can be found within meadows because seagrass cover within meadows is not always uniform and may be patchy and contain bare gaps or scars. In addition, a visual estimate was made of the overall percent cover of seagrass at each site.

Algae

At 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

At each site, a visual estimate was made of the overall percent cover of algae as well as the relative proportion of the total cover made up of each of the five algal functional groups. All sites within a mapped algae region were grouped to provide a mean percent cover of algae for that region.

Benthic macro-invertebrates (BMI)

At sites where habitat forming BMI were present, they were identified into the following four broad taxonomic groups:

- Hard corals - All massive, branching, tabular, digitate and mushroom scleractinian corals
- Soft corals - All alcyonarian corals i.e. corals lacking a hard limestone skeleton
- Sponges - All sponges were grouped together
- Other BMI - Any other BMI identified e.g. oysters, ascidians, bivalves, gastropods and holothurians

At each site, a visual estimate was made of the overall percent cover of each of the BMI broad taxonomic groups.

Habitat Mapping and Geographic Information System

All survey data were entered into a Geographic Information System (GIS) for presentation of seagrass, algae and BMI distribution and abundance. Rectified Quickbird images of Port Musgrave assisted with mapping. Other information including depth below mean sea level (MSL), substrate type, and the shape of existing geographical features such as reefs and channels was also interpreted and used in determining habitat boundaries.

Several GIS layers were created in ArcGIS® to describe Port Musgrave habitat forming marine communities:

• **Habitat characterisation sites** - point data containing seagrass percent cover and above ground biomass (for each species), algae and BMI percent cover and proportion of functional groups, dbMSL, time, sediment type, latitude and longitude from GPS fixes, sampling method and any comments.

• **Seagrass meadow characteristics** – area data for seagrass meadows with summary information on meadow characteristics. Seagrass community types were determined according to species composition from nomenclature developed for seagrass meadows of Queensland (Table 1). Abundance categories (light, moderate, dense) were assigned to community types according to above-ground biomass of the dominant species (Table 2). Seagrass meadows were assigned a meadow identification number which is used to reference individual meadows throughout the results and for comparison during future monitoring surveys.

• **Seagrass landscape category** – area data showing the seagrass landscape category determined for each meadow:

Isolated seagrass patches
The majority of area within the meadows consisted of unvegetated sediment interspersed with isolated patches of seagrass

Aggregated seagrass patches
Meadows are comprised of numerous seagrass patches but still feature substantial gaps of unvegetated 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 unvegetated sediment.

• **Algae bed characteristics** – area data for significant macro algae forming regions with summary information on habitat characteristics. Density was determined from mean percent cover of overall algae as well as macro-algae type at each site in the mapped area.

• **Habitat forming benthic macro-invertebrate community characteristics** – area data for habitat forming BMI community regions with summary information on habitat characteristics. Density was determined from mean percent cover of the BMI type at each site in the mapped area.

Table 1 Nomenclature for community types in the Port Musgrave 2009

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 Port Musgrave 2009

Density	Mean above ground biomass (g DW m^{-2})				
	Halodule uninervis **(narrow)**	***Halophila ovalis***	***Halophila decipiens***	***Thalassia hemprichii***	***Enhalus acoroides***
Light	< 1	< 1	< 1	< 15	< 40
Moderate	1 - 4	1 - 5	1 - 5	15 - 35	40 - 100
Dense	> 4	> 5	> 5	> 35	> 100

Each seagrass meadow was assigned a mapping precision estimate (±m) based on the mapping methodology used for that meadow (Table 3). Mapping precision estimates ranged from 5m for isolated intertidal seagrass meadows to 200m for larger extremely patchy intertidal meadows. The mapping precision estimate was used to calculate a range of meadow area for each meadow and was expressed as a meadow reliability estimate (R) in hectares. The reliability estimate for subtidal habitat is based on the distance between sites with and without the community-of-interest (i.e. seagrass) when determining the habitat boundary. Additional sources of mapping error associated with digitising aerial photographs into basemaps and with GPS fixes for survey sites were embedded within the meadow reliability estimates.

Table 3 Mapping precision and methodology for seagrass meadows in the Port Musgrave 2009

Mapping precision	Mapping methodology
5m	Meadow boundaries mapped in detail by GPS from helicopter; Intertidal meadows completely exposed or visible at low tide; Relatively high density of mapping and survey sites; Recent aerial photography aided in mapping.
10-50m	Meadow boundaries determined from helicopter and camera/grab; Offshore boundaries interpreted from survey sites and aerial photography; Relatively high density of mapping and survey sites;
100m	Meadow boundary interpreted from helicopter and camera/grab; All meadows with inshore boundary exposed and offshore boundary subtidal; Relatively high density of survey sites; Recent aerial photography aided in mapping.
200m	Intertidal meadow boundaries interpreted from helicopter and subtidal meadows; Very light and patchy cover of seagrass throughout meadow; Moderate density of survey sites; Recent aerial photography aided in mapping.

RESULTS

The first baseline survey was conducted between the 31st March and 6th of April 2009. This initial baseline was conducted at a time of year that typically follows heavy wet-season rainfall and catchment flows through the Wenlock and Ducie Rivers. A dry season survey was subsequently conducted from 16 – 23rd of September 2009 to provide a seasonal baseline on seagrass and other benthic habitat type dynamics.

The 2009 baseline surveys were the first detailed seagrass, algae and marine habitat assessments conducted for the Port Musgrave area. In general, seagrass, algae and benthic macro–invertebrate communities within the survey area were typical of estuarine habitats in the region including nearby Weipa (Chartrand and Rasheed 2009) and Skardon River (Roelofs *et al.* 2004).

In April 2009, 808 habitat characterisation sites were surveyed with an additional 851 sites assessed during September 2009 (Map 1a,b). During both surveys, the survey area was dominated by mud substrate with areas of shallow sand/mud banks on the perimeter consisting of low density areas of seagrass (Figure 1), algae (Figure 2) and oyster beds (Figure 3). The majority of the subtidal areas were comprised of open substrate (Figure 4). The proposed shipping channel route consisted of open mud substrate with no areas of seagrass, algae or significant benthic macro-invertebrate communities, although seagrass communities occurred on the mudbank between the Ducie and Wenlock Rivers and adjacent to the shipping channel near Cullen Point and near the mouth of Namaleta Creek (Maps 1-4).

Figure 1. Camera drop surveys at the intertidal/subtidal interface

Figure 2. Filamentous algae beds surveyed from the helicopter at spring low tide

Figure 3. Oyster beds on the intertidal banks adjacent to the Mapoon community

Figure 4. Open mud substrate as seen from the CCTV camera system during sled tows in the subtidal zone

Seagrass species, distribution and abundance

Five species (from two families) were identified in the survey area during the wet and dry season baseline surveys in 2009:

Family		Species and Species Description
CYMODOCEACEAE Taylor		***Halodule uninervis* (Forsk) Aschers** (wide and narrow leaf morphology) • Narrow leaf blades 0.25-5mm wide • Trident leaf tip ending in three points • 1 central longitudinal vein which does not usually split into two at the tip • Usually pale ivory rhizome, with clean black leaf scars along the stem • Dugong preferred food
HYDROCHARITACEAE Jussieu		***Halophila ovalis* (R. Br.) Hook F.** • Small oval shaped leaves (0.5 - 2cm long) • 8 or more cross-veins on leaf • No hairs on leaf surface • Dugong preferred food
		***Halophila decipiens* Ostenfeld** • Small oval shaped leaves (1.0 – 2.5cm long) • 6-9 pairs of cross-veins on leaf • Hairs on leaf surface • Dugong preferred food
		***Thalassia hemprichii* (Ehrenb.) Aschers.** • Long, ribbon-like leaves 10-40cm long • 10-17 longitudinal leaf veins • Short black bars of tannin cells on leaf blade • Leaf sheaths 3-7cm long • Thick rhizome (up to 5mm) with conspicuous scars between shoots
		***Enhalus acoroides* (R.f.) Royle** • Very distinctive seagrass • Very long, ribbon-like leaves (30-150cm long, 1.25 - 1.75cm wide) • Thick leaves with many parallel veins • Very thick rhizome (at least 1cm) with black, fibrous bristles

Seagrass was found on most intertidal mudbanks with a smaller proportion of subtidal seagrass found in the survey area (Maps 1-4). The densest seagrass meadows occurred on the western banks along the Mapoon community shoreline starting from Cullen Point and running approximately 12km along the shoreline and out to a maximum of 1km offshore (Maps 1-2). Most seagrass was found on substrates dominated by mud or mud/sand with a small composition of shell. No seagrass was found in depths greater than 2.6m below MSL in the wet and 2.1m below MSL in the dry.

Eight mixed species meadow types of varying density were identified in the wet and dry season baseline surveys (Maps 2-4). These were categorised according to species presence and dominance in each meadow:

1. *Halodule uninervis* (narrow)
2. *Halodule uninervis* (narrow) with *Halophila ovalis*
3. *Halodule uninervis* (narrow) with mixed species
4. *Halophila ovalis*
5. *Halophila decipiens*
6. *Halophila decipiens* with mixed species
7. *Enhalus acoroides*
8. *Enhalus acoroides* with mixed species

A total of 689.3 ± 388.2 ha of seagrass habitat was mapped in the wet season (April) and 1295.8 ± 637.5 ha in the dry season (September) (Table 4-5). Meadow area ranged from 0.1 to 294 ha with the smallest meadow located on an intertidal mudbank at the southern tip of the Mapoon community (Meadow 9) and the largest an intertidal meadow on the shoreline of the Mapoon community (Meadow 3; Map 2-3). Overall seagrass meadow area was dominated by *Halodule uninervis* (narrow) (with other species variants) in the wet season (73% of total meadow area). In the dry season, *Halodule uninervis* comprised a smaller proportion of the overall seagrass area (43%) with a corresponding increase in meadow area dominated by *Halophila* (38%).

In the wet season (April), ten individual meadows were mapped with nine of these found in the intertidal zone (Table 4; Map 1a). The majority of seagrass was present along the shoreline of the Mapoon community where seagrass cover was continuous on the northern section of the bank and formed aggregated patches to the south (Map 2a). Other less dense and patchier meadows were found in intertidal areas including on the mud bank to the east of Namaleta Creek, at the junction of the Ducie and Wenlock Rivers and a small patch of seagrass on the western bank near the mouth of the Wenlock River (Maps 1-4).

In the dry season (September), the majority of seagrass area mapped was once again present including the main area of seagrass adjacent to the Mapoon community. There were some changes to small isolated patch meadows between the two surveys but the most significant change was the addition of two new large areas of seagrass in the dry season:

- A large subtidal meadow (Meadow 11, 237.85 ± 172.4 ha) located adjacent to the intertidal meadows along the Mapoon community (Map 2b). The meadow was dominated by *Halophila decipiens* with a smaller component of *Halophila ovalis* and *Halodule uninervis* (narrow).

- A large intertidal meadow (Meadow 13, 245.96 ± 64.2 ha) located on the bank at the junction of the Ducie and Wenlock Rivers (Map 2b). The meadow was entirely composed of *Halophila ovalis* in isolated patches.

Meadows common to both the wet and dry season surveys maintained similar area and biomass with the exception of the *Enhalus acoroides* dominated meadows adjacent to Namaleta Creek and at the junction of the Ducie and Wenlock Rivers (Meadows 5 and 7; Maps 3-4; Figure 5). The landscape of the majority of meadows remained unchanged between surveys with isolated patches most common. Meadow 1 along the Mapoon shoreline was the only meadow to have higher density and coverage in the wet season with continuous cover with a shift to aggregated patches during the dry (Map 2).

Total mean above-ground seagrass biomass in Port Musgrave increased from the wet season survey to the dry season in 2009. Mean above-ground biomass for individual meadows ranged from 0.04 ± 0.04 gDW m^{-2} in the light *Halodule uninervis* (narrow) meadow (Meadow 6) in April to 5.96 ± 1.70 gDW m^{-2} in the light *Enhalus acoroides* with mixed species meadow (Meadow 7) in September. Above-ground biomass did not change significantly in most meadows that occurred in both the wet and dry season survey with the exception of meadows 1 and 5 (Figure 5, see Appendix). Species composition also remained fairly stable between seasons in most meadows (Figure 5). Meadow 2 did see a shift between *Halophila ovalis* and *Halophila decipiens* between surveys however these are closely related species with similar life history traits and morphology. The composition of Meadows 6 and 7 both changed slightly with the addition of *Halophila ovalis* during the dry season survey (35% and 10% of meadow species respectively).

There was evidence of use of many seagrass meadows by dugong and turtles. Dugong feeding trails were observed in many of the *Halodule uninervis* (narrow) and *Halophila ovalis* meadows, particularly along the Mapoon shoreline (Figure 6). In Meadows 1 and 3, dugong feeding trails were found at 40% and 13% of sites surveyed respectively in April and 21% and 42% of sites in September respectively. Turtles were also commonly sighted over the seagrass meadows throughout the survey area.

Table 4 Seagrass community types, mean above ground biomass and area in the Port Musgrave, April 2009.

Meadow ID	Community type	Species Present	Mean meadow biomass g DW m^{-2} ± SE	Number of sites	Area ± R (ha)
1 Intertidal/Subtidal	Moderate *Halodule uninervis* (narrow) with mixed species	*Halodule uninervis* (narrow), *Thalassia hemprichii, Halophila ovalis, Enhalus acoroides*	2.76 ± 0.55	43	202.55 ± 111.7
2 Subtidal	Light *Halophila ovalis*	*Halophila ovalis*	NA*	2	26.9 ± 19.9
3 Intertidal	Moderate *Halodule uninervis* (narrow) with mixed species	*Halodule uninervis* (narrow), *Thalassia hemprichii, Halophila ovalis*	3.20 ± 0.48	32	241.34 ± 126.6
4 Intertidal	Moderate *Halodule uninervis* (narrow)	*Halodule uninervis* (narrow)	1.61 ± 1.59	5	4.36 ± 4.0
5 Intertidal	Light *Enhalus acoroides*	*Enhalus acoroides*	0.17 ± 0.13	22	155.5 ± 123.4
6 Intertidal	Light *Halodule uninervis* (narrow)	*Halodule uninervis* (narrow)	0.04 ± 0.04	17	57.12 ± 2.12
7 Intertidal	Light *Enhalus acoroides*	*Enhalus acoroides*	2.77	1	0.81 ± 0.17
8 Intertidal	Light *Enhalus acoroides*	*Enhalus acoroides*	NA*	1	0.28 ± 0.10
9 Intertidal	Light *Halodule uninervis* (narrow)	*Halodule uninervis* (narrow)	0.61	1	0.11 ± 0.14
10 Intertidal	Light *Enhalus acoroides*	*Enhalus acoroides*	NA*	1	0.30 ± 0.11
Total All Meadows				**125**	**689.27 ± 388.24**

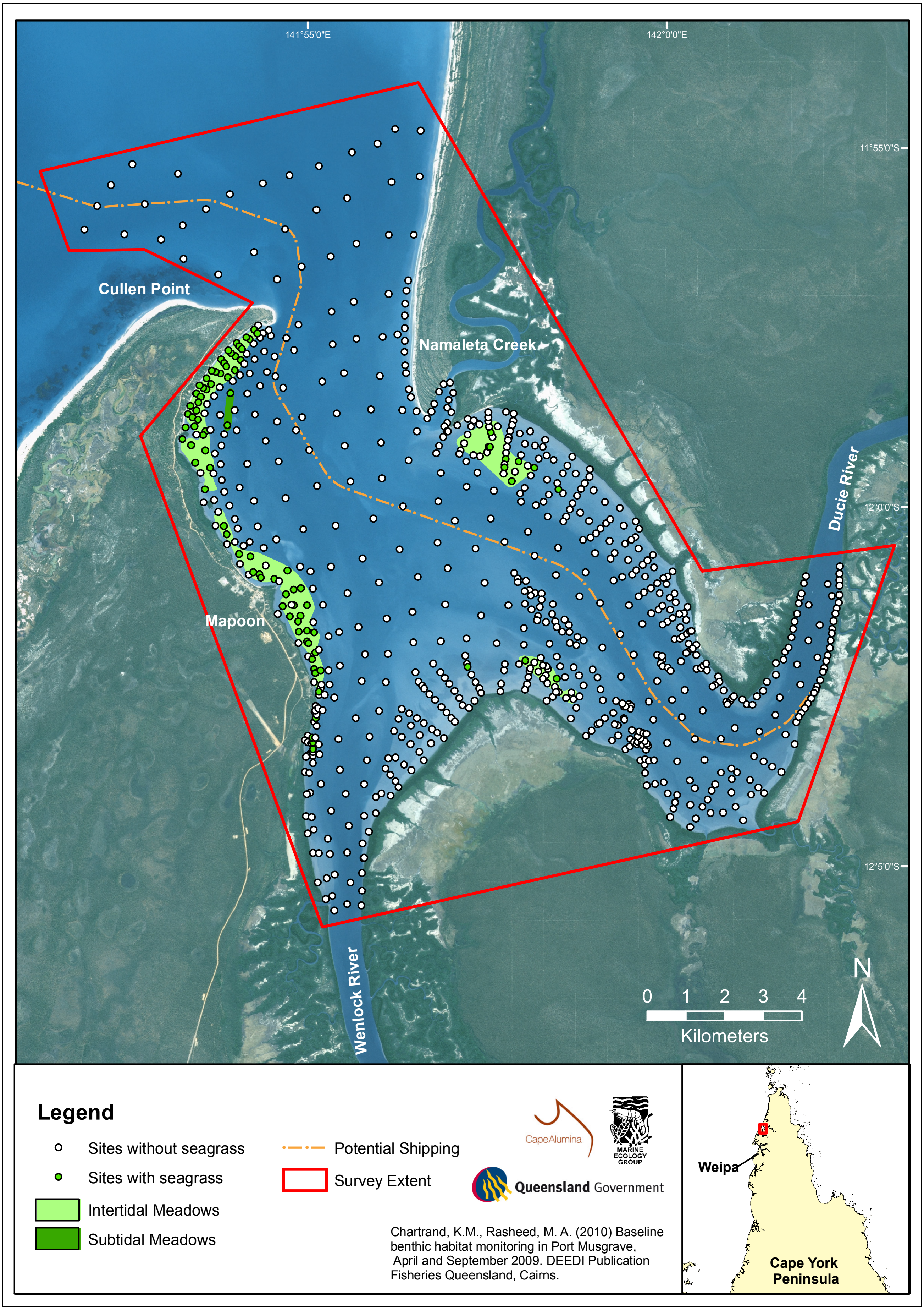
NA* - Seagrass present at site but too sparse to record biomass

Table 5 Seagrass community types, mean above ground biomass and area in Port Musgrave, September 2009.

Meadow ID	Community type	Species Present	Mean meadow biomass g DW m^{-2} ± SE	Number of sites	Area ± R (ha)
1 Intertidal/Subtidal	Light *Halodule uninervis* (narrow) with mixed species	*Halodule uninervis* (narrow), *Enhalus acoroides, Halophila decipiens, Halophila ovalis, Thalassia hemprichii*	1.62 ± 0.39	47	203.54 ± 136
2 Subtidal	Light *Halophila decipiens*	*Halophila decipiens*	1.67	1	4.72 ± 11.2
3 Intertidal	Moderate *Halodule uninervis* (narrow) with mixed species	*Halodule uninervis* (narrow), *Enhalus acoroides, Halophila ovalis, Thalassia hemprichii*	3.32 ± 0.51	38	294.34 ± 148.4
4 Intertidal	Moderate *Halodule uninervis* (narrow)	*Halodule uninervis* (narrow)	2.79 ± 0.95	6	7.28 ± 0.67
5 Intertidal	Light *Enhalus acoroides*	*Enhalus acoroides*	1.07 ± 0.33	23	214.98 ± 70.4
6 Intertidal	Light *Halodule uninervis* (narrow) with *Halophila ovalis*	*Halodule uninervis* (narrow), *Halophila ovalis*	0.15 ± 0.09	22	54.37 ± 2.4
7 Intertidal	Light *Enhalus acoroides* with mixed species	*Enhalus acoroides, Halodule uninervis* (narrow), *Halophila ovalis*	5.96 ± 1.70	5	31.66 ± 31.6
9 Intertidal	Light *Halodule uninervis* (narrow)	*Halodule uninervis* (narrow)	2.92 ± 1.76	2	1.94 ± 0.31
11 Subtidal	Moderate *Halophila decipiens* with mixed species	*Halophila decipiens, Halodule uninervis* (narrow), *Halophila ovalis*	3.15 ± 0.58	26	237.85 ± 172.4
12 Intertidal	Light *Halodule uninervis* (narrow)	*Halodule uninervis* (narrow)	NA*	1	1.08 ± 0.2
13 Intertidal	Light *Halophila ovalis*	*Halophila ovalis, Enhalus acoroides*	1.02 ± 0.31	27	245.96 ± 64.2
Total All Meadows				**196**	**1295.78 ± 637.47**

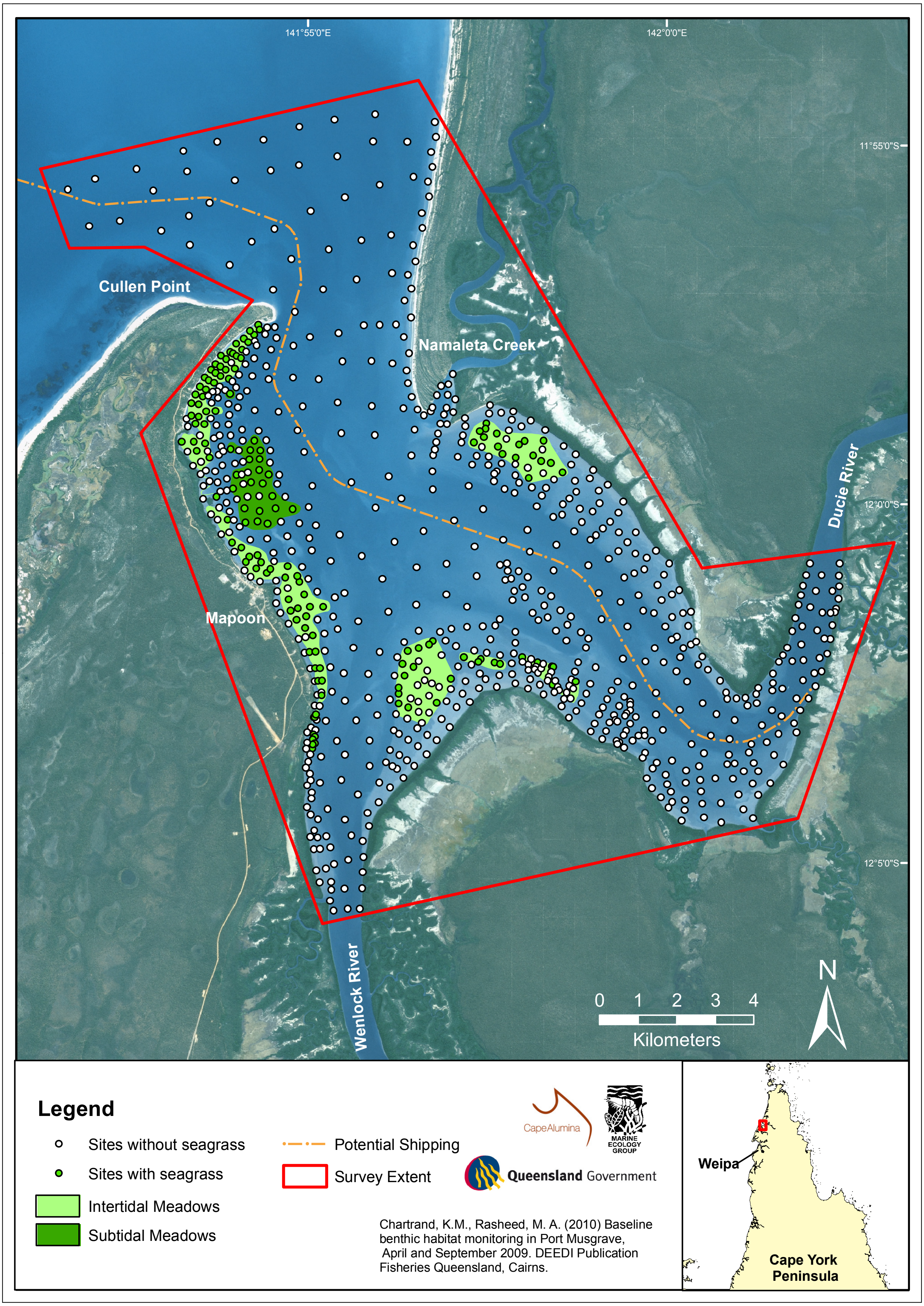
NA* - Seagrass present at site but too sparse to record biomass

Map 1a. Location of wet season (April) baseline 2009 seagrass assessment sites and seagrass meadows in Port Musgrave

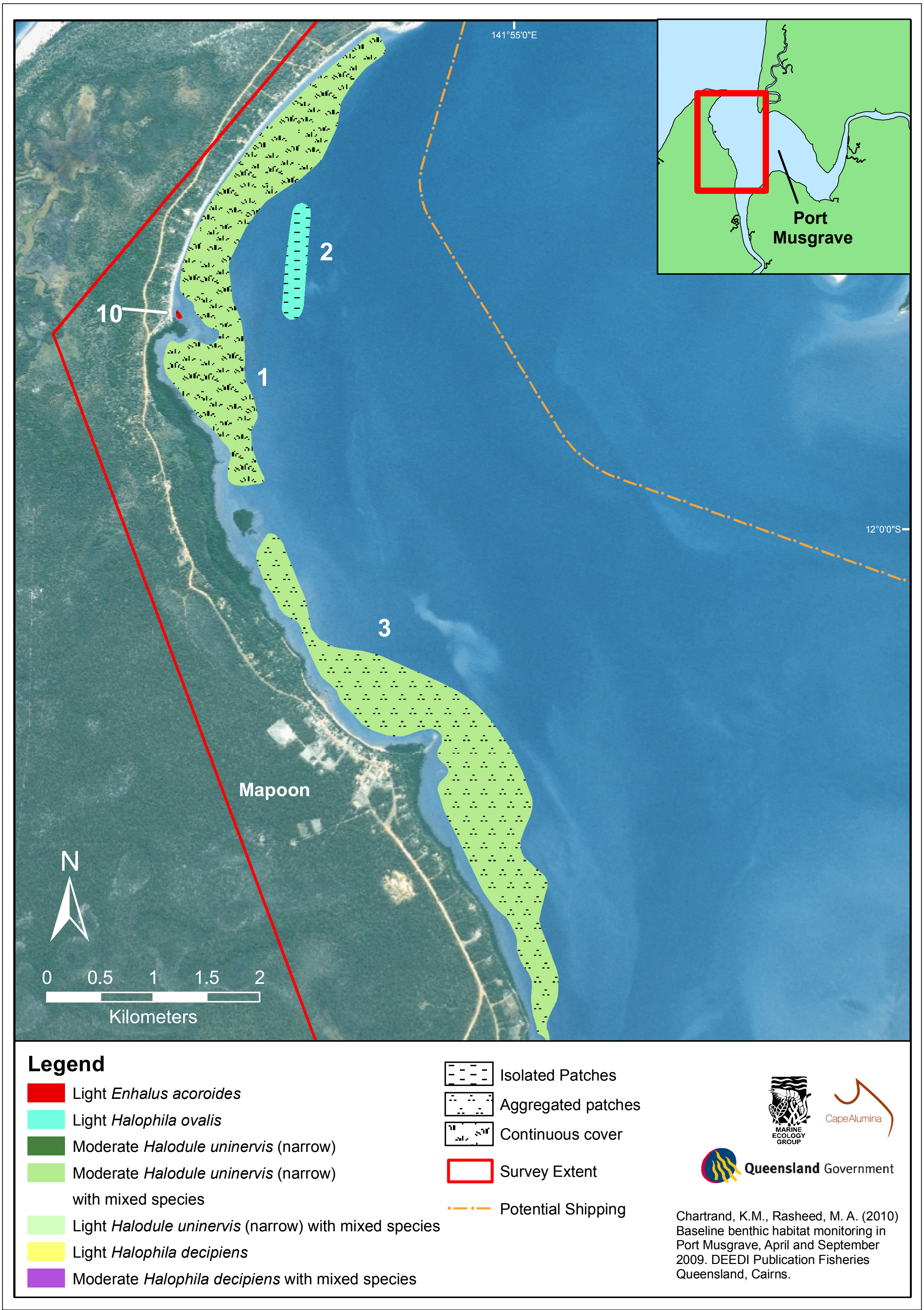


Chartrand, K.M., Rasheed, M. A. (2010) Baseline benthic habitat monitoring in Port Musgrave, April and September 2009. DEEDI Publication Fisheries Queensland, Cairns.

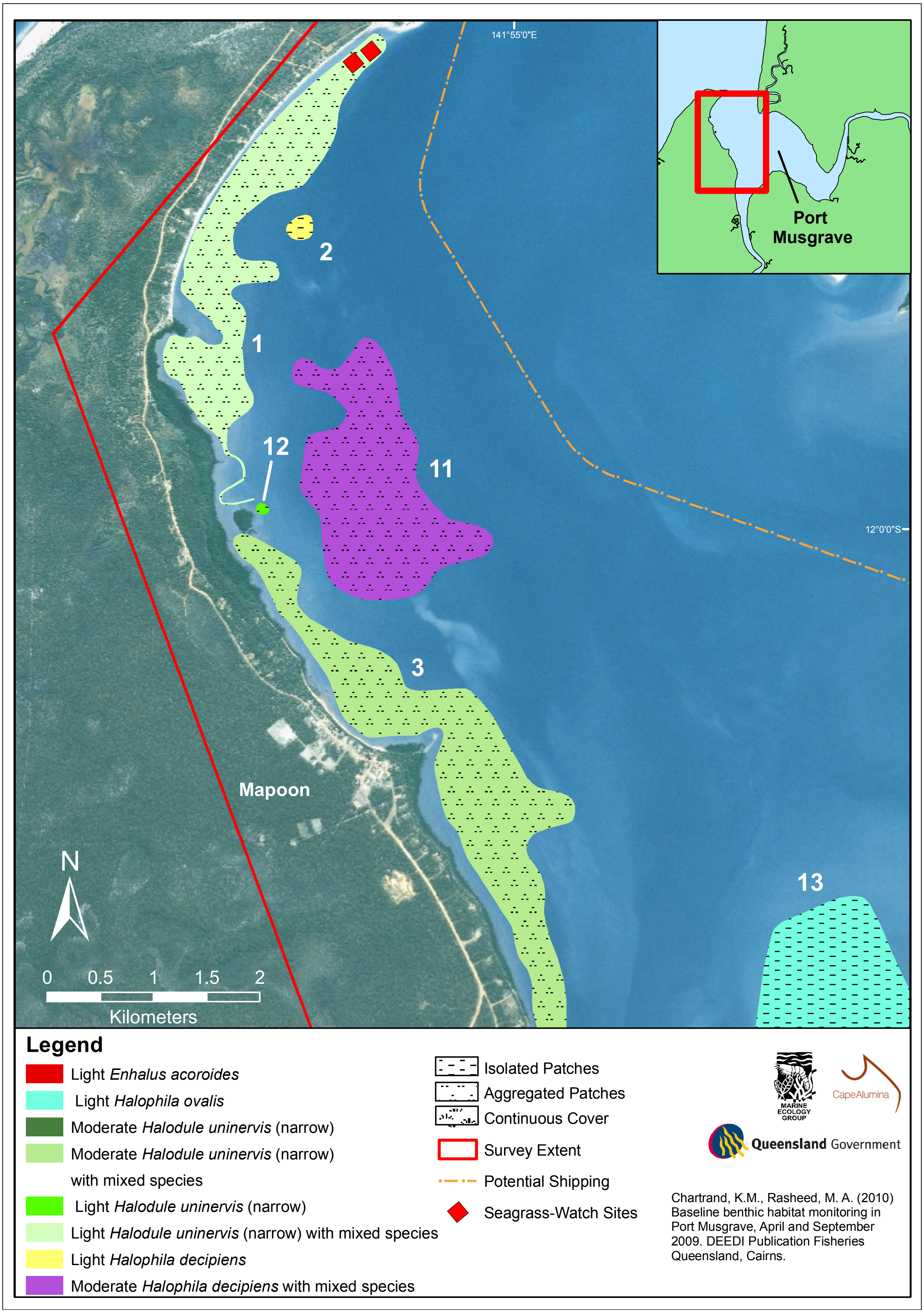
Map 1b. Location of dry season (September) baseline 2009 seagrass assessment sites and seagrass meadows in Port Musgrave



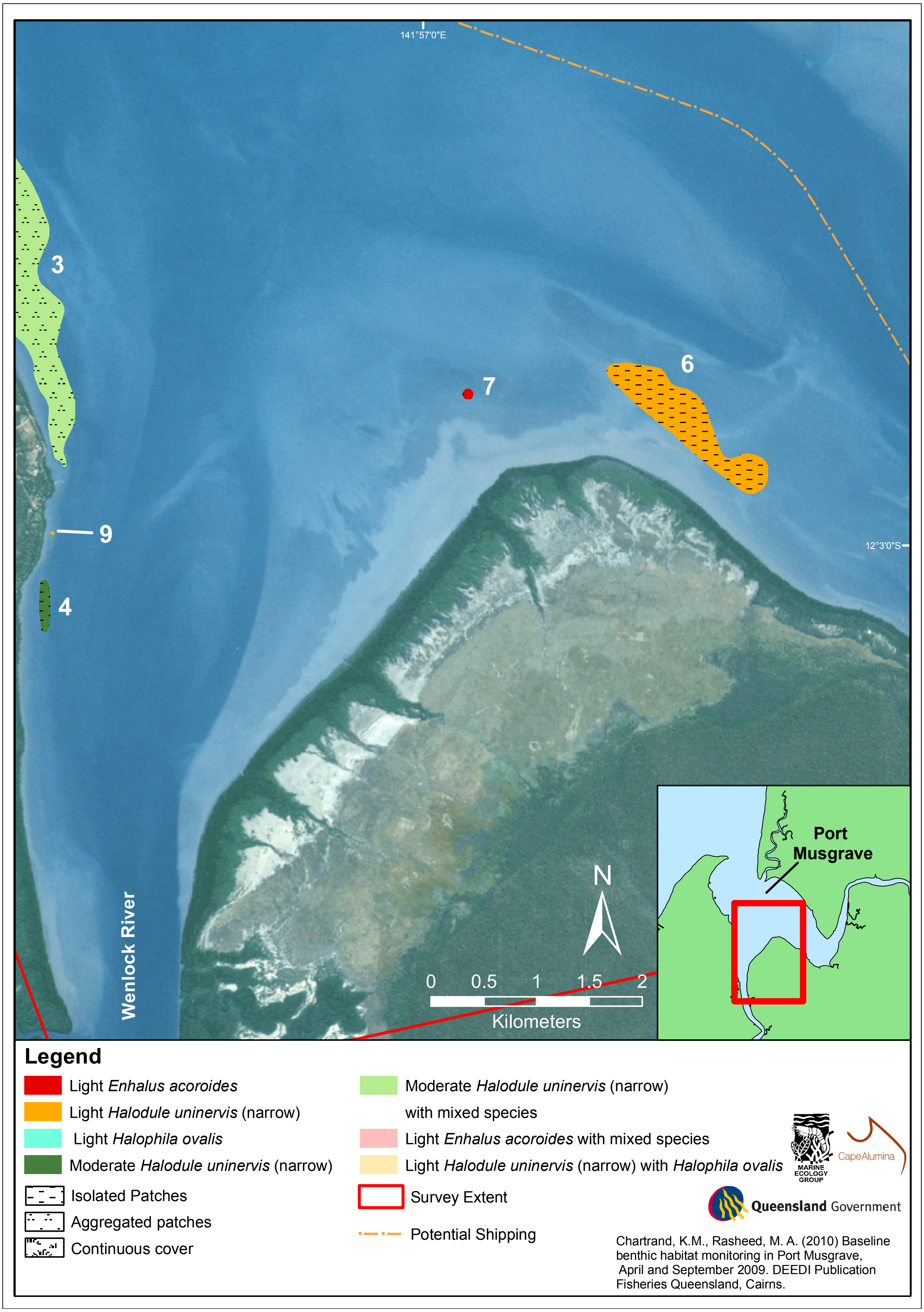
Map 2a. Wet season 2009 seagrass meadow composition and cover type in Port Musgrave



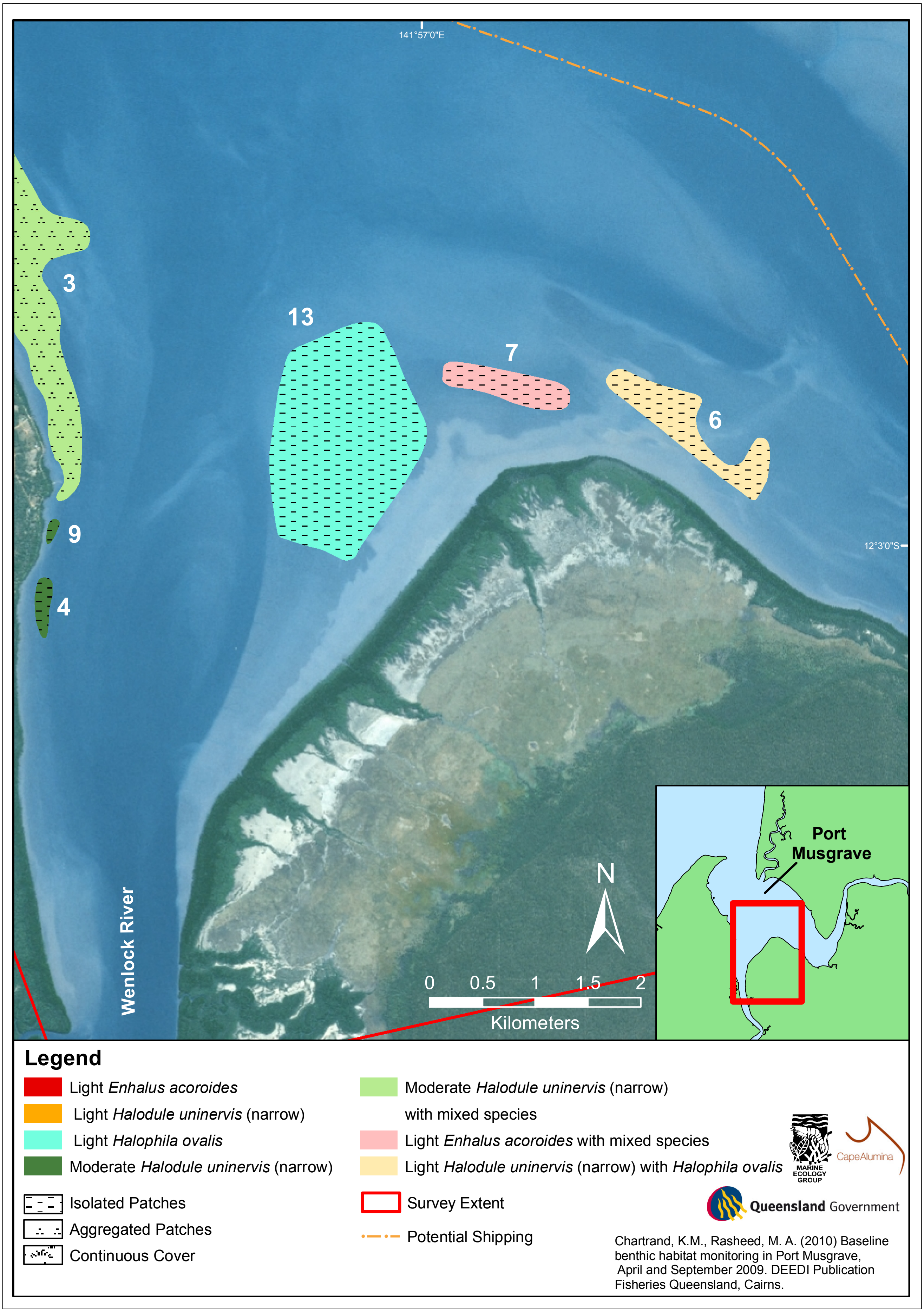
Map 2b. Dry season 2009 seagrass meadow composition and cover type in Port Musgrave



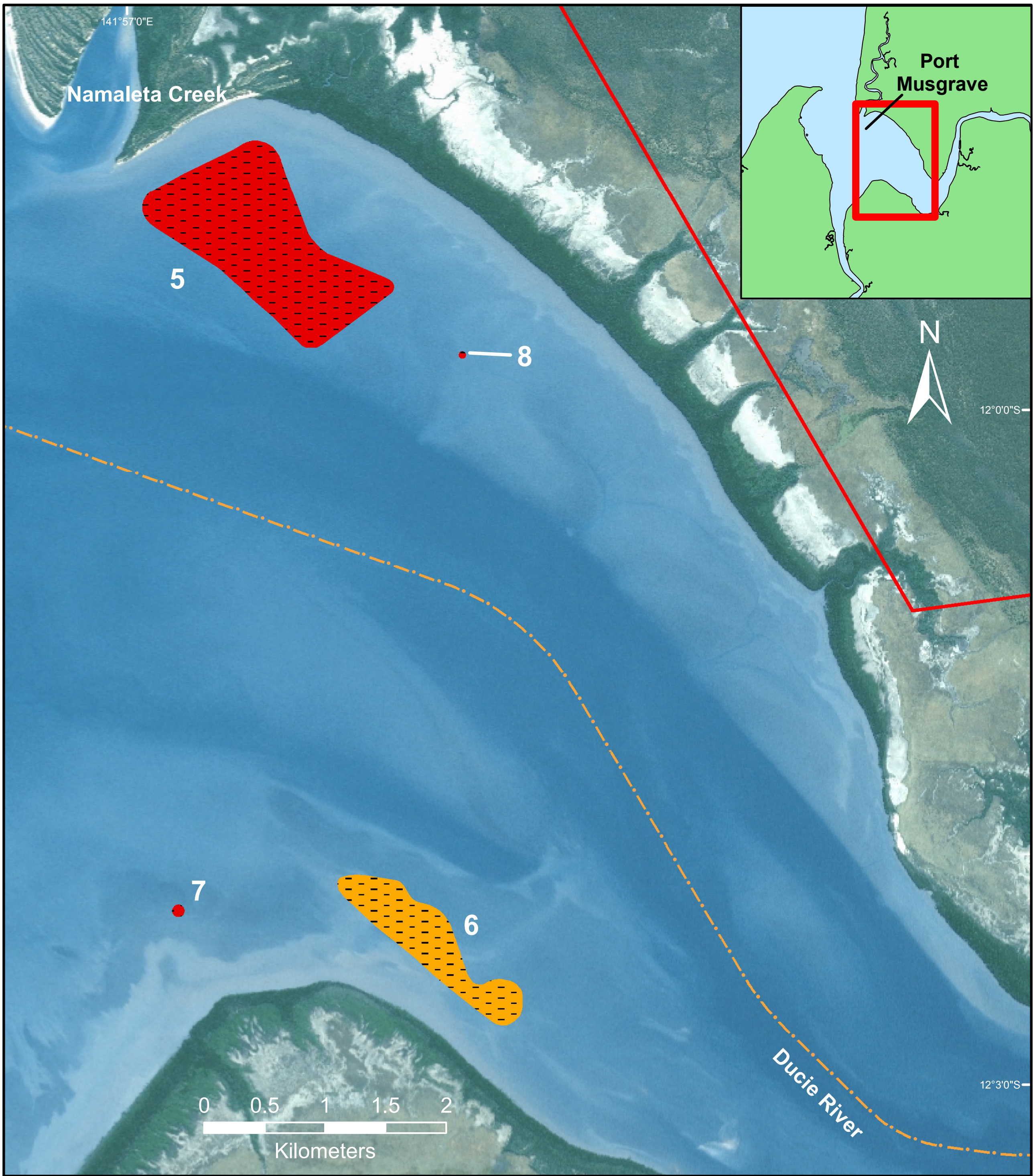
Map 3a. Wet season 2009 seagrass meadow composition and cover type in Port Musgrave



Map 3b. Dry season 2009 seagrass meadow composition and cover type in Port Musgrave



Map 4a. Wet season 2009 seagrass meadow composition and cover type in Port Musgrave



Legend

- Light *Enhalus acoroides*
- Light *Halodule uninervis* (narrow)
- Light *Halophila ovalis*
- Light *Enhalus acoroides* with mixed species
- Light *Halodule uninervis* (narrow) with *Halophila ovalis*

- Isolated Patches
- Aggregated patches
- Continuous cover
- Survey Extent
- Potential Shipping

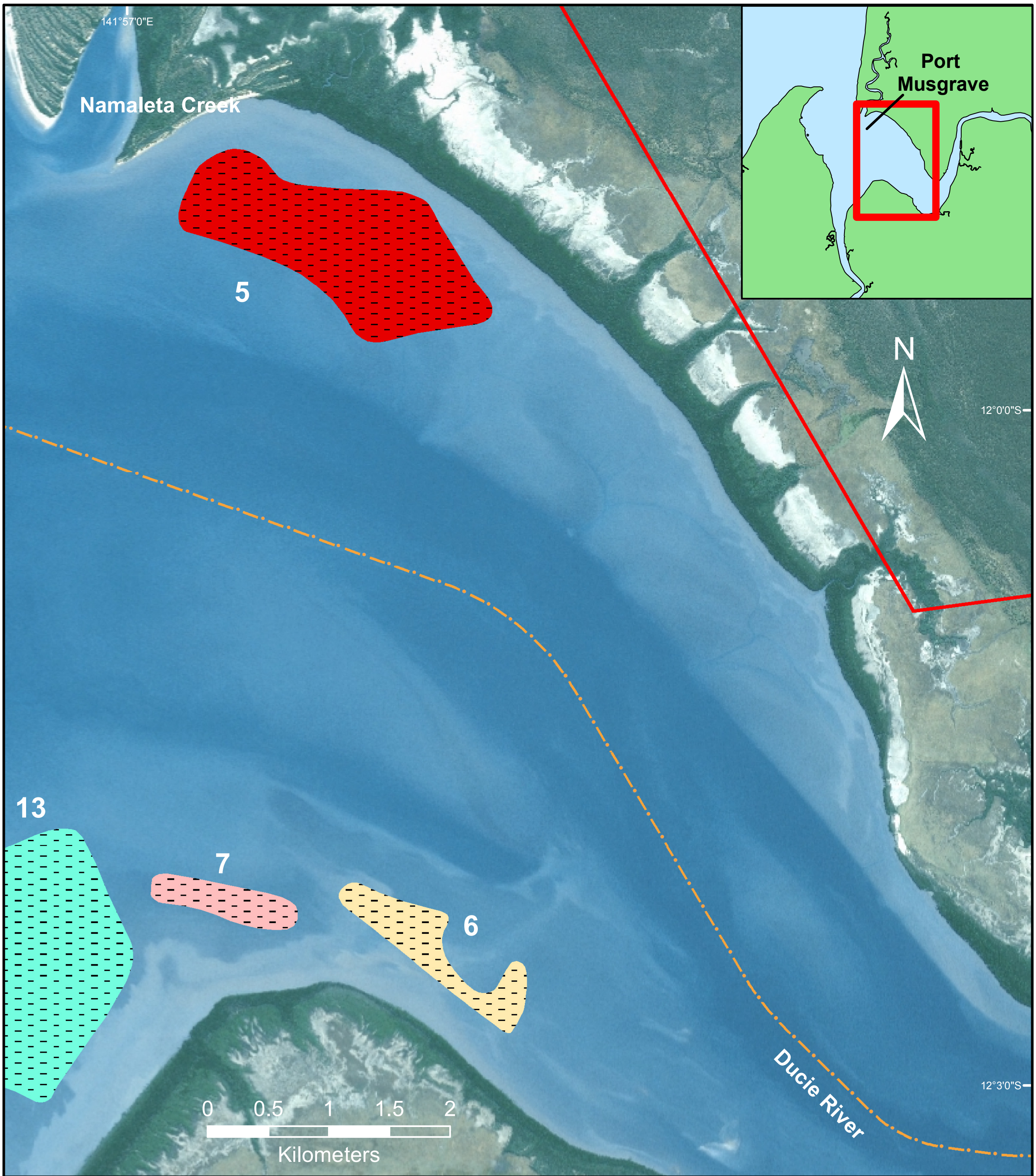
MARINE ECOLOGY GROUP

CapeAlumina

Queensland Government

Chartrand, K.M., Rasheed, M. A. (2010) Baseline benthic habitat monitoring in Port Musgrave, April and September 2009. DEEDI Publication Fisheries Queensland, Cairns.

Map 4b. Dry season 2009 seagrass meadow composition and cover type in Port Musgrave



Legend

- Light *Enhalus acoroides*
- Light *Halodule uninervis* (narrow)
- Light *Halophila ovalis*
- Light *Enhalus acoroides* with mixed species
- Light *Halodule uninervis* (narrow) with *Halophila ovalis*
- Isolated Patches
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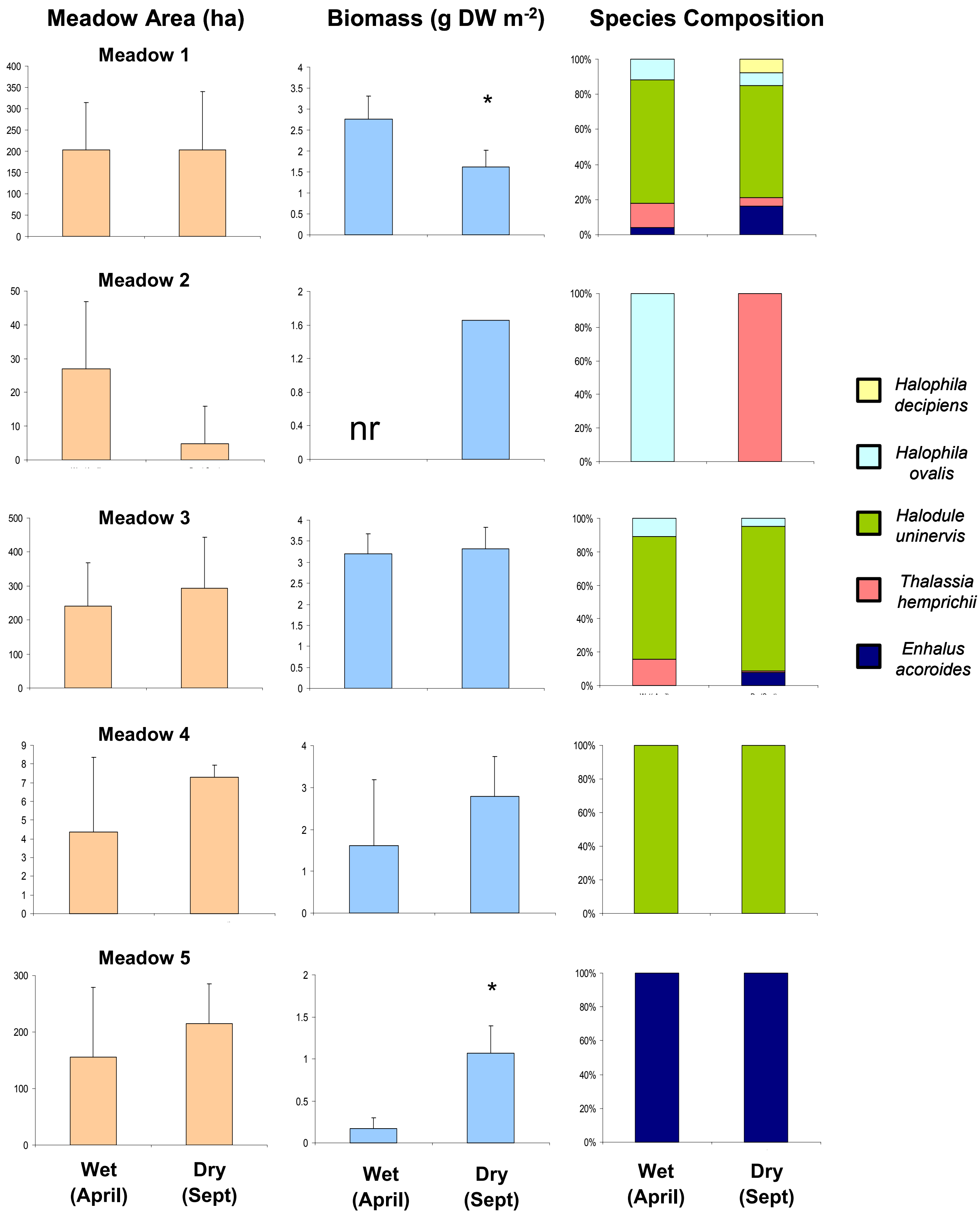


* Significant – see One-Way ANOVA table in the Appendix

Figure 5. Changes in meadow area, biomass and species composition for seagrass meadows in Port Musgrave between the wet season and dry season 2009. (np – not present, nr – not recorded)

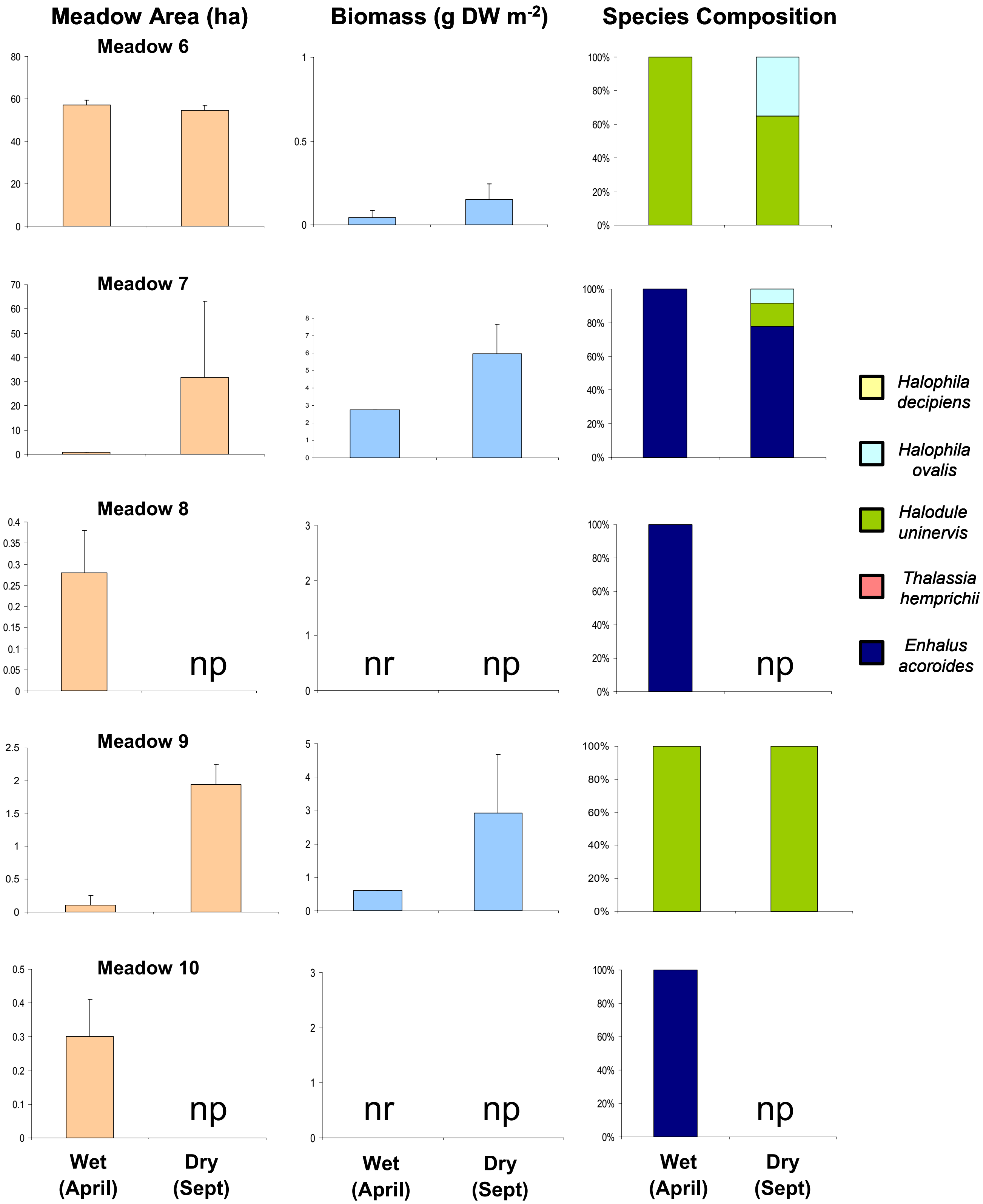


Figure 5. Changes in meadow area, biomass and species composition for seagrass meadows in Port Musgrave between the wet season and dry season 2009. (np – not present; nr – not recorded, seagrass present in meadow but too sparse to record biomass)

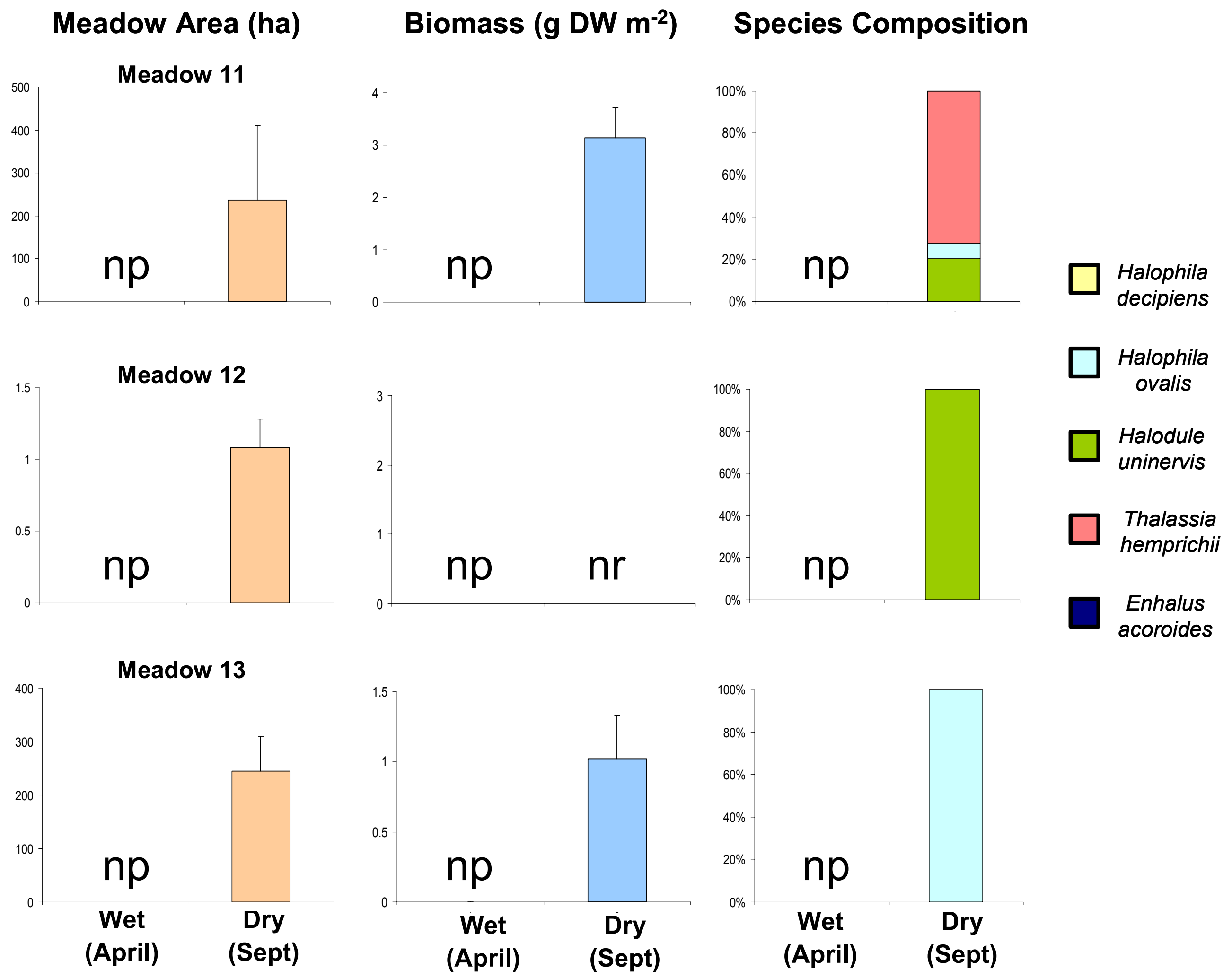


Figure 5. Changes in meadow area, biomass and species composition for seagrass meadows in Port Musgrave between the wet season and dry season 2009. (np – not present; nr – not recorded, seagrass present in meadow but too sparse to record biomass)

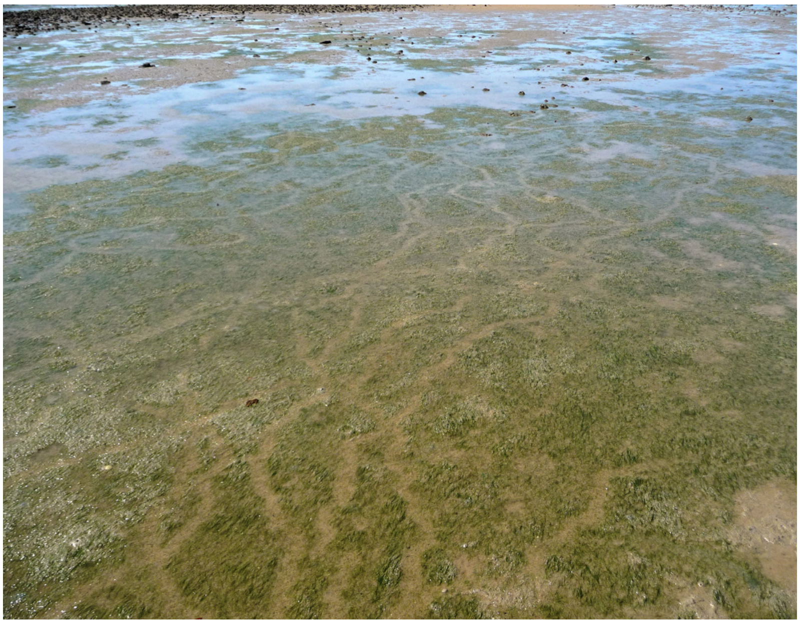


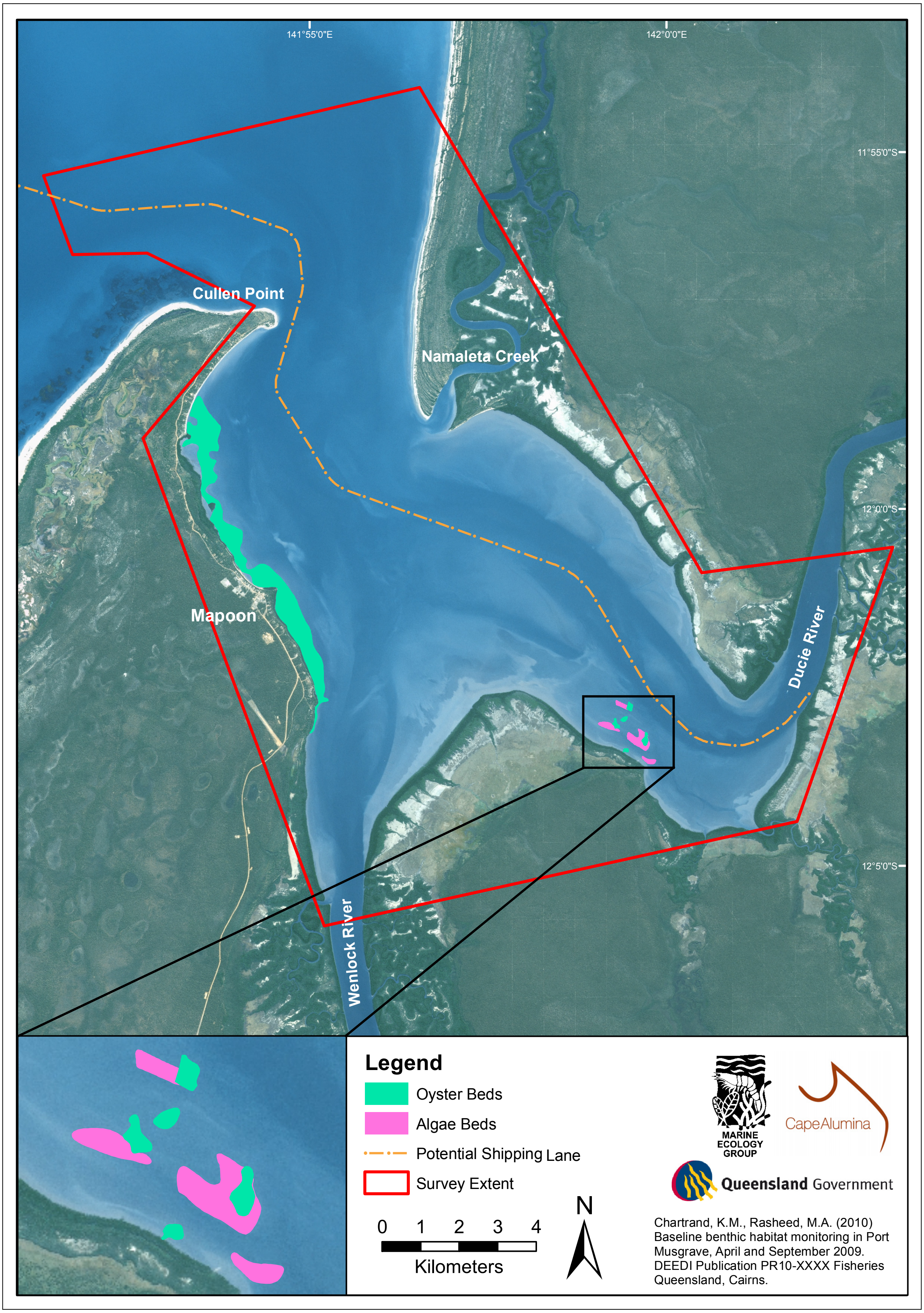
Figure 6. Dugong feeding trails observed from the helicopter in Meadow 1

Other Significant Benthic Habitat Forming Communities

Algae formed a very low percent coverage (≤1%) of the benthos in both intertidal and subtidal areas throughout Port Musgrave during both baseline surveys. The major functional groups present were filamentous, turf and erect macrophytic algae. Microalgae formed thin films on many of the intertidal mudbanks but did not represent a significant habitat or community group to be mapped and included in further analysis as part of the baseline survey. Filamentous algae beds in Port Musgrave were present only during the wet season survey on intertidal sandbanks at the mouth of the Ducie River (Figure 2, Map 5). These algae beds were high density mats (≥50% cover) consisting of a single unidentified filamentous species. These dense filamentous beds along with any other significant functional algae group were not present during the dry season survey and therefore no map is presented to represent the seasonal distribution. Turf and erect algae forms were also interspersed within seagrass beds at very low densities but did not form definitive beds (Map. 5).

Extensive oyster beds were recorded on intertidal banks along the Mapoon shoreline interspersed within the 12km seagrass meadow and covering an area of 367 ha (Map. 5). Oysters were also present in isolated pockets throughout the survey area on shallow banks at the mangrove/mudbank interface but at densities too sparse to map into discrete beds. The oyster population was quite stable between surveys and therefore was not re-mapped between seasonal surveys.

Map 5. Algae and oyster beds in Port Musgrave during the wet season, April 2009



Comparison with Historical Seagrass Data

A previous survey of coastal seagrasses in the Port Musgrave area was conducted by Fisheries Queensland (then the Department of Primary Industries) in October/November 1986 as part of a broader scale mapping project to assess juvenile prawn populations (Coles *et al.* in prep). These surveys did not sample at the same intensity as the present biannual baselines and were unable to reach a significant portion of the shallow intertidal areas within Port Musgrave. As a consequence direct statistical comparisons were not appropriate, however, the 1986 survey provides a perspective on species composition and distribution in the area.

In the 1986 survey, *Halophila decipiens* and *Halodule uninervis* (narrow) were found in the vicinity of Meadows 1 and 2. *Halophila decipiens* and *Halodule uninervis* (narrow) were also found near the eastern bank at one site (at 10-50% cover) offshore from the *Enhalus acoroides* (Meadow 5) mapped in the 2009 wet and dry season baselines (Map 4). No seagrass was mapped on the mudbanks at the junction of the Ducie and Wenlock Rivers and *Enhalus acoroides* was not observed during these early assessments of Port Musgrave. The difference in findings between 1986 and 2009 may be due to the limitations in the 1986 survey methodology rather than the absence of meadows and species.

Port Musgrave Climate Data

Climate data for the Port Musgrave area is derived from the Weipa Airport weather station, the closest available information for the region. Total annual rainfall was below average in 2009 (since 1973; Figure 7). Solar radiation was higher in September than during the April survey which follows typical seasonally higher solar radiation from September to November (Figure 8). Maximum average monthly air temperature has trended upwards slightly from 2000 to present. September 2009 had on average a 2.5°C higher maximum average air temperature than during the April survey (Figure 9).

Tidal exposure of intertidal seagrass banks in the Port Musgrave region is typically higher during the dry season with peak exposure from June to August (Figure 10). A decline in exposure results in less desiccation and extreme temperature conditions at the seagrass blade surface. Concurrently, higher tides may result in less irradiance reaching certain depths which may impact on the ability to maintain positive net productivity for some subtidal and lower intertidal species in turbid waters. The interactions of these two conflicting conditions will impact on local seagrass dynamics as tidal regimes shift over time. At this stage, it is too early to distinguish these relationships between seagrass dynamics and environmental parameters in Port Musgrave, however some of these questions can be answered as a long term dataset develops for Port Musgrave seagrasses.

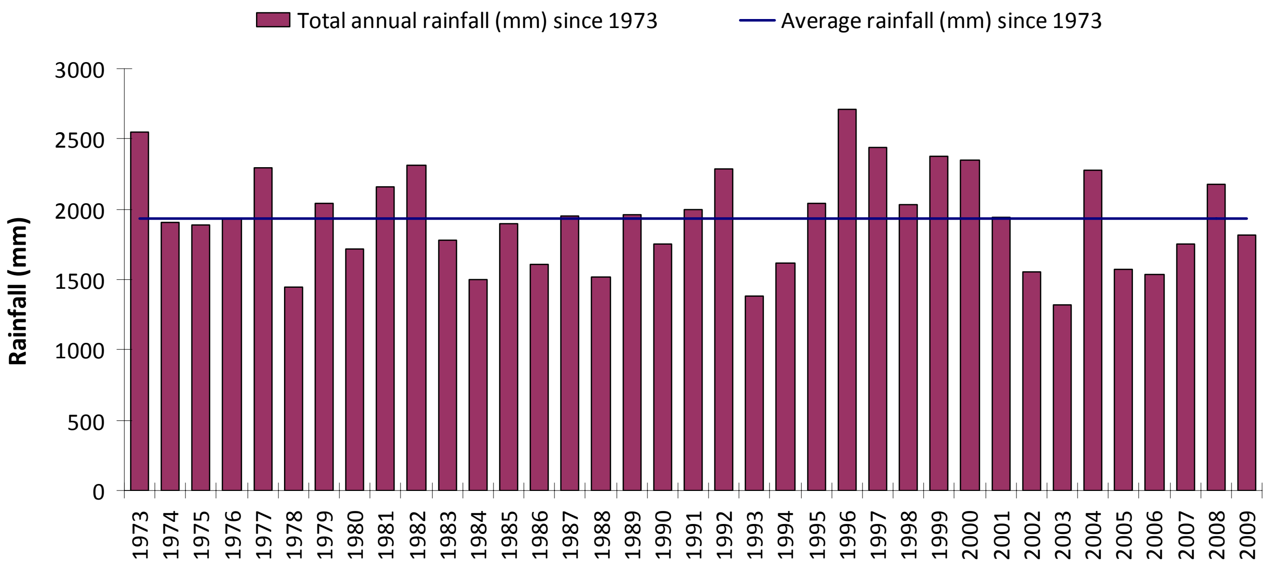


Figure 7. Total annual rainfall at Weipa airport from 1973 – 2009 (Bureau of Meteorology, 2009)

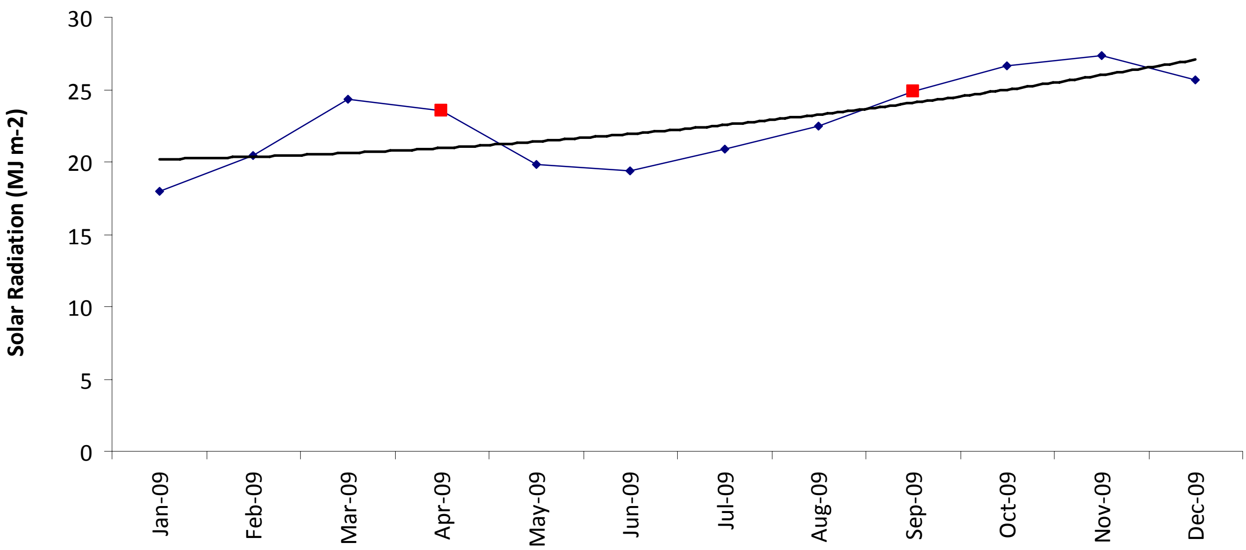


Figure 8. Mean monthly maximum solar radiation recorded at Weipa airport in 2009 (Bureau of Meteorology, 2009)

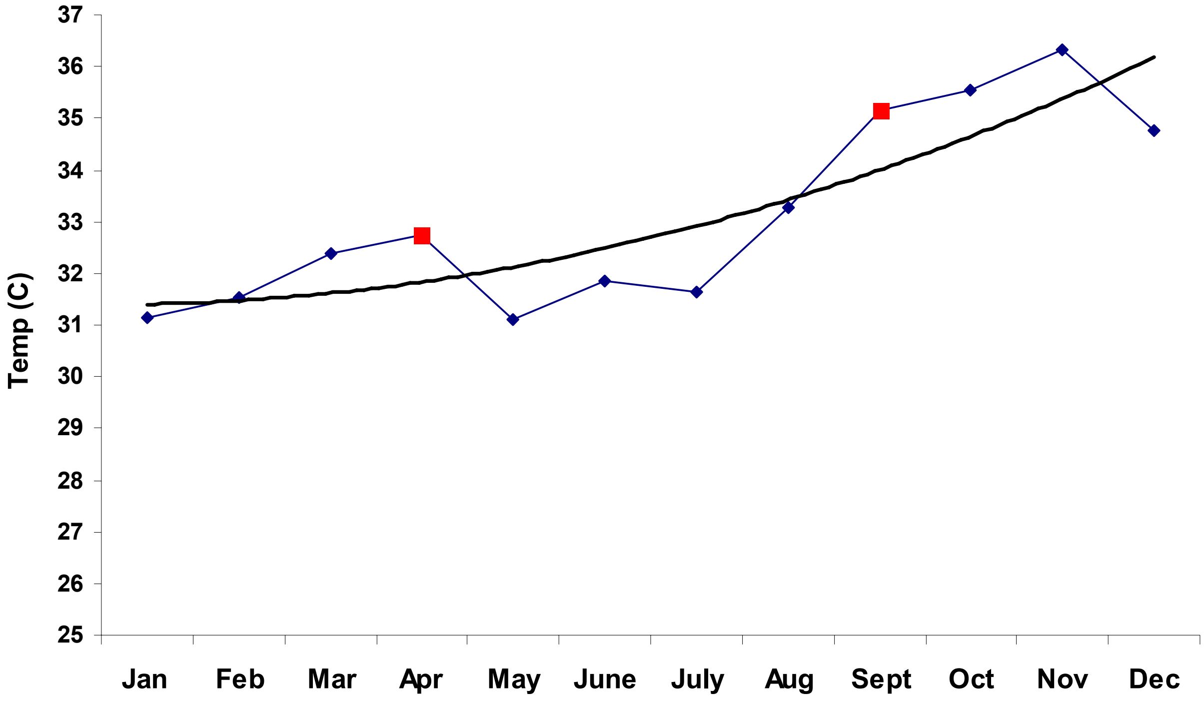


Figure 9. Average monthly maximum mean temperature recorded at Weipa airport in 2009 (Bureau of Meteorology, 2009)

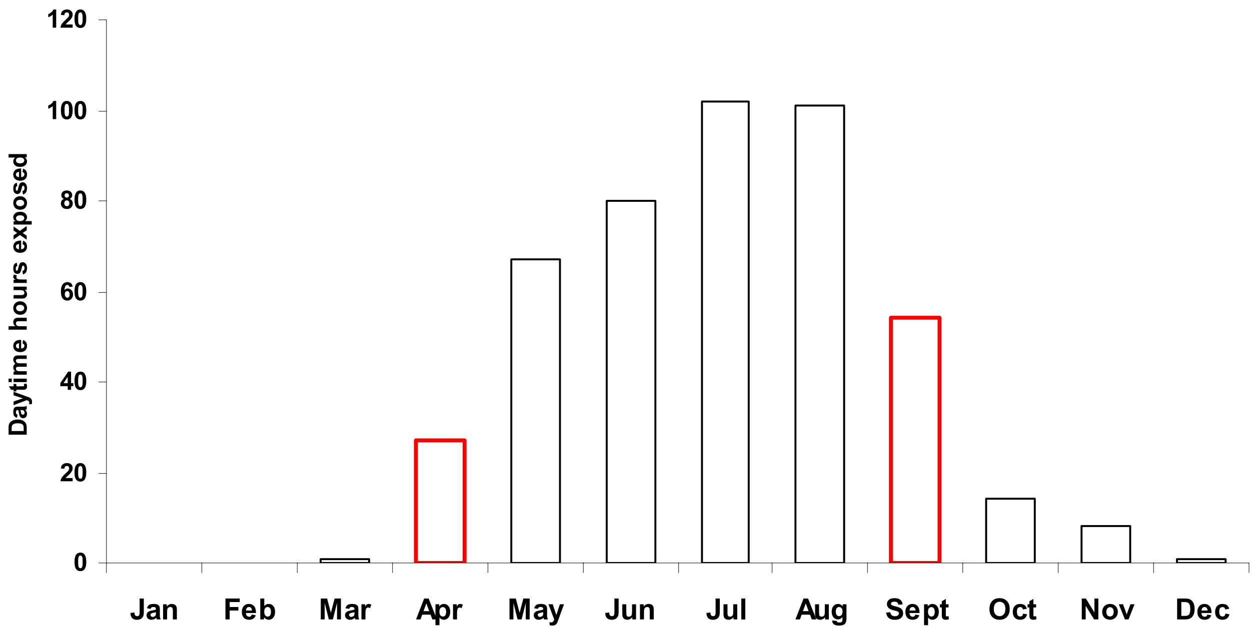


Figure 10. Total monthly hours intertidal seagrass banks were exposed (based on Weipa Humbug Point tidal data using a 1.0m exposure depth; adapted from Environmental Protection Agency 2009)

DISCUSSION

The 2009 wet and dry season baseline surveys were the most comprehensive assessment of seagrass distribution and abundance that have been conducted within Port Musgrave. Port Musgrave is one of the few large embayments in Far North Queensland with an under-developed coastline containing healthy, diverse seagrass meadows. Meadows identified ranged from very low density, highly patchy *Halophila spp.* in the subtidal, to more dense, continuous, *Halodule uninervis* along the shoreline of the Mapoon community. The range of seagrass meadows included those known to be important nursery grounds for commercial fisheries, as well as those utilised for food by dugong and turtles. Seagrass covered many of the intertidal mudbanks, and while the distribution was broadly similar between the wet and dry season surveys there were substantial additions of seagrass during the dry season with broad increases in both intertidal and subtidal *Halophila spp*. These changes were typical of seasonal fluctuations for tropical seagrass communities. Macro algae and benthic macro-invertebrates were a relatively minor component and with the exception of coastal oyster banks did not form significant habitat within the survey area.

Seagrass Distribution and Abundance

Changes in the availability of light with increasing depth, together with the effects of exposure related stress at the intertidal margin are major factors shaping the distribution of seagrasses (Short *et al.* 2001; Erftemeijer and Herman 1994; Taylor *et al*. 2007; Rasheed *et al*. 2007a; Rasheed *et al*. 2007b). The pattern of species and biomass changes observed in the field results from the differing responses of seagrass species to these and other factors controlling seagrass growth. *Halophila* species for example, are well adapted to lower light conditions and typically dominate deepwater and highly turbid areas (Kenworthy *et al*. 1989; Chartrand *et al.* 2008). At the other extreme, seagrasses growing in areas exposed at low tide are dominated by species that can cope well with exposure related stress such as *Halodule uninervis* (narrow leaf form) and *Enhalus acoroides* (Bjork *et al.* 1999; Rasheed *et al.* 2007a).

In subtidal areas of Port Musgrave, *Halophila decipiens* and *Halophila ovalis* formed waxing and waning sparse meadows in the nearshore area of Mapoon. *Halophila species are* adapted to lower light levels and turbid water conditions (Kenworthy *et al*. 1989; Birch and Birch 1984), explaining their presence in the muddy waters and habitat in Port Musgrave. These species have morphological and structural features that enable them to maximise their light harvesting capacity in a low light environment giving them a low minimum quantum requirement for growth (Josselyn *et al*. 1986, Ralph *et al.* 2007). However, extreme and chronic low light is also the major limiting factor for a *Halophila* deepwater meadow. Studies have found that complete shading — such as a prolonged dredging event — can stimulate changes in the architecture and growth characteristics within 9-14 days and will cause rapid decline in structurally small species like *Halophila decipiens* after approximately 30-40 days (Longstaff *et al*. 1999; Ralph *et al*. 2007). The prolonged turbidity during the wet season resulting from outflows of the Wenlock and Ducie River systems were likely to have resulted in such low light conditions that the meadow was unable to sustain its presence. *H. decipiens* is classically described as a pioneer species, dominating a newly established meadow or following a disturbance event such as natural wet season flooding. It 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). Such characteristics of *Halophila* species may explain the seasonal meadow dynamics in the subtidal areas of Port Musgrave. Furthermore, human-induced disturbance events such as dredging works have the potential to cause declines in subtidal areas due to the poor background light conditions in Port Musgrave.

Seasonality and Interannual Change

Many of the factors that influence seagrass growth vary both seasonally and annually. This leads to tropical seagrass meadows varying substantially in density and area between seasons (McKenzie 1994; Rasheed 1999, 2004) as well as between years (eg. Chartrand *et al.* 2008; Rasheed *et al.* 2007a; 2007b). The changes in seagrass distribution and abundance that occurred between the wet and dry season in Port Musgrave followed the typical seasonal pattern for seagrass meadows elsewhere in tropical Queensland. Seagrasses of tropical Queensland are generally at their peak in distribution and abundance during late spring/early summer and decline during winter months (Mellors *et al.* 1993; McKenzie 1994; Rasheed 1999; 2004).

The causes of natural seasonal change in seagrass are linked to a variety of factors, but broadscale seasonal patterns are most likely the result of seasonality in light and temperature (Duarte *et al.* 2006). In North Queensland, seagrasses flourish from August to November, when sediment resuspension and runoff are at their lowest, light levels are higher and nutrient fluctuations are minimised. Post the wet season, increases in turbidity from river inputs and greater resuspension of sediments causes light levels to drop and nutrient fluctuations are larger, leading to a decrease in seagrass growth (Coles *et al*. 2007; Mellors 2003). While light and temperature are important other influences such as seasonally available nutrient inputs from wet season floods, changes to salinity and daytime exposure may also influence seagrass seasonal and interannual patterns of change (Figure 7).

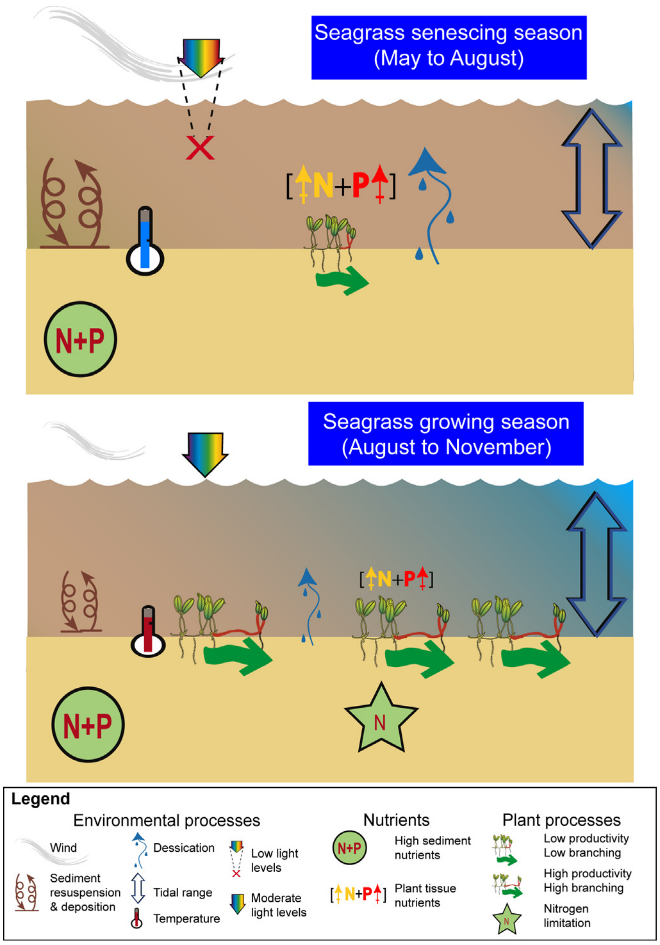


Figure 7 Conceptual diagram of controls and key processes limiting growth between seasons of intertidal *Halophila ovalis* (from Mellors 2003)

Local and regional climate conditions in North Queensland are well documented to affect seagrass abundance and distribution from year to year (Taylor *et al*. 2007; Rasheed *et al*. 2007a; Rasheed *et al*. 2007b). Typically, when local climate conditions are in a drought-like state, intertidal seagrasses decline due to exposure to high temperatures and increased desiccation, whilst subtidal seagrasses thrive due to higher light levels reaching the bottom (Taylor *et al*. 2007; Rasheed *et al*. 2007a; Rasheed *et al*. 2007b). The opposite is generally true when climatic conditions are within average ranges.

The extent of seasonal and interannual changes in Port Musgrave's seagrasses are likely to vary depending on the seagrass meadow type. Meadows dominated by *Halophila* and *Halodule* are typically highly variable in location, shape and abundance between the wet and dry season (eg. Weipa – Roelofs *et al*. 2001; Mourilyan Harbour – McKenna *et al*. 2007; Karumba – Rasheed and Taylor 2007; Townsville – Rasheed and Taylor 2008). *Halophila* species display a typical colonising growth strategy with fast growth and high reproductive output (Birch and Birch 1984; Rasheed 2004) including the production of seeds that remain viable in sediments for multiple years (McMillan 1991). They can rapidly colonise areas that have been disturbed but due to their small size, they lack large stores of energy reserves and rapidly decline when conditions become unfavorable for seagrass growth (Birch and Birch 1984; Rasheed 2004). Larger growing species such as *Enhalus acoroides* has a greater capacity to endure unfavorable conditions and tend to be more stable in their distribution and abundance. However these species take substantially longer to recover should they be lost (Rasheed 2004). Anecdotal evidence from Mapoon community rangers have indicated dense beds of persistent *Enhalus* along the eastern mudbank where patchy *Enhalus* was observed during the baseline surveys. Changes in the density and distribution of this meadow might be a result of a natural stress or disturbance event such as chronic exposure and high temperatures.

While seagrasses in Port Musgrave are likely to change between years according to variable climate, results from a previous survey in 1986 indicates that the broad distribution of seagrasses is similar between years in at least part of the embayment. Species shifts on the eastern bank may be a result of longer term shifts in sediment composition, light availability and exposure. Earlier surveys did not extend into large portions of Port Musgrave accounting for some of the difference in species and meadow distributions. Additionally, improvements in survey methodology allowed for a greater coverage of intertidal regions adding previously unmapped areas of seagrass in the most recent surveys. The wet and dry season surveys in 2009 provide a good baseline to begin establishing the ranges of natural seasonal and inter-annual change in seagrass meadows.

In addition to seagrass seasonality, algae dynamics have natural fluctuations related to wet and dry season climate patterns. During the April wet season survey, filamentous algae beds occurred on shallow sandbanks at the mouth of the Ducie River. The absence of these dense algae mats during the dry season survey may be indicative of a seasonal pulse of nutrients related to high river flows creating ideal conditions for ephemeral algae colonisation.

Value of Port Musgrave's Seagrass Meadows

The area of seagrasses mapped is likely to provide an important source of primary production supporting the regions marine ecosystem. Recent studies in North Queensland have shown seagrass meadows to be incredibly productive, completely turning over their above ground biomass every 9 to 25 days (Rasheed *et al.* 2008).The seagrass meadows contained species important as a food resource for dugong and turtle as well as meadows known to support commercial fisheries species.

Seagrass meadows in Queensland are essential nursery grounds for a range of commercial prawn and fish species (Coles *et al.* 1993). They provide shelter for juveniles and small adults from larger fish predators as well as an essential food source (Loneragan *et al.* 1998). Intertidal and shallow subtidal seagrasses in Cairns Harbour have been valued at $1.2M per year in 1992 Australian dollars (Watson *et al*. 1993). The 1986 survey of juvenile prawns found six species in Port

Musgrave including the commercially significant endeavour (*Metapenaeus endeavour;* Coles *et al.* in prep).

Seagrass Resilience and Implications for Port Management

Seagrasses can be impacted by a range of port activities including the effects of dredging. Dredging of deep channels can impact seagrasses by: 1) direct removal; 2) burial by spoil material; and 3) increased turbidity as a result of resuspended sediments and ship movements (Cabaço *et al*. 2008; Erftemeijer and Lewis 2006). The severity of impacts on seagrasses is affected by the intensity and duration of the activity, as well as the natural physical and environmental conditions of the area (Carruthers *et al.* 2002). While seagrasses were not found in the direct footprint of the potential shipping channel, seagrasses near Cullen Point and on the western bank of the Ducie River mouth were adjacent to the channel and potentially at risk from increased turbidity associated with dredging. Dredge plumes can negatively impact on seagrasses (due to low light levels) when the turbidity levels are significantly greater and more prolonged than natural variation (Erftemeijer and Lewis 2006; Orpin *et al*. 2004). Effective ways to mitigate the intensity and length of dredge related turbidity could be employed to protect seagrasses. Mitigation options may include but are not limited to shortening the dredge window and dredging during an ebbing spring tide to flush re-suspended sediments from the area. Seagrasses in the Port Musgrave area are likely to be subjected to periods of naturally high turbidity associated with high wind and wave action as well as pulses of high turbidity from wet season flooding of the Wenlock and Ducie Rivers. It is probable then, that seagrasses in the area are adapted to pulsed high turbidity events and have a reasonable resilience to turbidity associated with dredging, particularly if effective dredge mitigation strategies are in place.

Seagrass species vary in their sensitivity and resilience to impacts including those associated with port activity and dredging. The resilience of seagrass meadows is a result of a complex interaction of many factors including their carbohydrate reserves, ability of photosystems to recover, capacity for vegetative propagation, seed bank occurrence and disturbance regime. As Port Musgrave contained a range of species and meadow types it follows that there would be a corresponding range of tolerances and capacity to recover from impacts. For example the capacity of seagrass species to withstand burial by dredge spoil is strongly size-dependant with small species less tolerant. However small species such as *Halophila decipiens* often dominate in regularly used spoil grounds (eg. Chartrand *et al.* 2008) despite as little as 2cm of sediment causing 100% mortality (Cabaço *et al*. 2008). This is due to their ability to rapidly colonise disturbed areas through high reproductive output and generation of large seed banks (Kenworthy 2000). Larger growing species such as *Enhalus acoroides* may have a greater capacity to withstand burial but once they are lost take substantially longer to recover (Cabaço *et al*. 2008).

The baseline surveys presented here and subsequent monitoring program will provide a reference point to assess future seagrass changes as well as developing an appreciation of the natural ranges of seagrass change. This information is vital to assess the natural versus anthropogenic causes of seagrass change and develop effective management options to protect these valuable habitats. This will become increasingly important with pressures from coastal and port development and the impacts of climate change.

Long Term Monitoring Program

The results of the baseline surveys were used to develop a long term monitoring program that will survey seagrass abundance, distribution and species composition each September/October and March/April. Conducting the assessment at this time of year will enable direct comparisons with the baseline and previous surveys, as well as capturing seagrasses at their peak density. The program uses the successful methodology and sample design developed by the Marine Ecology Group for their network of established seagrass monitoring programs, including Cairns (Campbell *et al*. 2002), Mourilyan Harbour (McKenzie *et al*. 1996), Gladstone (Rasheed *et al.* 2003), Karumba (Rasheed *et al.* 2001), Townsville (Rasheed and Taylor 2008), Thursday Island (Rasheed *et al.* 2002) and Weipa (Roelofs *et al*. 2001).

A subset of 5 meadows identified in the baseline surveys have been selected for monitoring (Map 6). These meadows represent the range of meadow types found in the area suitable for monitoring and also capture areas of interest and likely impact identified in the baseline survey including proximity to potential dredging activities and proposed loading facilities. Monitoring meadows include both intertidal and subtidal seagrasses as well as meadows preferred as food by dugong and those likely to support high fisheries productivity. Intensity of sampling sites will be sufficient to estimate variability within seagrass meadows so that effective measurements of seagrass change can be developed using power analysis techniques (see Campbell *et al.* 2003; Rasheed *et al.* 1996; McKenzie *et al.* 1996; Lee Long *et al.* 1996; Chartrand and Rasheed 2009). Power analysis will be completed following the first monitoring survey in April 2010.

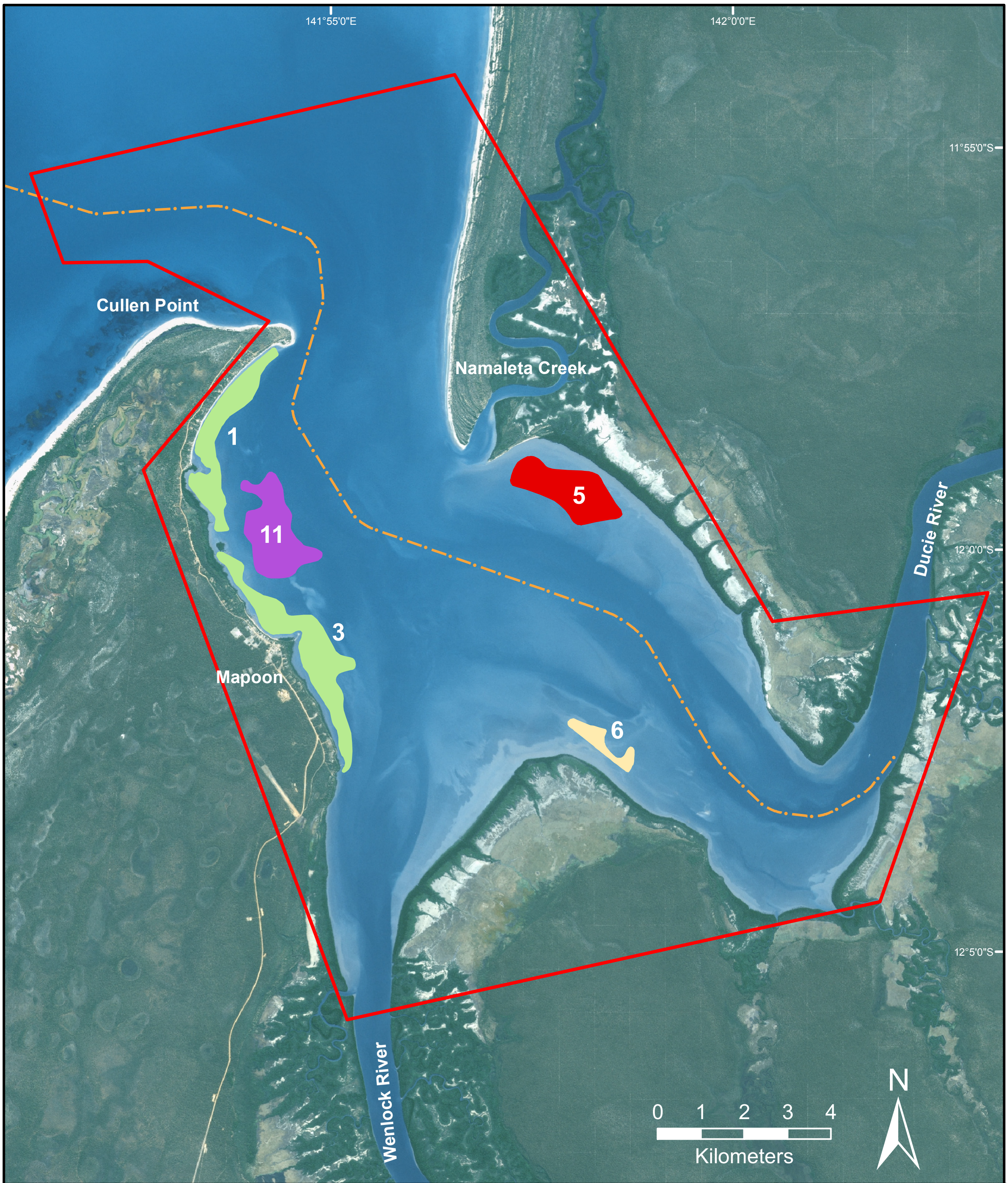
The monitoring plan will aim to:

1. Conduct biannual long term seagrass monitoring surveys of seagrass distribution and abundance in Port Musgrave
2. Compare results of monitoring with the baseline surveys conducted in 2009 and assess any changes in seagrass distribution and abundance in relation to natural events or human induced port and catchment activities;
3. Discuss the implications of mapping and monitoring results for overall health of Port Musgrave's marine environment and provide advice to relevant management agencies.

The first of the annual seagrass monitoring surveys will be conducted in April 2010.

In addition to long term seasonal monitoring by MEG, a community-based seagrass monitoring program, Seagrass-Watch, was initiated in 2009 with the first monitoring sites set up during the September 2009 baseline survey. Seagrass-Watch is an internationally recognised volunteer program that provides long-term datasets on seagrass condition. Seagrass-Watch sites in Port Musgrave are located at the northern end of Meadow 1 on the Mapoon shoreline (Map 2b). Following sufficient training and adaptation to protocols, local Mapoon rangers will manage the Seagrass-Watch sites and perform quarterly monitoring with support from CAPL and Fisheries Queensland. The next Seagrass-Watch monitoring will take place during low tide windows in April 2010.

Map 6. The location and description of proposed seagrass monitoring meadows in Port Musgrave



Legend

Community Type

- Light *Enhalus acoroides*
- Moderate *Halodule uninervis* (narrow) with mixed species
- Light *Halodule uninervis* (narrow) with *Halophila ovalis*
- Moderate *Halophila decipiens* with mixed species

Potential Shipping

Survey Extent

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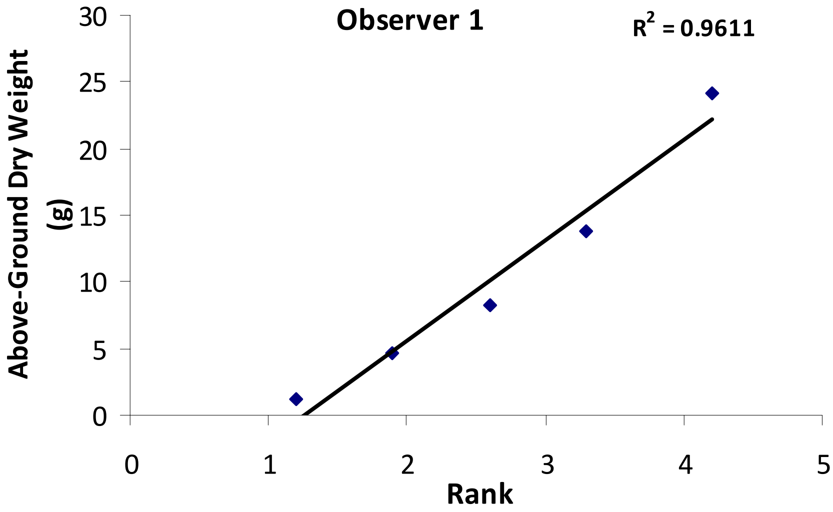
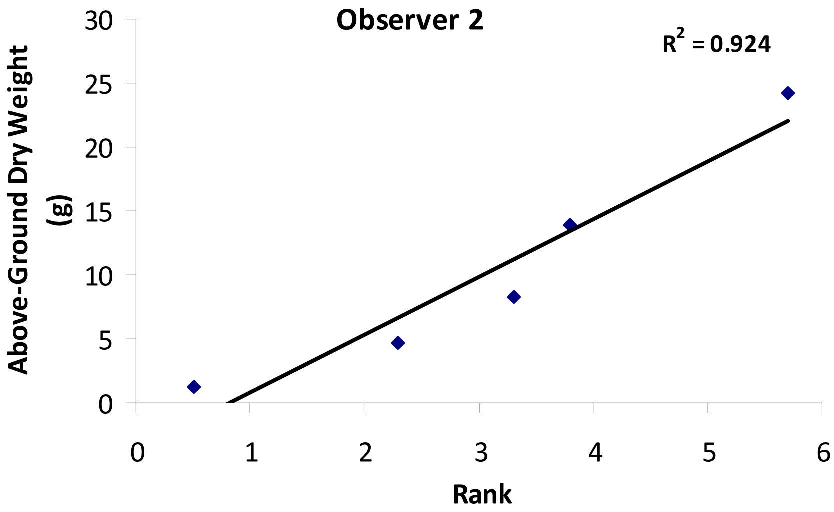
APPENDIX

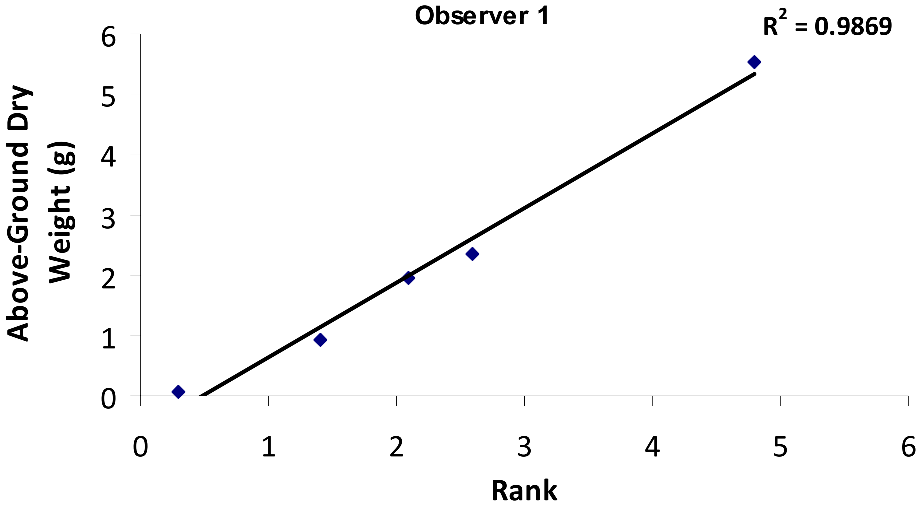
Calibration regressions for above-ground biomass estimation at habitat characterisation sites.

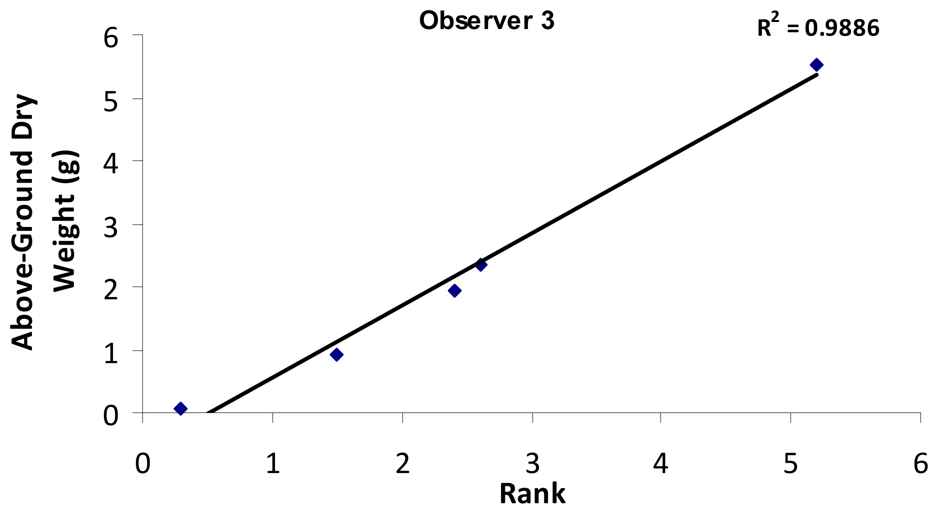
High Rank Scale Regressions





Low Rank Scale Regressions





Results of Kruskal-Wallis One-Way ANOVA for mean above-ground biomass versus survey month (April wet season and September dry season) for Port Musgrave seagrass meadows. Only meadows with n>1 for sites surveyed and meadows present during both surveys were included in analysis.

Meadow 1	DF	SS	MS	F	P
Between Years	1	3210.44	3210.44	4.96	**<0.05**
Within Years	88	56953.6	647.2		
Total	89	60164			
Meadow 3					
Between Years	1	12.1032	12.1032	0.03	**>0.05**
Within Years	68	28416.9	417.896		
Total	69	28429			
Meadow 4					
Between Years	1	29.7	29.7	3.44	**>0.05**
Within Years	9	77.8	8.644		
Total	10	107.5			
Meadow 5					
Between Years	1	1037.3	1037.31	10.95	**<0.01**
Within Years	43	4071.69	94.69		
Total	44	5109			
Meadow 6					
Between Years	1	3.15441	3.15441	0.07	**>0.05**
Within Years	37	1664.35	44.9823		
Total	38	1667.5			
Meadow 7					
Between Years	1	2.7	2.7	0.73	**>0.05**
Within Years	4	14.8	3.7		
Total	5	17.5			