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Seagrass Resources in the Whitsunday Region 1999 and 2000

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The Department of Primary Industries, Queensland has taken all reasonable steps to ensure the information contained in this publication is accurate at the time of the survey. Seagrass distribution and abundance can change seasonally and between years, and readers should ensure that they make appropriate enquires to determine whether new information is available on the particular subject matter.

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EXECUTIVE SUMMARY

1. 5553±1182 ha of coastal and island seagrass habitat was mapped in the Whitsunday region from broad-scale surveys conducted in January 1999 and 2000 between Cape Gloucester and Midgeton.

2. This represents a 40% increase in seagrass habitat compared to 1987, however losses have occurred at specific localities.

3. Island seagrass communities were mostly sub-tidal meadows of mixed wide-bladed species. Coastal seagrass habitats were predominantly intertidal communities dominated by *Halodule uninervis* (narrow leaf), *Zostera capricorni,* and *Halophila ovalis*. Sub-tidal communities of mixed wide-bladed species also occurred in some coastal locations where water clarity and light penetration were sufficient for seagrass growth.

4. Whitsunday Island supported the two largest single meadows, however only a few islands were surveyed for seagrass resources in the Whitsunday region during the survey.

5. Seasonally occurring species (*Halophila decipiens* and *H. tricostata*) were found at some island and coastal sites at the deeper margins of sub-tidal meadows.

6. The increase in seagrass meadows in Repulse Bay, along the northern mainland coast (between Gloucester Island and Bluff Point) and Whitehaven Beach since the 1987 survey, suggest that seagrass meadows have generally expanded over the past 13 years. An increase in dugong numbers over the past decade has also been recorded for Repulse Bay and the northern mainland coast.

7. Localised loss of seagrass meadows has occurred in Pioneer Bay since the 1987 broad-scale survey. The seaward meadow edge in Pioneer Bay has contracted by more than 1km. Other studies have documented increasing point and non-point source nutrients and sediments into the bay.

8. Macro-brown algae (predominantly *Sargassum* sp.) dominated the sub-tidal parts of fringing-reef and rocky shores. Live coral cover was low at most of these fringing reef sites.

9. Green sea turtles were common wherever seagrass meadows occurred, and these meadows are an important component to sea turtle feeding in the region. Potential still exists for vessel and propeller strikes on sea turtles in the Whitsunday region.

10. Dugong feeding trails were common in some coastal intertidal meadows in Pioneer Bay and the Midge Point area, and sightings of dugong are frequent at some island sites. Vessel activity in the major seagrass areas may need to be managed to help protect the low dugong populations of the Whitsunday region.

11. Coastal intertidal seagrass meadows in the Whitsundays, particularly those adjacent to mangrove habitats, are similar to habitats elsewhere along the Queensland coast that support very productive fish and prawn populations of commercial and recreational fisheries value. Primary productivity in these large meadows is likely to be important to the overall coastal fisheries productivity.

12. Anthropogenic threats to Whitsunday region seagrasses include: sewage effluent and runoff in Pioneer Bay (coastal) and vessel use (anchoring) at Whitehaven Beach (Whitsunday Island). Urban development at Hydeaway and Dingo Beach may present impacts of sediment run-off and septic ground-water flows onto near-shore seagrasses. Chronic impacts on water quality and seagrasses along the Whitsunday coast from adjacent agricultural catchments are poorly understood and require attention.

13. Eight locations have been selected for long-term monitoring of seagrasses within the Seagrass-Watch Program. These include intertidal sites at Hydeaway Bay, Dingo Beach, Pioneer Bay, Laguna Quays, Midge Point, and Midgeton, and sub-tidal sites at Whitehaven Beach and Cid Harbour.

INTRODUCTION

The Environmental Protection Agency/Queensland Parks and Wildlife Service (EPA/QPWS) and Department of Primary Industries responded to concerns of local community groups and procured Natural Heritage Trust (Coast and Clean Seas) funding to initiate a community-based seagrass monitoring program in the Whitsundays region in 1998. The major concerns voiced by the community were of coastal development in urbanised areas (marinas, sewage, stormwater runoff and vessel traffic), catchment inputs from highly modified agricultural lands (cane and pasture) and anchor damage from high vessel use at some island sites. Nutrient inputs from boat usage may also impact both nearshore and offshore seagrass communities.

As part of the program, broad-scale mapping of seagrass resources in the region was required to establish a baseline of the extent of seagrasses and the seagrass resources available for use by dugong, sea turtles, fish and other marine fauna. The mapping of seagrass distribution was a key step to help identify a range of monitoring sites that could be used to assess changes in seagrass ecosystems caused by anthropogenic and natural influences, and report on the condition and health of seagrass communities throughout the region. This report presents the results of surveys conducted in January 1999 and January 2000. The following objectives were set:

1. To describe the extent of the major seagrass habitats in the Whitsunday region between Cape Gloucester and Midge Point, on GIS format;
2. To identify the major human and natural threats to these resources;
3. To select key locations for monitoring the health of seagrasses in the region; and
4. Provide comments on seagrass conservation issues relevant to fisheries, dugong and turtle population management.

General Seagrass Ecology

Seagrasses are important nursery habitat for commercial species of penaeid prawns and fish (Coles and Lee Long 1985; Coles *et al.* 1993; Watson *et al.* 1993). Seagrass meadows in Queensland are also essential food for dugong, *Dugong dugon* (Miller) and green sea turtles, *Chelonia mydas* (Linnaeus) (Lanyon *et al.* 1989). Intertidal seagrasses also provide important habitat for wading birds. Seagrasses in coastal regions are important for maintaining water quality and for buffering nutrient and sediment loads from land, helping to stabilise sediments and assimilate nutrients (Short 1987). Seagrasses are an important source of primary carbon production in food chains that constitute coastal systems. They establish detrital-based food chains (which are the basis for fisheries productivity for target commercial and recreational fish species) and herbivore-based food chains (which are critical to dugongs and green sea turtles). Coastal seagrass meadows are therefore an important resource both economically and ecologically.

Natural seasonal variation in seagrass biomass has been documented (McKenzie 1994) and more recent detailed surveys have indicated some large long-term changes in seagrass distribution at regional scales (Lee Long *et al.* 1998). The causes and scale of these long-term changes, and their ecological consequences for faunal populations of fisheries and conservation value are poorly understood.

The potential for widespread seagrass loss has been well documented and the causes of loss can be natural, such as cyclones and floods (Poiner *et al.* 1989), due to human influences such as agricultural runoff (Preen *et al.* 1995), industrial runoff (Shepherd *et al.* 1989), oil spills (Jackson *et al.* 1989), harbour dredging (Onuf 1994), or any combination of these (Pringle 1989).

Whitsunday region seagrasses

Seagrasses are a major component of the Whitsunday region marine ecosystems and their contribution to the total primary carbon production is critical to regionally important dugong and turtle populations and productive fisheries. Coastal meadows are important nursery habitat to juvenile fish and prawns, and provide habitat for migratory wading birds.

Seagrasses in the Whitsundays were first mapped during a broad-scale survey between Bowen and Water Park Point in March 1987 (Coles *et al.* 1987, Lee Long *et al.* 1993). That survey found eleven seagrass species and mapped approximately 5700 ha of coastal and island seagrass habitat. Coastal locations included intertidal and shallow sub-tidal habitats and Whitsunday Island had the largest areas of seagrass, mostly sub-tidal habitat.

An assessment of the extent of change in seagrass resources from the original surveys to the present is hampered by the difference in mapping techniques. The original broad-scale survey was based on a lesser spatial intensity of dive observations so mapping resolution and error is larger than in the present survey. The error of mapping for the 1987 survey has not been determined.

Whitsunday region dugongs & marine turtles

Large numbers of green sea turtles inhabit the Whitsunday region and dugongs are common in some localities. These species are of important conservation value internationally and receive much attention in the context of management of the Great Barrier Reef World Heritage Area.

Dugongs are the only strictly marine mega-herbivores, feeding almost exclusively on seagrasses. Dugongs prefer seagrasses that are lower seral or "pioneer" species (Preen 1995a, 1995b), especially species of the genus *Halophila* and *Halodule*, which are lower in fibre and higher in digestibility (*Halophila*) and available nitrogen (*Halodule*) (Lanyon 1991; Aragones, 1996).

In Australia there are an estimated 85,000 resident dugongs, which is the largest remaining population of dugong (Marsh *et al.* 2002). They inhabit coastal waters of Shark Bay in Western Australia, the northern coast of Australia and along the eastern coast to Moreton Bay in south-eastern Queensland (Marsh *et al.* 1999). A survey in 1994 estimated 1642 (± 236) dugongs in the southern Great Barrier Reef region. The population in Whitsundays coastal waters in 1994 was estimated to be 210 (± 50) and in 1999 the population had increased to 804 (± 425) (Marsh and Lawler 2001).

The long-term health of dugong populations is affected by a wide range of natural (flood, cyclone, ENSO climatic conditions) and human (land-use, coastal development) impacts on dugongs and seagrass resources (Marsh *et al.* 1999). Widespread loss of seagrass meadows in Hervey Bay due to cyclone related flooding in 1992 was responsible for a 10 fold decline in Hervey Bay dugong population from approximately 1700 to ~71 ± 40 individuals (Preen *et al.* 1995; Preen & Marsh 1995). Land-use practices contributing to high sediment and nutrient runoff from the catchment were implicated in the loss of seagrass and exacerbated the impacts of the natural catastrophic event. As Australia contains internationally significant populations, it has special obligations for conservation and management of dugongs (Marsh *et al.* 2002). Worldwide, the dugong is listed in the 2000 IUCN Red List of Threatened Animals as being *vulnerable* to extinction. The species is likely to be classified as endangered in the near future if the factors causing declines continue.

Dramatic declines in dugong populations in the southern Great Barrier Reef Marine Park and in Hervey Bay since 1987 prompted a November 1996 meeting of the Great Barrier Reef Ministerial Council to declare the need for emergency action to save dugong in the GBR. An outcome was to establish a two-tiered system of Dugong Protection Areas (DPAs) within the Great Barrier Reef region in which gill- and mesh-netting was either restricted/banned or modified. The Council deemed incidental dugong catch and drowning in commercial nets to be a major threat to dugong populations. In the Whitsunday's region, a Dugong Protection Area was established in northern Repulse Bay. The Council also acknowledged that another cause for the decline in dugong numbers might be habitat loss, and one of the objectives of the Seagrass-Watch program is to examine long-term changes in seagrass abundance for comparison against turtle and dugong population health.

Of the six species of marine turtles found in eastern Queensland waters, the green sea turtle (*Chelonia mydas*) is the only species that feeds principally on seagrasses. These turtles have a worldwide distribution in tropical and subtropical waters, inhabiting tidal and subtidal habitats including coral and rocky reefs, seagrass meadows and algal turfs on sand and mud flats. Green sea turtles are common in the Whitsunday region, and in Queensland waters there are two genetically distinct nesting areas - the northern and southern. As with most species of marine turtles, green sea turtles may take between 30 to 50 years to reach maturity. The green sea turtle is listed in the 2000 IUCN Red List of Threatened Animals as being *endangered* to extinction.

Present day dugong and turtle populations are exposed to numerous impacts that contribute to a decline in numbers. Factors identified as posing a real or potential risk to populations include: boat traffic, pollution, coastal development, traditional hunting, commercial gill netting, habitat degradation, disturbance of nesting sites, commercial trawling, land-use practices and run-off, natural impacts including tropical cyclones, floods, storms and predators. For turtle and dugong populations to exist in a healthy state, these impacts must be effectively managed and where possible, prevented.

Whitsunday region fisheries resources

The fisheries resources of the region support an important trawl fishery for prawns and scallops and there is a large recreational fishery for coastal and estuarine species as well as various pelagic species and some reef fish (Williams 1997).

Trawl fisheries exist for banana prawns nearshore and tiger and endeavour prawns in the inner Barrier Reef lagoon waters of eastern Queensland. In the Whitsunday region these occur mostly in Repulse Bay and north of Pioneer Bay. Amongst the islands, fast tidal currents and rough seabed preclude trawling. Redspot king (*Penaeus longistylus*) and western king prawns (*P. latisulcatus*) are caught in deeper waters, primarily in the outer lagoon. Bycatch species of commercial value in the Whitsunday region trawl fishery include shovel-nosed lobsters and squid (Williams 1997).

Coastal and estuarine finfish fisheries (both recreational and commercial) are based mostly in Repulse Bay, and some fishing occurs in the Bays north of Pioneer Bay. The commercial catch of estuarine fish is predominantly barramundi, blue salmon, grunter, and king salmon, taken in rivers and foreshores by gill net (Williams 1997). These fishing methods also target inshore whiting, mullet, yellowfin bream, garfish, dusky flathead and trevally. Juveniles of several of these species occur in areas associated with seagrass and mangroves (eg., Coles *et al.*1993, Blaber 1980). Dusky flathead are also dependent on estuarine and inshore coastal habitat throughout their lifecycle. Mackerel fisheries (recreational and commercial) along the Queensland coast are often centred around bait-fish populations near seagrass and mangrove habitats, and these are common in the Whitsunday region. A mackerel fishery occurs around the Whitsunday islands.

The mud crab (*Scylla serrata*) is a large fishery in Queensland (Williams 1997), but only relatively small numbers are caught along the Whitsunday coast. Juveniles and adults inhabit sheltered estuaries, tidal reaches of mangrove lined rivers and streams, intertidal seagrass meadows and mangrove forests.

Queensland's second largest Fish Habitat Area (FHA's) at 71,000 ha includes much of Repulse Bay (Beumer *et al.* 1997). Fish Habitat Areas have been declared to enhance existing and future fishing activities and to protect the habitat upon which fish and other aquatic fauna depend (Zeller 1998).

METHODOLOGY

Description of study locality

The Whitsunday region on the central east Queensland coast, extends from Gloucester Island to Midge Point and includes a convoluted coastline and several large continental islands (Colfelt 1997) (Figure 1). The coastal region includes mostly low mountains and hills with rainforest that fringe several small bays.

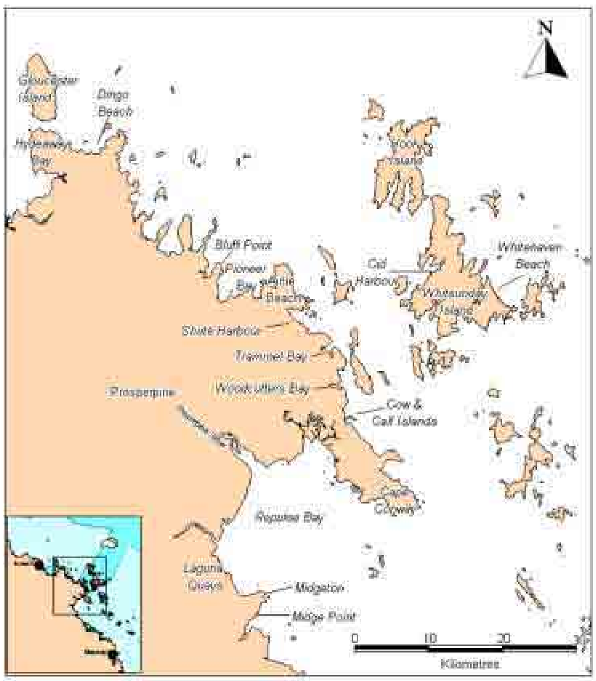

Figure 1. The Whitsunday region survey area

The Repulse Bay Wetlands in the Central Queensland bioregion, include intertidal sand and mud flats, seagrass meadows, mangrove forests, salt flats/marshes, often contiguous with freshwater *Melaleuca* wetlands and coastal wallum swamps. These wetland types are exceptionally important feeding grounds for migratory shorebirds and important for a wide range of other shorebirds, waterfowl and seabirds, marine fish, crustaceans, dugong, sea turtles and dolphin.

The coast and islands are partly protected from oceanic swells by the Great Barrier Reef. Depths on the coast increase gently from the sheltered bays out to approximately 30-50m in the waters around the islands. Inshore sediments are primarily sandy, with a higher mud content in small sheltered bays (Maxwell 1968). Most of the shoreline is rocky, except for beaches in the larger bays and small fringing reefs in some of the northern bays.

Climate in the region is subtropical and coastal. Seasonal influences are derived from the tropical zone to the north, the temperate zone to the south and thunderstorms originate in the south west (Dredge *et al.* 1977). Mean annual rainfall is 1382.5 mm (from 28 years data) at Hayman Island and 1792.4 (from 101 years data) at Proserpine (Bureau of Meteorology 2000). Rainfall is greatest between December and March. Mean daily temperatures range from 16.5°C to 30.5°C with July being the coolest month and January the hottest (Bureau of Meteorology 2001). Mean 3pm wind speeds range from 15 to 18 km/hr. Winds are predominantly SE to E from February to October and predominantly NE to NW from November to January (Colfelt 1997). Tides are semi-diurnal and tidal ranges at Shute Harbour range from 1.3 m (neaps) to 2.7m (springs) (Anon. 1999).

The Whitsundays marine waters receive inputs from 4 major catchments: the Pioneer, Plane Creek, Proserpine, and O'Connell catchments. Rivers from the Pioneer and Plane Creek catchments flow into the northern section of the Whitsundays between Edgecumbe Bay and Pioneer Bay. Repulse Bay at the southern end of the region receives flows from the

Proserpine and O'Connell rivers in the north and Dempster Creek to the south at Midge Point.

The Pioneer and Plane Creek catchments consist of a mix of agricultural land-use including sugarcane pastures, beef grazing and urban development. The major development nodes at Airlie Beach and Shute Harbour include tourism precincts, residential development, car parks, sewage outfalls, marinas and boating facilities. Small but expanding residential areas at Hydeaway Bay and Dingo Beach have only septic systems for sewage treatment.

The Proserpine and O'Connell catchments have been extensively cleared for grazing agriculture (QDPI 1993) and some tourism development has occurred in proximity to marine habitats (Laguna Quays, north of Midge Point in southern Repulse Bay). The main land-use is sugar, beef grazing and agriculture in the lower catchment areas. Land use practices in this catchment have resulted in problems due to flooding, stream-bank erosion and land degradation. Nutrients applied to agricultural lands and sediments are major pollutants entering coastal waters of the Whitsunday region. Fertiliser use is high with 7,430 tonnes of N and 998 tonnes of P used on sugarcane and pastures in 1990 (Pulseford 1996). Annual sediment loads from the O'Connell River (366,809 tonnes), Proserpine River (227,314 tonnes) and Pioneer River (288,343 tonnes) are high, and more than double that of Plane Creek (114,860 tonnes) (Anon 2001). Annual nutrient loads from the O'Connell River (1,666 tonnes of N, 365 tonnes of P), Proserpine River (1,169 tonnes of N, 256 tonnes of P), Pioneer River (1,169 tonnes of N, 256 tonnes of P) and Plane Creek (1,612 tonnes of N, 353 tonnes of P) are high (Anon 2001). All four rivers entering the Whitsundays region pose a high risk to the health and condition of inshore coastal waters of the Whitsundays. It has been recommended that these loads be reduced by 50% by the year 2011 to reduce current threats to the health of nearshore marine ecosystems (Anon 2001).

This recommendation is consistent with reports of high concentrations of nitrogen (234-700 $\mu g\ L^{-1}$) and phosphorus (40-191 $\mu g\ L^{-1}$) in waters of the Proserpine and O'Connell Rivers (Waterwatch unpublished data, 2001) that exceed ANZECC guidelines. Concentrations of suspended particulate matter and chlorophyll *a* have also been found to be high in Repulse Bay, close to the Proserpine River mouth, compared with sites to the north at a distance from river inputs (van Woesik *et al.* 1999). Sediments have the potential to reduce available light for seagrass photosynthesis and smother seagrass shoots preventing growth. Nutrients bound to the sediments can also be rapidly used by algae (macroalgae) culminating in reduced light penetration and excessive epiphytic growth on seagrass shoots. Herbicide and pesticide concentrations in coastal sediments and seagrasses in the Newry region, situated to the south of the Whitsundays, were relatively low compared to the northern wet tropics region (Haynes *et al.* 2000a). Sources of herbicides and pesticides including organochlorine compounds include current and past applications by coastal agricultural industries (sugarcane pastures, dairy) and a range of domestic, public health and agricultural purposes in urban areas (Haynes *et al.* 2000a). The persistent use of these types of compounds together with possible continued illegal use of banned organochlorine compounds increases the potential for chronic exposure of seagrass ecosystems to these toxicants from freshwater discharges into coastal regions of the Whitsundays. In addition experimental studies suggest that herbicide (Diuron) concentrations in Queensland sediments pose a risk to seagrass functioning (Haynes *et al.* 2000b).

Survey Methods

Three techniques were used to map seagrasses in intertidal and shallow sub-tidal (2-10m below MSL) areas.

Intertidal seagrass distribution was assessed using free divers, aerial photographs and helicopter reconnaissance. A helicopter was used to conduct an aerial survey of intertidal seagrasses on 15th April 2000 (Map 1). During the flights, observers interpreted the distribution of seagrass onto Admiralty survey charts to aid interpretation when mapping on the GIS.

Aerial photographs were sourced from the Beach Protection Authority photographic flight runs taken in 1993 and 1998. These photos are taken at low tide when intertidal areas are exposed and are easily interpreted for presence or absence of most seagrasses.

Dive-based surveys were conducted on the 8-15th Jan 1999 and 24-30th Jan 2000 (Map 1). At each dive site, an observer would free-dive to the sea bottom and make observations of benthic habitat characteristics in 3 quadrats. This information was then recorded on a datasheet at the surface. Dive sites were distributed haphazardly along transects that ran perpendicular to the shoreline. The distance between sites (approximately 50-500 m apart) varied according to changes in depth and habitat type. Inshore survey transects extended from the upper intertidal reaches to beyond the outer edge of seagrass meadows, and to 12m below MSL. Haphazardly selected sites between transects were dived to check for continuity of habitats.

Data Collection

Seagrass habitat characteristics including above-ground seagrass biomass, species composition, % algae cover on seabed, sediment type, water depth and geographic location were recorded at each site.

Above-ground seagrass biomass was determined by a “visual estimates of biomass” technique modified from Mellors (1991). At each sampling site, observers recorded an estimated rank of seagrass biomass and species composition in three replicates of a 0.25 m^2 quadrat per site. On completion of the survey, each observer ranked ten quadrats that were harvested and the above-ground dry biomass (g DW m^{-2}) measured. The regression curve representing the calibration of each observer’s ranks against the known harvested biomass values was used to calculate above-ground biomass from all their estimated ranks during the survey. Photographic examples of above-ground dry biomass (g DW m^{-2}) are included in Appendix 1.

All divers had strong linear regressions (r^2>0.85) when calibrating above-ground biomass estimates against a set of harvested quadrats.

Divers collected voucher specimens where taxonomic verification was required. Seagrass species were identified according to taxonomic keys of Kuo and McCoombe (1989) and Lanyon (1986). Seagrass voucher specimens for taxonomic use were lodged with the QDPI Northern Fisheries Centre Herbarium Collection. Algae species were identified according to Cribb (1996) and percent cover of algae was estimated for each site.

Field descriptions of sediment type were recorded for each site: shell grit, rock gravel, coarse sand, sand, fine sand and mud or a combination of these.

Water depths of survey sites were recorded with an echo-sounder and converted to depths in metres (m) below mean sea level (bMSL), correct to local tidal plane datum’s (Queensland Department of Transport 1999, 2000). Transects were used to determine depth distribution of seagrasses at major localities (depths below MSL).

Geographic location of sampling sites (±5 m) was determined with a differential Global Positioning System (dGPS), and projected to a Longitude/ Latitude AGD 84 datum.

Dugong and green sea turtle sightings were recorded at each locality.

Geographic Information Systems (GIS)

The GIS basemap of the study region including coastline, sandbanks, mangroves and islands was created using rectified aerial photographs, the Digital Cadastral Database (DCDB courtesy DNR) and AusLig© database (digitised at 1:250,000 scale).

Sampling sites with associated information were imported into the GIS and displayed spatially. Polygons of the intertidal and shallow sub-tidal seagrasses, with all associated data, were created as a layer in MapInfo® using the survey information and interpretation of aerial photographs. A CD Rom copy of the GIS with metadata was archived at QPWS (Airlie Beach) and the original archived with the custodians, Department of Primary Industries, at the Northern Fisheries Centre in Cairns.

Areas of individual seagrass meadows were drawn in MapInfo©GIS polygons using the above datasets. Meadows were classified into seagrass community types according to the dominant species composition. Some seagrass community types occurred in a range of habitats, so the dominant seagrass habitats were also identified. Another layer in the GIS was created according to abundance of above ground seagrass biomass g dry weight m^{-2} and follows a nomenclature developed for seagrass meadows of Queensland (Appendix 2). Depth of seagrasses were also examined by selected localities.

Errors in GIS maps include those associated with digitising and rectifying basemaps and with Global Positioning System (GPS) fixes for survey sites. The point at which divers estimated bottom vegetation may be up to 5 m from the point at which a GPS fix was obtained. Differentially corrected GPS fixes were also only precise to within 5 m. These errors are considered to be within the errors associated with distance between survey sites.

Each seagrass meadow was assigned a qualitative mapping value, determined by the data sources and likely accuracy of mapping (McKenzie *et al.* 2001). A rank system for mapping quality was used, based on the range of mapping information available for each area and associated estimates of reliability (R) in mapping meadow boundaries (Table 1). A mapping quality rank of 1 is the highest. Estimates of reliability in mapping meadow boundaries ranged from 10 m to 100 m.

Table 1 Mapping quality for seagrass meadows mapped in the Whitsunday Region.

Map Quality	Data sets	Comments
1	Aerial photograph and helicopter	Photos of high resolution. Helicopter survey confirmed seagrass presence and this technique able to visually interpret meadow edges at a high spatial accuracy. *Error = 10 m.*
2	Aerial photographs & ground truth with dive survey	Detailed checking of meadow boundary during dive surveys. Aerial photographs of high resolution. *Error = 10 to 30 m.*
3	Aerial photographs & ground truth with dive survey	Some meadow boundaries checked, and several transects during ground truth survey. Aerial photos of high resolution. *Error = 10 to 50 m.*
4	Dive survey only	Detailed meadow boundary checked during dive surveys, with use of Auslig and topographic maps *Error = 20 to 80 m.*
5	Dive survey only	No image or photo available at required resolution. Some meadow boundaries checked during ground truth survey. *Error = 20 m to 80m.*
6	Dive survey only	Subtidal meadows not visible in remote-sensing images. Data densities generally low (1-2 sites) and reliant solely on dive survey. No visual detection of meadow edges, technique reliant on interpolation between sites. *Error = 30 m to 100m.*

RESULTS

Seagrass species and communities

From a total 1594 coastal and island sites, (1133 sites in January 1999, and 461 sites in January 2000) seagrass was present at 854 sites (54%) (Map 1). 177 meadows were mapped in the study region (Map 2).

Ten seagrass species, in three Families were identified in the Whitsundays. The Whitsundays region encompasses the coastline and coastal islands from the southern tip of Gloucester Island to Midgeton. The Whitsundays region was divided into 4 sub-regions, Northern coast, Central coast, Whitsunday Island and Repulse Bay (northern and southern) (Table 2). These geographic sub-regions are based on the species composition of seagrass meadows, the influences of catchment based activities and regional climatic factors. The highest diversity of seagrass species (9 species) was found along the Northern mainland coast from Dingo Beach to Bluff Point. The lowest diversity of seagrass species occurred in Repulse Bay, where 5 species were identified (Table 2). *Halodule uninervis* (wide leaf form) was the most common seagrass across the region, observed at 494 (31%) of sites. *Cymodocea rotundata* was the least common seagrass, and found at one site in Hydeaway Bay.

Table 2 Seagrass species present in the Whitsundays region, January 1999 and January 2000

SEAGRASS FAMILY	SEAGRASS SPECIES	NORTHERN WHITSUNDAYS COAST (DINGO BEACH, TO BLUFF POINT),	CENTRAL WHITSUNDAYS COAST (PIONEER BAY TO CAPE CONWAY)	WHITSUNDAY ISLAND	REPULSE BAY
ZOSTERACEAE Drummortier	*Zostera capricorni*	✓	✓	X	✓
CYMODOCEACEAE Taylor	*Cymodocea rotundata*	✓	X	X	X
	Cymodocea serrulata	✓	✓	✓	X
	Halodule uninervis	✓	✓	✓	✓
	Syringodium isoetifolium	✓	✓	✓	X
HYDROCHARITACEAE Jussieu	*Halophila decipiens*	✓	X	✓	✓
	Halophila ovalis	✓	✓	✓	✓
	Halophila tricostata	X	✓	✓	X
	Halophila spinulosa	✓	✓	✓	✓
	Thalassia hemprichii	✓	✓	✓	X

* *Halodule uninervis* (narrow leaf form) and *Halodule pinifolia* have been considered as one species for analyses of depth and biomass patterns.

Seagrass Spatial Distribution

Meadow types

The total area of seagrass mapped in the Whitsunday region survey, was 5553±1182 ha. The surveys did not include all seagrass habitat in the region, as many offshore Islands, parts of Whitsunday Island and the central section of Repulse Bay were not sampled in this survey. Seagrass meadows occurred mostly in sheltered bays with sufficient shelter for seagrass growth on intertidal and shallow banks, and in the lee of Whitsunday Island where water clarity was sufficient for seagrass growth at subtidal depths (Map 2). Coastal meadows grew mostly intertidal to shallow sub-tidal, and meadows at island locations were mostly sub-tidal (Figure 2) [1].

Twenty seagrass meadow/community types were identified based on species dominance (Table 4). Meadows dominated by *Halodule uninervis* were the most common community type on coastal intertidal banks (Maps 3-15). These meadows made up 72.3 % (4125 ha) of the total seagrass in the Whitsundays. Other meadows in intertidal regions were composed of *Halophila ovalis* (7.3%, 406 ha) and *Zostera capricorni* (7.8%, 432ha). Meadows dominated by *Cymodocea serrulata* (106 ha), *Halophila triciostata* (68.7 ha) *Thalassia hemprichi* (66.9 ha), *Syringodium isoetifolium* (16.2 ha) and *Halophila decipiens* (0.49 ha) were the least common seagrass communities and together comprised less than 5% of the total seagrass area in the Whitsundays.

Subtidal meadows dominated by *Halodule uninervis* (wide leaf form) (14.71±0.8 g DW m^{-2}) and *Cymodocea serrulata* (14.15±0.5 g DW m^{-2}) had the highest biomass of all meadows in this sub-region. These meadows were located on the eastern side of Whitsunday Island, and the northern Whitsunday coast. Subtidal meadows with the least above ground biomass were dominated by *Halophila spinulosa* (1.22 and 4.92 g DW m^{-2} for monospecific and multi-species meadows respectively) (Table 4) and were located mainly in the northern Whitsundays west of Dingo Beach, south of Shute Harbour near Cow and Calf Island and at Whitehaven Beach. Subtidal meadows with the least above ground biomass were dominated by *H. tricostata* 1.03±0.16 g DW m^{-2}. Intertidal meadows with the highest above-ground biomass were dominated by *Zostera capricorni* and located from Pioneer Bay to Midge Point (Maps 6-12). Intertidal meadows with *Halodule uninervis* as a common species had relatively low biomass ranging from means of 1.42 to 1.92 g DW m^{-2} (Table 4). These meadows were located throughout the nearshore Whitsundays region.

Regional description

Coastal seagrass meadows north of Cape Conway did not extend beyond 1km from land, and were limited to waters less than 11m depth below mean sea level (Maps 3-10, Figure 3). Seagrass meadows in Repulse Bay were found within 3 km of land and were limited to waters less than 5.1m below mean sea level (Map 10-12, Figure 3). Seagrass meadows dominated by *Halodule uninervis* (wide leaf form) were widely distributed and occurred predominantly in sheltered areas along the northern Whitsundays coast mostly restricted to areas less than 1 km from the coast (Maps 3-14). In waters off Whitsunday Island *Halodule uninervis* (wide leaf form) meadows were found in association with *Cymodocea serrulata, Halophila spinulosa* and *Halophila ovalis* (Maps 13 &14). The *Halodule uninervis* dominated meadow in the north west region of Whitsunday Island formed the largest

[1] Maps 3-14 in this report are magnified for identification of small meadows. Estimates of mapping error are not to be inferred from the scale of these presentation maps. These can be obtained from the original GIS and be used when measuring changes in distribution.

seagrass meadow found in this survey, extending 5.6 km along the coast and 3.4 km perpendicular from the coast (1432.7±113 ha) (Map 13). Smaller meadows were found in coastal areas. *Halodule uninervis* (narrow leaf form) meadows occurred mostly in intertidal reaches of Repulse Bay, Pioneer Bay and in most of the embayments of the mainland coast. One small *Halodule uninervis* (narrow leaf form) meadow was found at the northern end of Whitehaven Beach. Small meadows of *Halophila tricostata* and *Halophila spinulosa* were found in subtidal island and coastal locations often in deeper waters (> 5m) than *Halodule uninervis*. *Zostera capricorni* meadows were located along the mainland coast from Pioneer Bay to Midgeton, while *Thalassia hemprichii* dominated 3 meadows from Hydeaway Bay to Shute Harbour.

To capture information on seagrass meadow biomass and areal extent at a fine geographical scale in the Whitsundays region was divided into 14 localities (Table 3). These localities represent groups of meadows that are exposed to localised catchment influences and climatic forces. Above-ground biomass and seagrass meadow area was generally higher at island meadows compared to coastal fringing meadows. The greatest areas of seagrass at coastal regions were at Northern and Southern Repulse Bay and HydeawayBay/Dingo Bay. The lowest biomass and area of seagrass occurred along the central Whitsundays coast from Earlando to Woodcutters Bay (Table 3).

Table 3 Mean above-ground seagrass biomass (g DW m^{-2}) and the areal extent of seagrass for 14 localities in the Whitsunday region

Location	Mean biomass (g DW m^{-2} ±SE) (sites with seagrass present)	Areal Extent (ha±ha)
HydeawayBay/ Dingo Bay *(to George Point)*	2.95±0.2	388.9±100
George Pt to Earlando	3.11±0.2	243.9±60
Earlando to Woodwark Bay	0.53±0.1	233.6±77
Pioneer Bay to Funnel Bay	0.59±0.1	141.1±40
Shute Harbour	1.35±0.1	258.6±83
Trammel & Woodcutters Bays	4.03±0.4	122.4±52
Cow & Calf Islands to Cape Conway	2.86±0.3	271.5±82
Northern Repulse Bay	0.31±0.03	822.4±157
Southern Repulse Bay *(Laguna Quays, Midgeton & Midge Point)*	0.14±0.02	692.3±134
Cid Harbour (Whitsunday Island)	7.25±0.5	340.2±101
North-western coast of Whitsunday Island *(Hook Is to Daniel Point)*	14.77±0.7	1432.7±113
Tongue Inlet *(Whitsunday Island)*	10.71±0.6	241.6±62
Whitehaven Beach *(Whitsunday Island)*	7.73±0.5	363.6±116
South Molle Island	0.01±0.004	4.0±3.0
TOTAL (all locations)	5.5±0.1	5553±1182

Table 4 Mean above-ground seagrass biomass and areal extent of each seagrass community type identified in the Whitsundays region surveys in January 1999 and January 2000.

Code	Seagrass Community Type	Mean biomass (g DW m^{-2})	Area (ha±R)
1	*Halophila decipiens*	0.206	0.49±0.39
2	*Halophila ovalis*	0.956	105.3±89.5
3	*Halophila tricostata*	1.039	68.7±46.6
4	*Halophila ovalis* with *Halodule uninervis*	1.147	300.5±86.9
5	*Halophila spinulosa*	1.221	151.8±52.1
6	*Halodule uninervis (narrow)*	1.429	745.3±172.2
7	*Halodule uninervis(narrow)* with *Halodule uninervis (wide) and Halophila ovalis*	1.476	81.3±13.5
8	*Halodule uninervis(narrow)* with *Zostera capricorni*	1.53	323.1±34.8
9	*Halophila ovalis with Halophila spiunulosa*	1.58	0.69±0.49
10	*Halodule uninervis (narrow)* with *Halophila ovalis*	1.92	22.75±3.26
11	*Thalassia hemprichi* with *Halophila ovalis*	2.49	66.9±9.8
12	*Halophila uninervis* (wide)	3.39	181.2±69.3
13	*Syringodium isoetifolium* with *Halodule uninervis* (wide)	4.01	16.2±7.0
14	*Halodule uninervis* (wide) with mixed species	4.16	233.3±34.4
15	*Zostera capricorni* with *Halodule uninervi* and *Halophila ovalis*	4.23	77.4±17.8
16	*Zostera capricorni*	4.29	354.2±37.8
17	*Halophila spinulosa* with *Halophila ovalis* and *Halodiule uninervis*	4.92	286.1±154.7
18	*Halodule uninervis* (wide) with *Halophila ovalis*	7.68	676.6±170.3
19	*Cymodocea serrulata* with *Halodule uninervis* (wide) and *Syringodium isoetifolium*	14.15	106.0±23.9
20	*Halodule uninervis* (wide) with *Cymodocea serrulata* and *Halophila ovalis*	14.71	1755.7±156.6

Seagrass depth distributions

Seagrasses were found from 0.05m (*Zostera capricorni* and *Halophila ovalis)* to 15 m below MSL (*Halophila decipiens* and *H. tricostata*) in the present survey (Figure 2). *Halophila ovalis* had the greatest depth range (0.04-13.4 m below MSL), and *Thalassia hemprichii* grew in the narrowest depth range (0.5-1.6 m below MSL) (Figure 2).

Mean depths of occurrence for individual seagrass species were between 1.0m and 8.9m, and were deepest for *Halophila* species (Figure 2). Mean depths of many ribbon leaf bladed species (*Zostera capricorni*, *Thalassia hemprichii, Cymodocea rotundata* and *Halodule uninervis* (narrow leaf form)) were less than 1.5m below MSL (Figure 2).

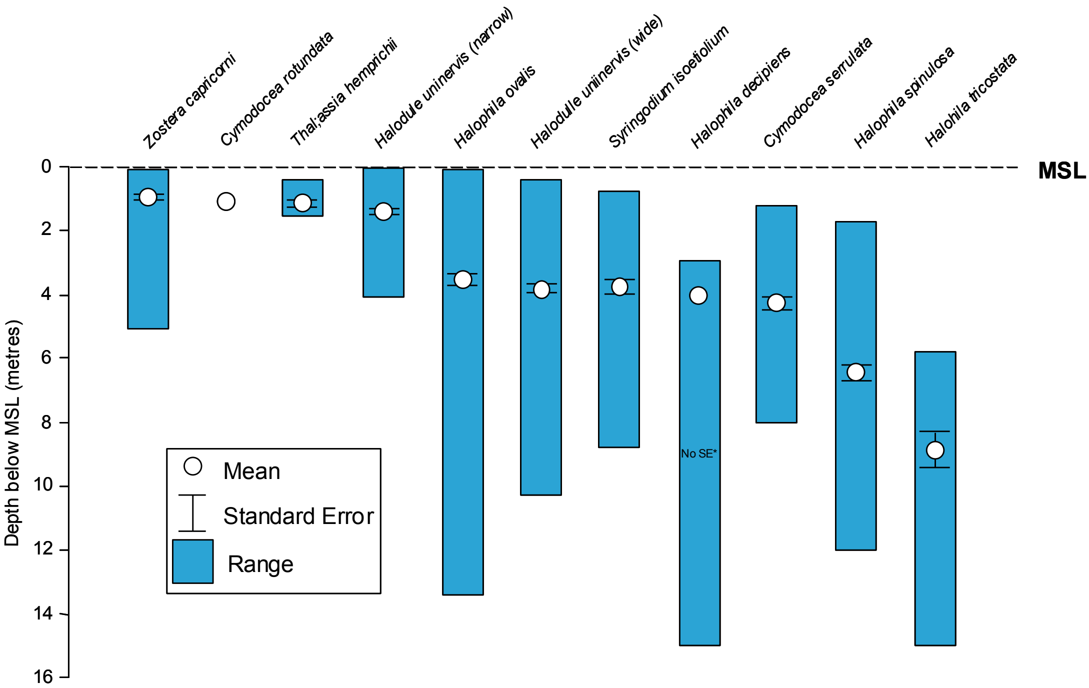

Figure 2. Mean and range of depths of occurrence for seagrass species found in the Whitsunday region, January 1999 and 2000.

Seagrasses in coastal locations were most often limited to depths less than 11m, while seagrasses growing at island locations (eg. Whitehaven Beach) grew to 15m below MSL (Figure 3). Seagrasses were shallowest in Repulse Bay (limited to < 5m depth), while seagrasses from Dingo Beach to Bluff Point reached 10.2m. From Pioneer Bay to Cape Conway seagrass meadows were found to 11.5m below MSL (Figure 3).

Species of seagrasses at island locations were found at greater depths than the same species from coastal locations (Figure 3). For example, the mean depth of *Halophila ovalis* was 1.5m below MSL in northern Repulse Bay, compared to 5.9m at Whitehaven Beach (Figure 3).

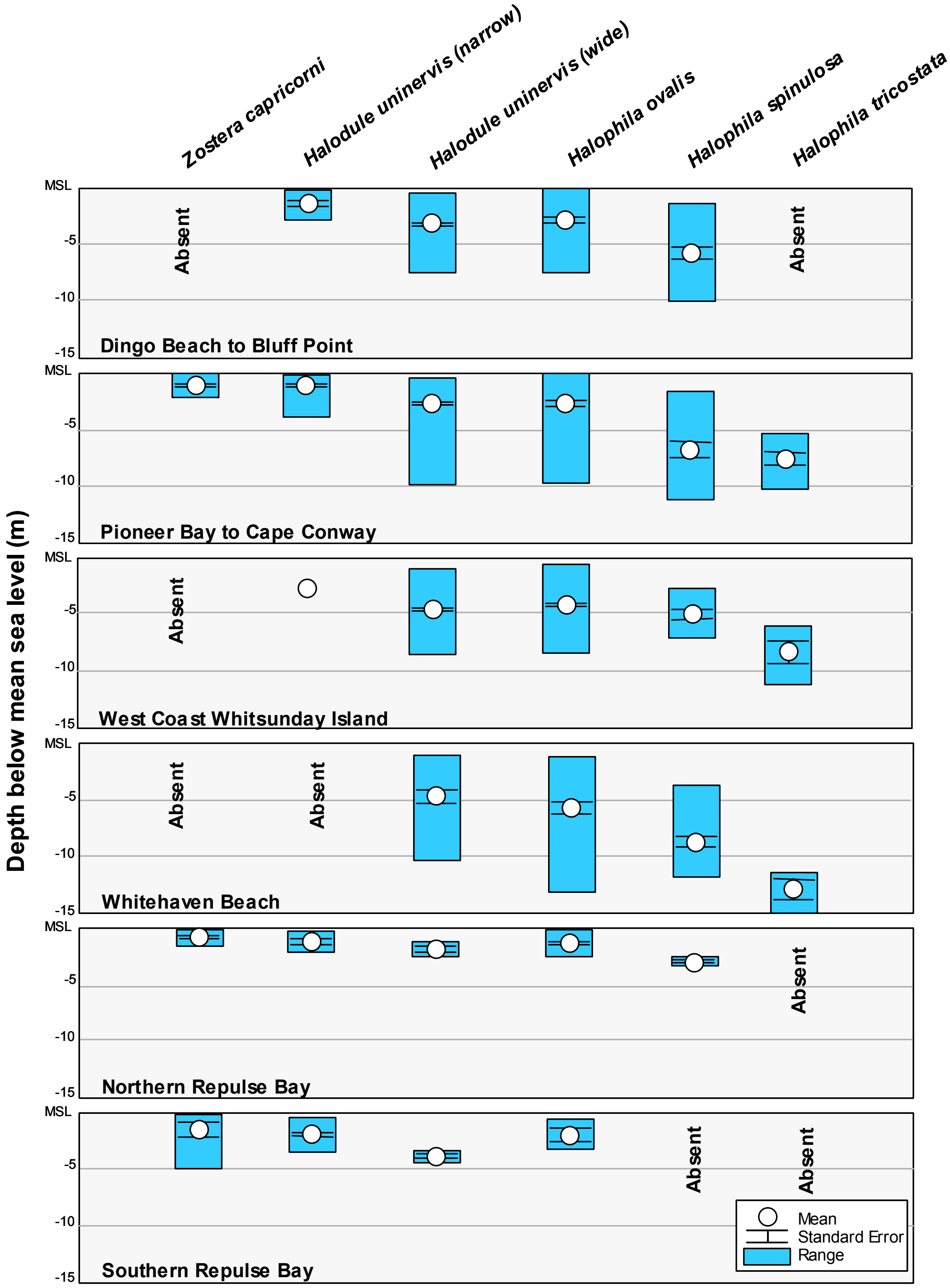

Figure 3. Mean and range of depths of occurrence for selected seagrass species at localities in the Whitsunday region, January 1999 and 2000.

Seagrass Biomass

Maximum above-ground seagrass biomass for all seagrass species was 36.3 g DW m^{-2} located at a shallow subtidal meadow at Tongue Inlet on the east coast of Whitsunday Island. Mean above-ground biomass of all seagrass species in the Whitsunday survey region was less than 6.5 g DW m^{-2} and greatest for *Halodule uninervis* (wide leaf form) (Figure 4). *Halophila* species had the lowest mean above-ground biomass (all species <2.2 g DW m^{-2}), while the ribbon bladed species, such as *Zostera capricorni, Cymodocea serrulata* and *Halodule uninervis* (wide leaf form) had the highest mean biomass (>4 g DW m^{-2}) (Figure 4).

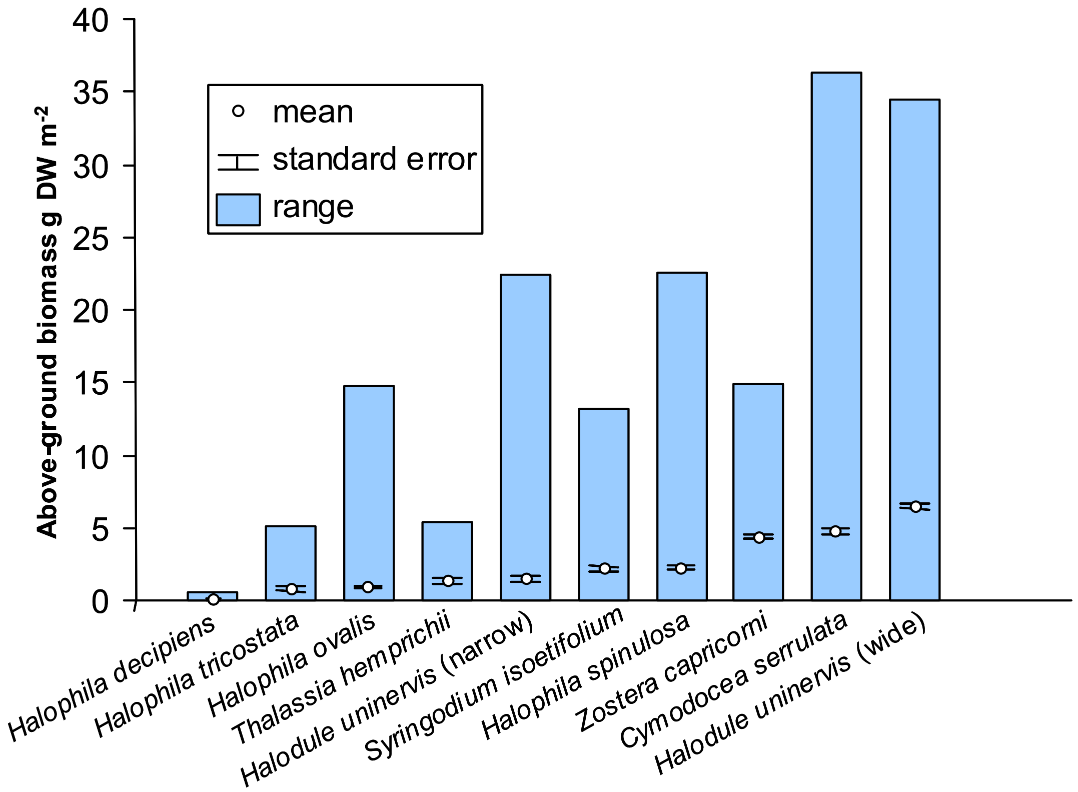

Figure 4. Means, range and SE for estimated above-ground biomass for seagrass species (all sites pooled), Whitsundays, January 1999 and January 2000.

For seagrass regions identified in this survey, mean above-ground seagrass biomass ranged from 0.01 ±0.004g DW m^{-2} on South Molle Island to 14.8 ±0.8 g DW m^{-2} along the north-west coast of Whitsunday Island (Figure 5).

Seagrass meadows dominated by *Halodule uninervis* (wide leaf form) and *Cymodocea serrulata* at island locations (eg. Cid Harbour, Whitehaven Beach) yielded a higher seagrass biomass, compared to nearshore *Zostera capricorni* and *Halodule uninervis* (narrow leaf form) dominated seagrass meadows located along the coastal fringe (eg. Earlando, Pioneer Bay, Midge Point) (Figure 5).

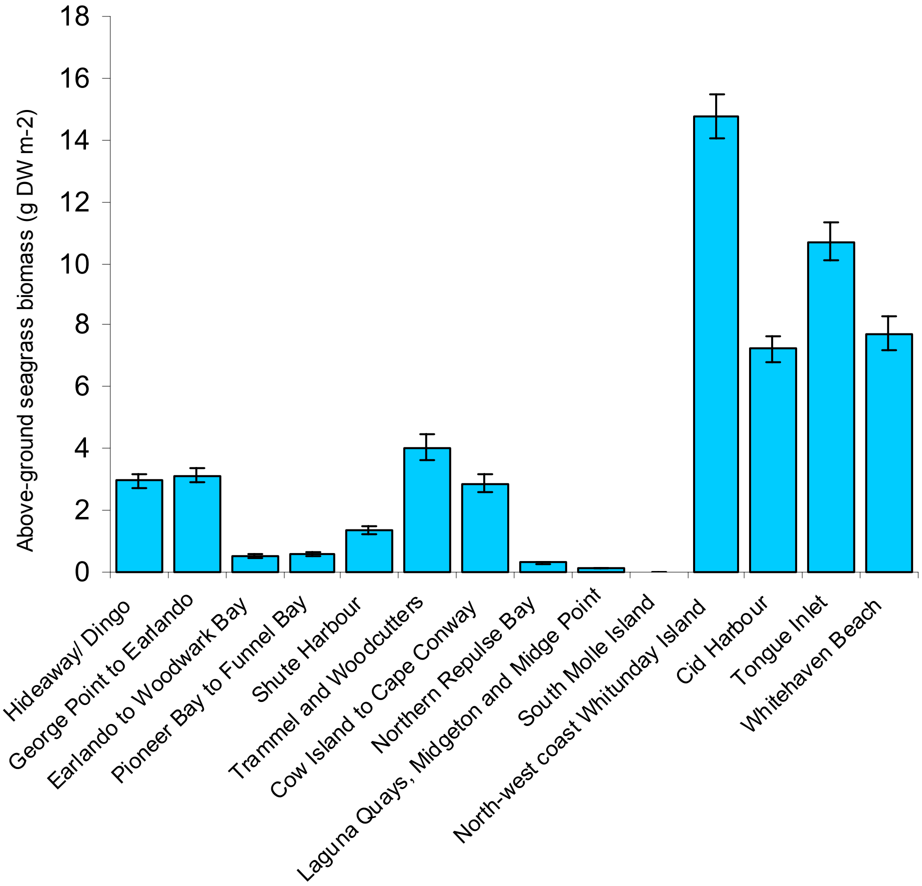

Figure 5. Mean above-ground seagrass biomass (g DW m^{-2}, all sites pooled) for Whitsunday Regions, January 1999-2000. *Error bars represent 95% confidence limits.*

Map 1

Dive survey sites in the Whitsunday Region, January 1999 and January 2000

LEGEND

- Seagrass
- No Seagrass
- Helicopter flight path

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002) Seagrass Resources of the Whitsunday Region, 1999-2000. DPI Information Series QI02043 (DPI, Cairns) 50pp.

Sampling dates: Dive survey 8-15 January 1999 and 24-30 January 2000.

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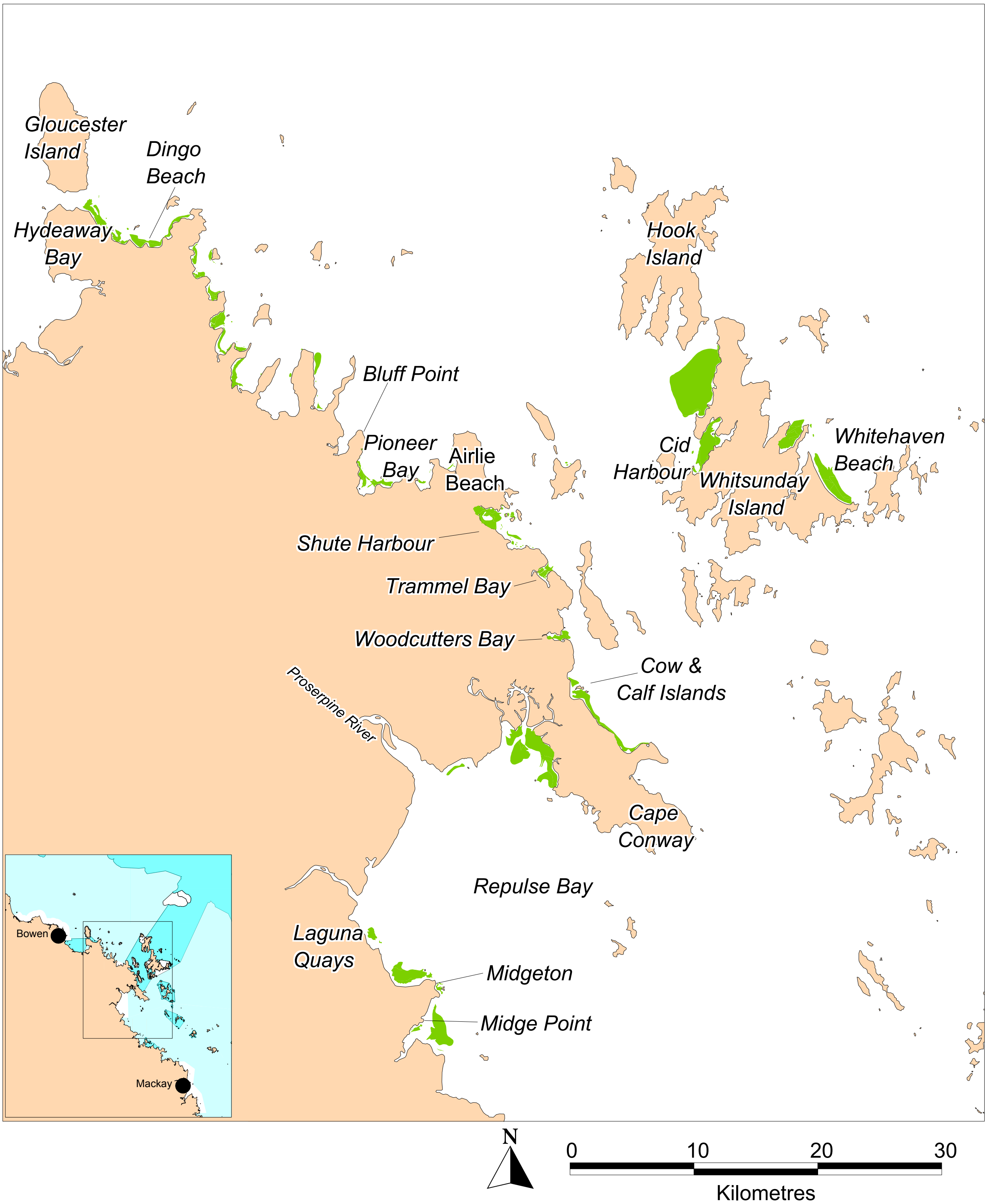
Map 2

Seagrass meadows in the Whitsunday Region, January 1999 and January 2000



LEGEND

Seagrass meadows

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002) Seagrass Resources of the Whitsunday Region, 1999-2000. DPI Information Series QI 02043 (DPI, Cairns) 50pp.

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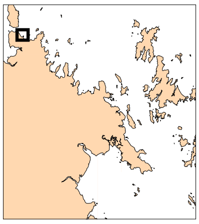
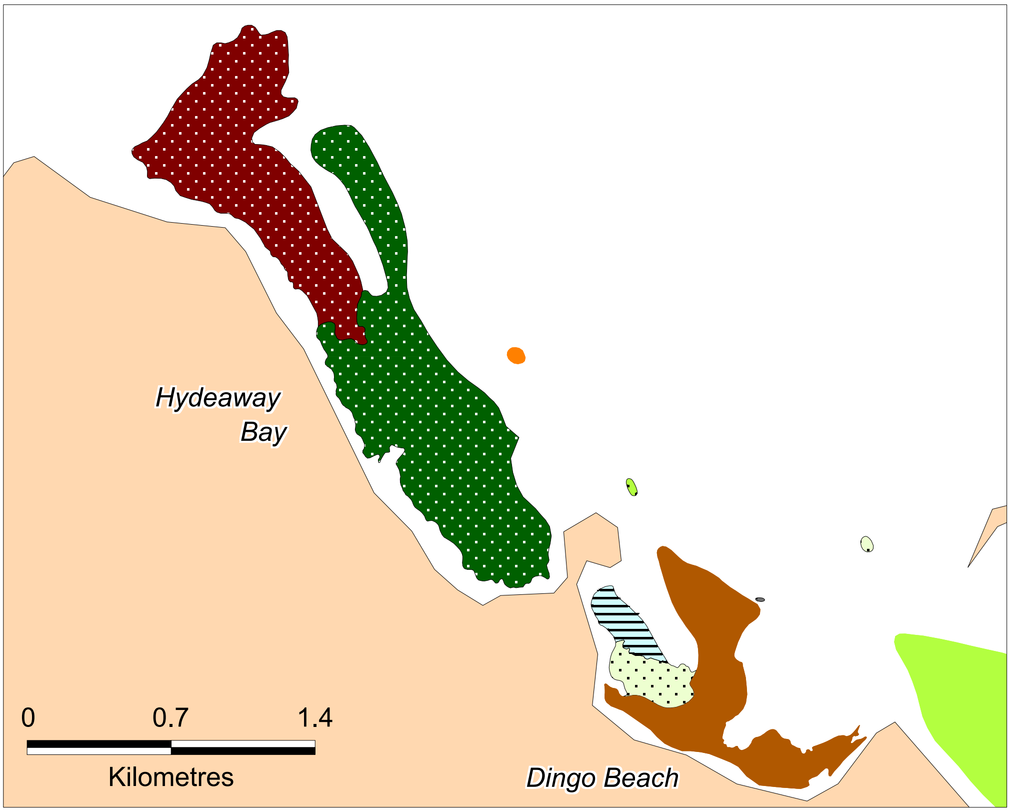
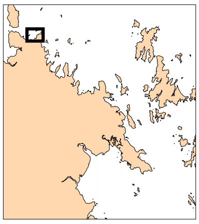
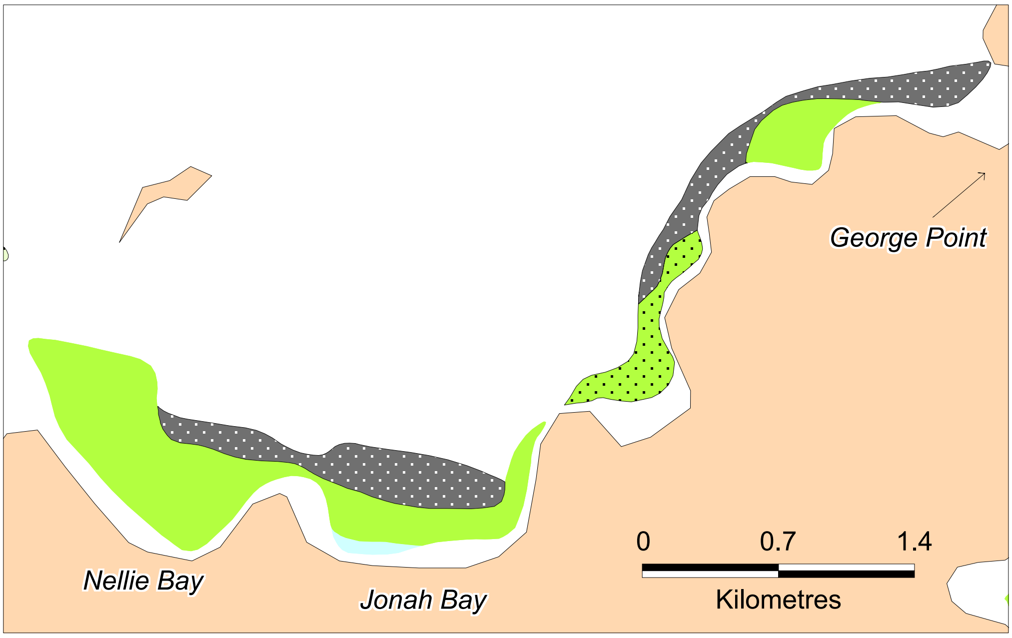
Map 3 Seagrass meadows of Hydeaway Bay, Dingo Beach, Nellie Bay, and Jonah Bay, January 1999









SEAGRASS COMMUNITIES

- *Halodule uninervis (narrow leaf)*
- *Halodule uninervis (wide leaf)*
- *Halodule uninervis (wide leaf) with Halophila spp.*
- *Halodule uninervis (wide leaf) with mixed species*
- *Halophila ovalis with Halophila spinulosa*
- *Halophila ovalis with Halodule uninervis*
- *Halophila spinulosa with Halophila spp./ Halodule uninervis*
- *Thalassia hemprichii with Halophila ovalis*

SEAGRASS ABUNDANCE

Light Moderate Dense

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002) Seagrass Resources of the Whitsunday Region, 1999-2000. DPI Information Series QI02043 (DPI, Cairns) 50pp.

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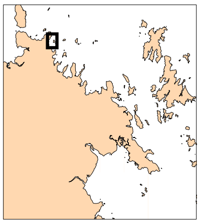
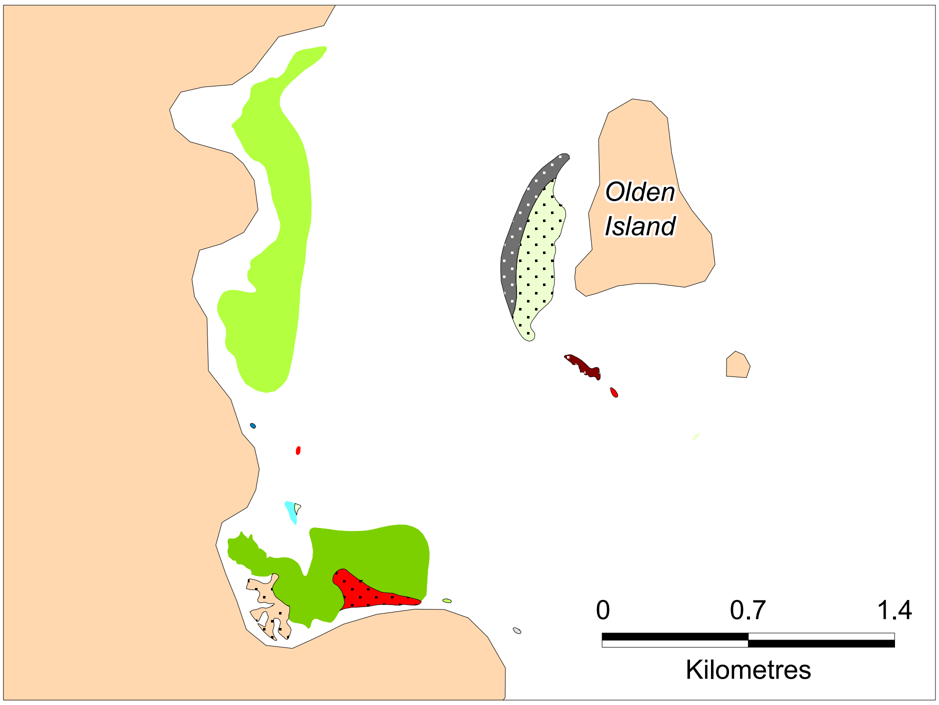
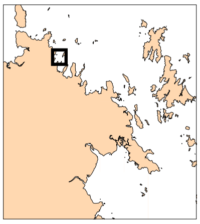
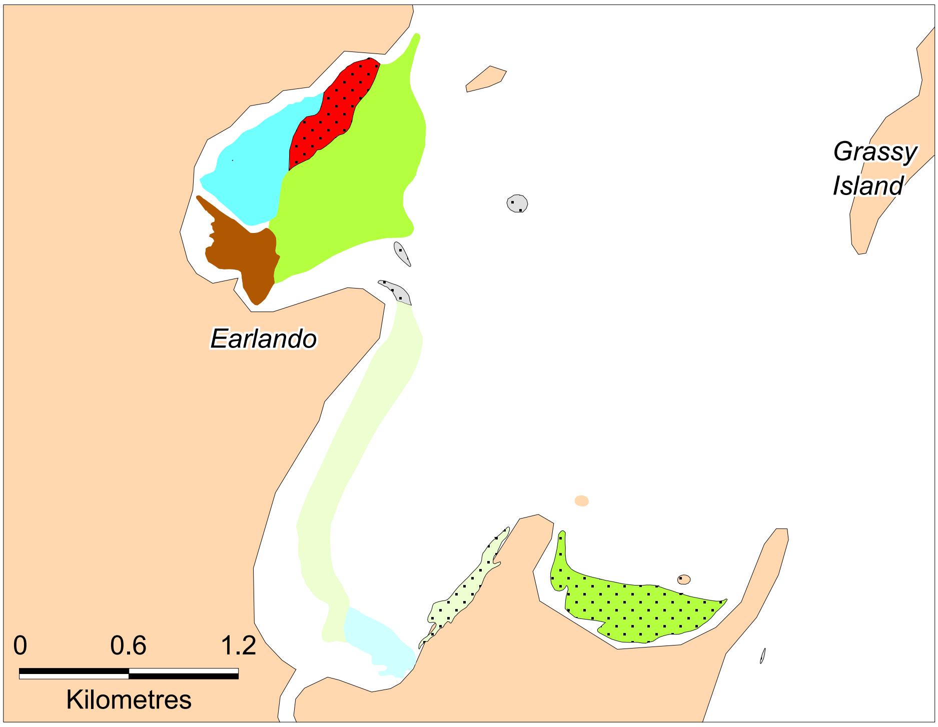
Map 4

Seagrass meadows of Earlando and Olden Island
January 1999









SEAGRASS COMMUNITIES

- *Halodule uninervis (narrow leaf)*
- *Halodule uninervis (narrow leaf) with Halophila ovalis*
- *Halodule uninervis (narrow leaf) with Halodule uninervis (wide leaf)/ Halophila spp.*
- *Halodule uninervis (wide leaf)*
- *Halodule uninervis (wide leaf) with Halophila spp.*
- *Halodule uninervis (wide leaf) with Cymodocea serrulata/ Halophila spp.*
- *Halodule uninervis (wide leaf) with mixed species*
- *Halophila ovalis*
- *Halophila ovalis with Halophila spinulosa*
- *Halophila ovalis with Halodule uninervis*
- *Halophila spinulosa*
- *Halophila spinulosa with Halophila spp./ Halodule uninervis*
- *Syringodium iseotifolium/ Halodule uninervis (wide)*
- *Thalassia hemprichii with Halophila ovalis*

SEAGRASS ABUNDANCE

Light   Moderate   Dense

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002) Seagrass Resources of the Whitsunday Region, 1999-2000. DPI Information series QI02043 (DPI, Cairns) 50pp.

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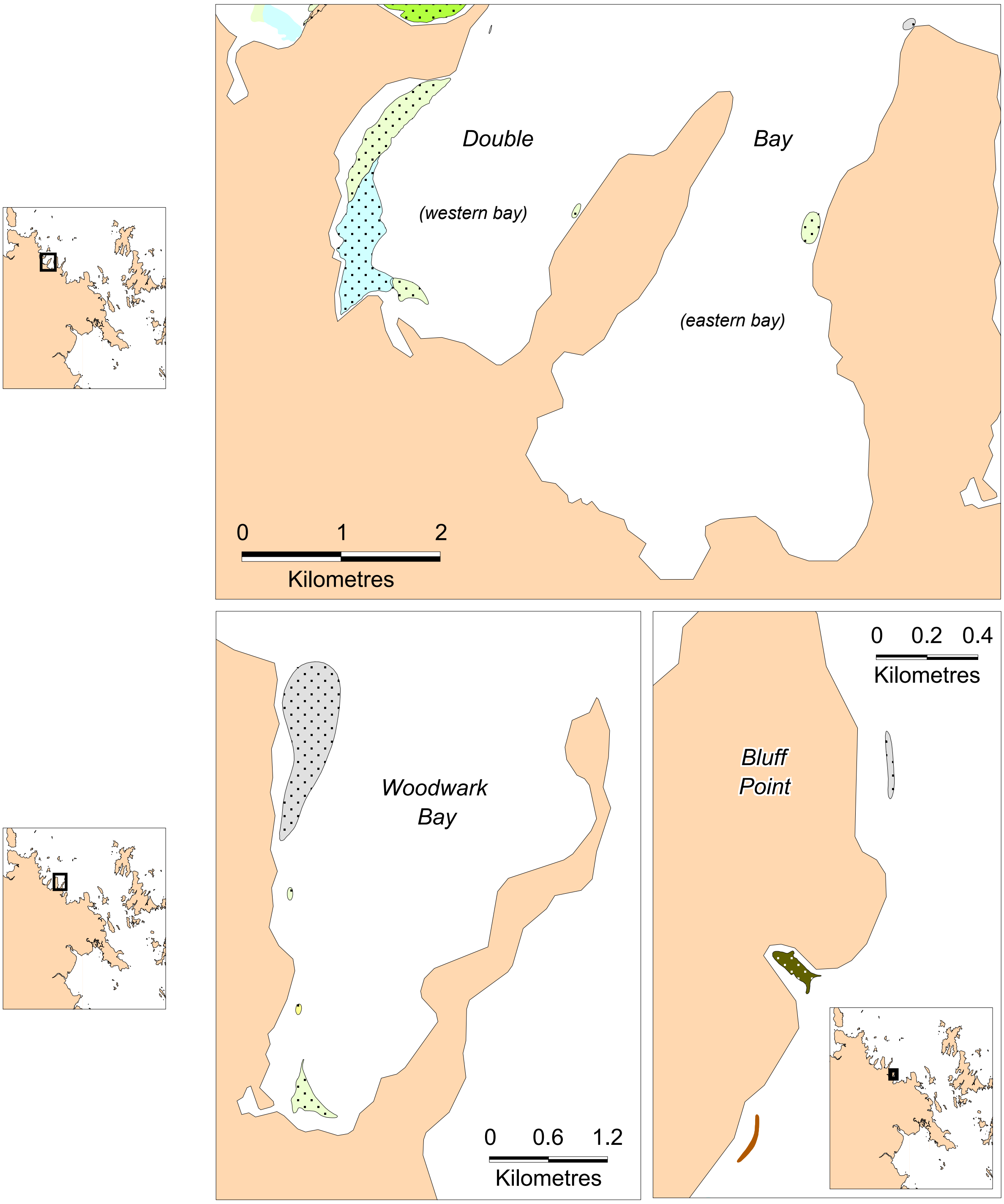
Map 5

Seagrass meadows of Double Bay, Woodwark Bay and Bluff Point, January 1999



SEAGRASS COMMUNITIES

- *Halodule uninervis (narrow leaf)*
- *Halodule uninervis (wide leaf)*
- *Halophila ovalis with Halodule uninervis*
- *Halophila spinulosa*
- *Halophila decipiens*
- *Zostera capricorni with Halodule uninervis/Halophila ovalis*

SEAGRASS ABUNDANCE

Light Moderate Dense

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002) Seagrass Resources of the Whitsunday Region, 1999-2000. DPI Information Series QI02043 (DPI, Cairns), 50pp.

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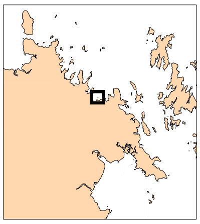
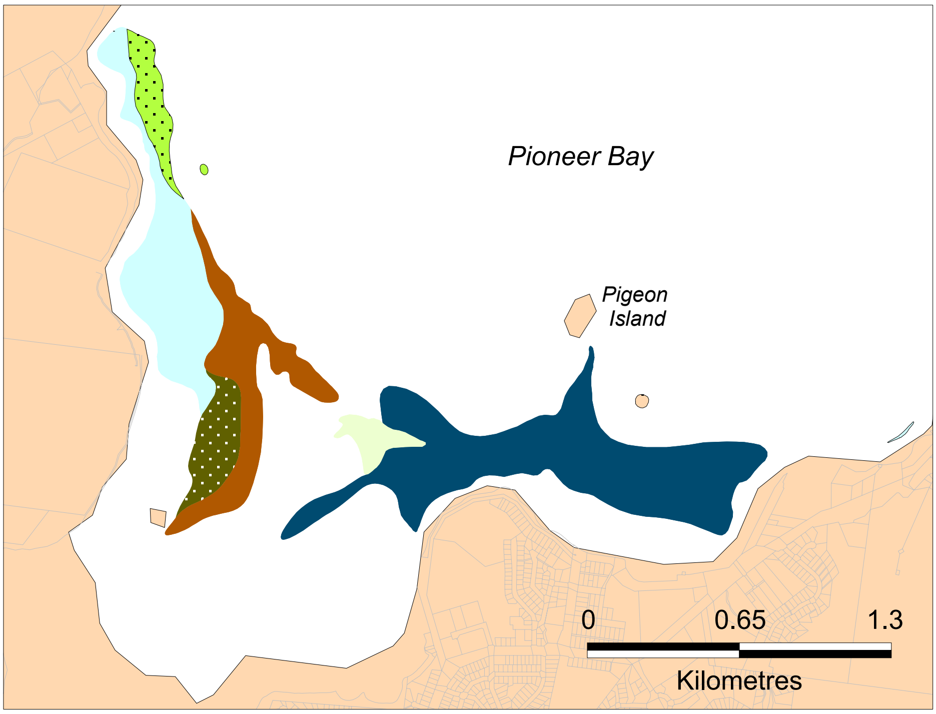
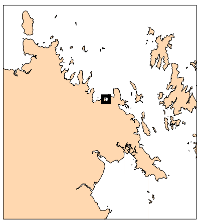
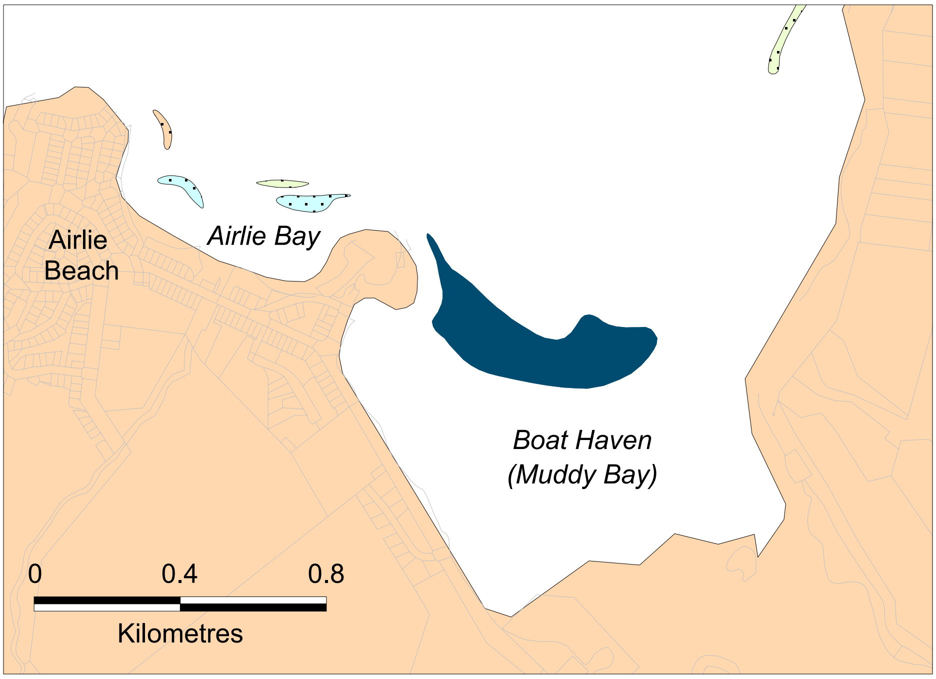
Map 6

Seagrass meadows of Pioneer Bay and Boat Haven, January 1999









SEAGRASS COMMUNITIES

- *Halodule uninervis (narrow leaf)*
- *Halodule uninervis (narrow leaf) with Zostera capricorni*
- *Halodule uninervis (wide leaf)*
- *Halodule uninervis (wide leaf) with Halophila spp.*
- *Halophila ovalis*
- *Halophila ovalis with Halodule uninervis*
- *Zostera capricorni with Halodule uninervis/Halophila ovalis*

SEAGRASS ABUNDANCE

Light | Moderate | Dense

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002)
Seagrass Resources of the Whitsunday Region, 1999-2000.
DPI Information Series QI02043 (DPI, Cairns), 50pp.

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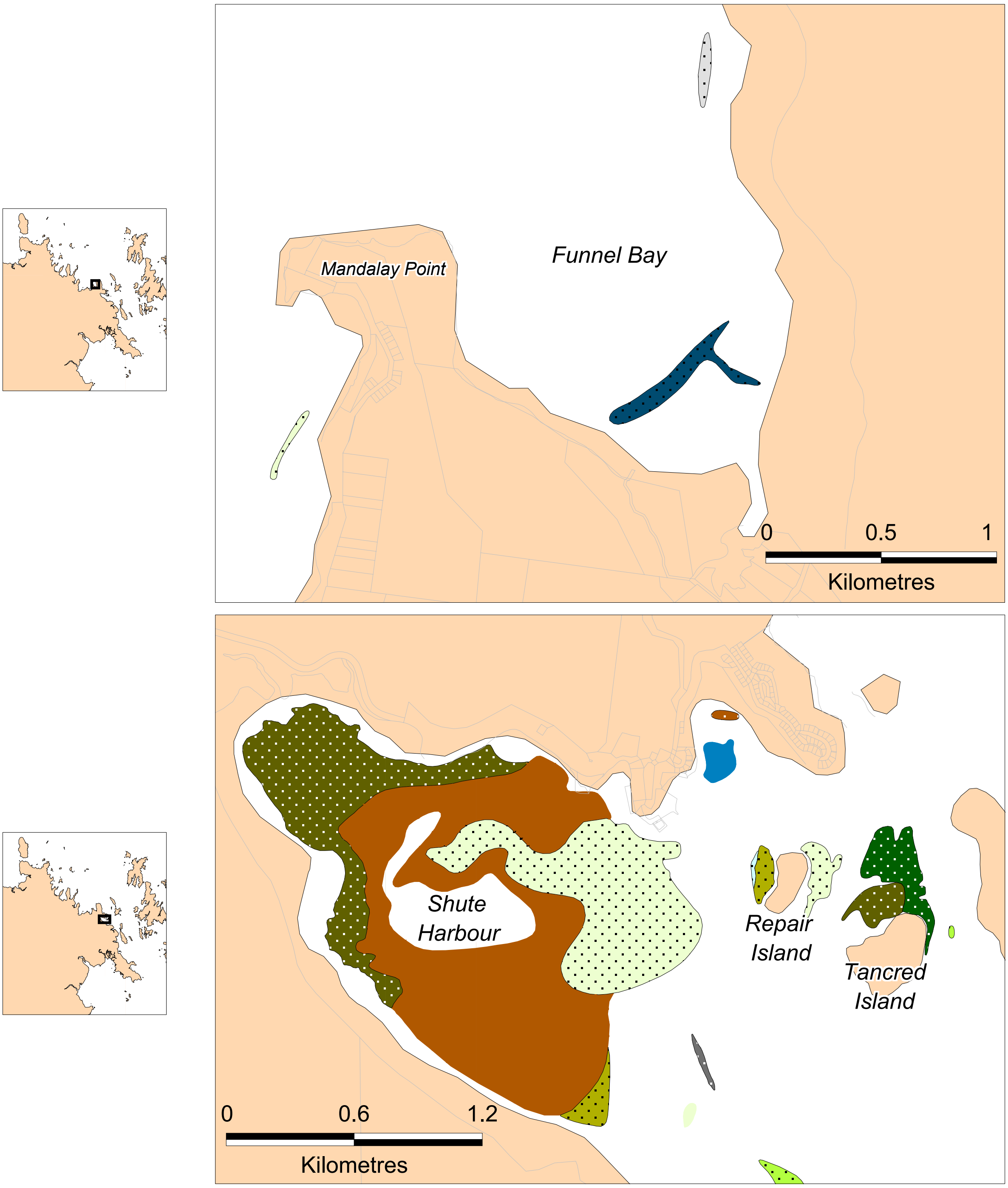
Map 7

Seagrass meadows of Funnel Bay and Shute Harbour January 1999



SEAGRASS COMMUNITIES

- *Halodule uninervis (narrow leaf)*
- *Halodule uninervis (narrow leaf) with Halodule uninervis (wide leaf form)/ Halophila ovalis*
- *Halodule uninervis (narrow leaf) with Zostera capricorni*
- *Halodule uninervis (wide leaf)*
- *Halodule uninervis (wide leaf) with Halophila spp.*
- *Halodule uninervis (wide leaf) with mixed spp.*
- *Halophila ovalis*
- *Halophila ovalis with Halodule uninervis*
- *Halophila spinulosa*
- *Halophila spinulosa with Halophila spp./Halodule uninervis*
- *Zostera capricorni*
- *Zostera capricorni with Halodule uninervis/Halophila ovalis*

SEAGRASS ABUNDANCE

- Light
- Moderate
- Dense

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002) Seagrass Resources of the Whitsunday Region, 1999-2000. DPI Information Series QI02043 (DPI, Cairns), 50pp.

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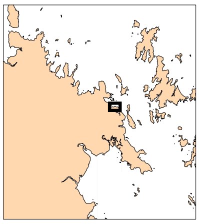
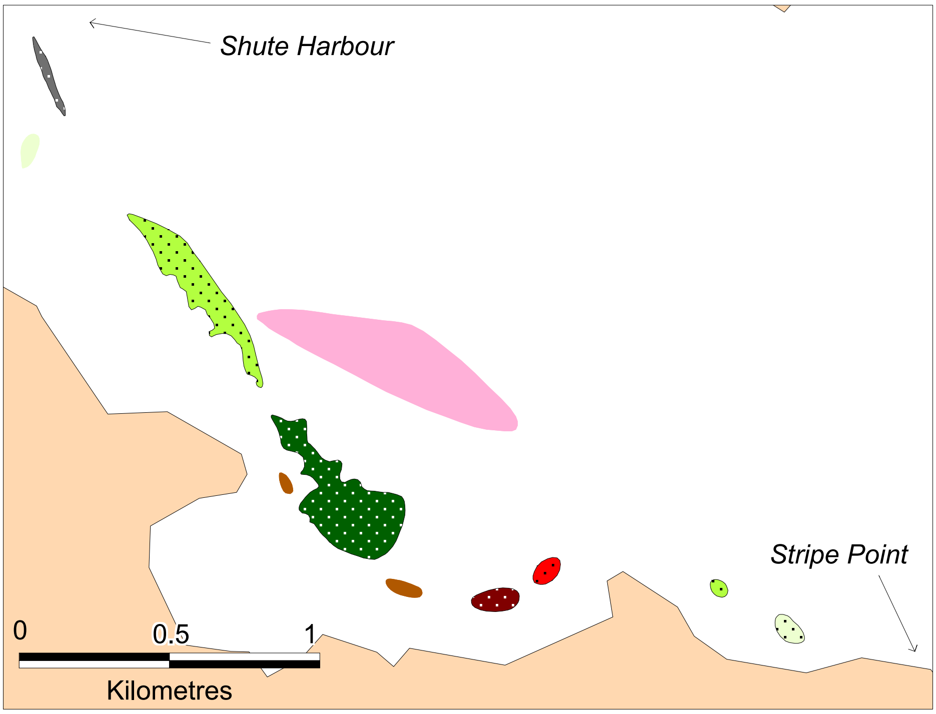
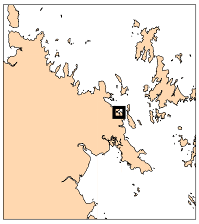
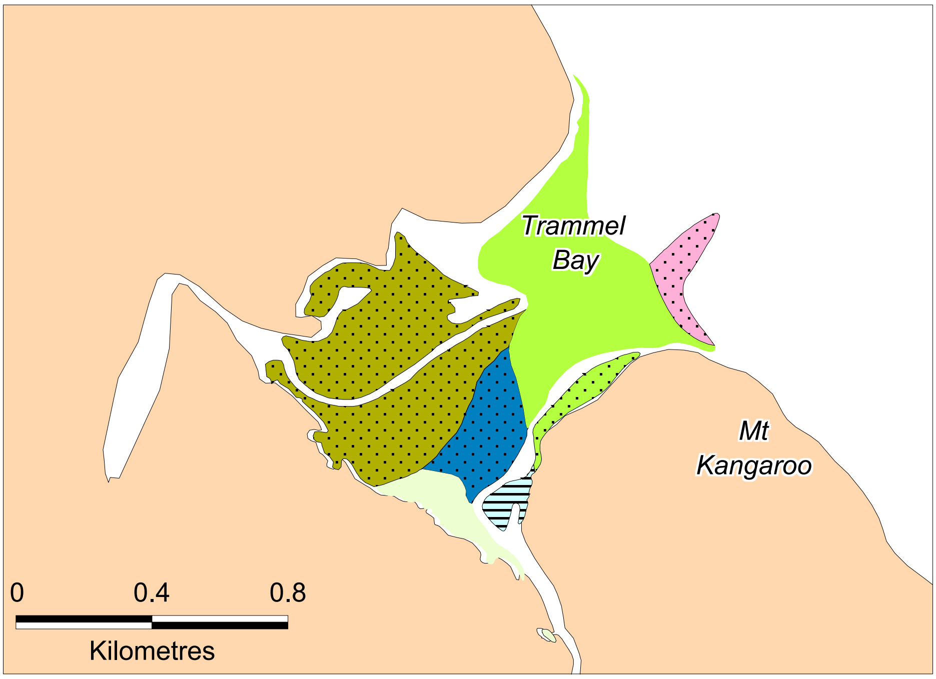
Map 8

Seagrass meadows between Shute Harbour and Stripe Point, and Trammel Bay, January 1999









SEAGRASS COMMUNITIES

- *Halodule uninervis (narrow leaf)*
- *Halodule uninervis (narrow leaf) with Halodule uninervis (wide leaf form)/ Halophila ovalis*
- *Halodule uninervis (wide leaf)*
- *Halodule uninervis (wide leaf) with Halophila spp.*
- *Halodule uninervis (wide leaf) with mixed spp.*
- *Zostera capricorni*
- *Halophila tricostata*
- *Halophila ovalis with Halodule uninervis*
- *Halophila spinulosa with Halophila spp./Halodule uninervis*
- *Syringodium isoetifolium with Halodule uninervis (wide leaf)*
- *Thalassia hemprichii with Halophila ovalis*

SEAGRASS ABUNDANCE

Light | Moderate | Dense

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002) Seagrass Resources of the Whitsunday Region, 1999-2000. DPI Information Series QI02043 (DPI, Cairns), 50pp.

Sampling dates: Dive survey 8-15 January 1999 and 24-30 January 2000

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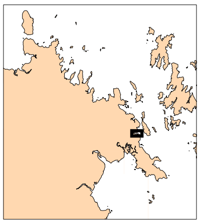
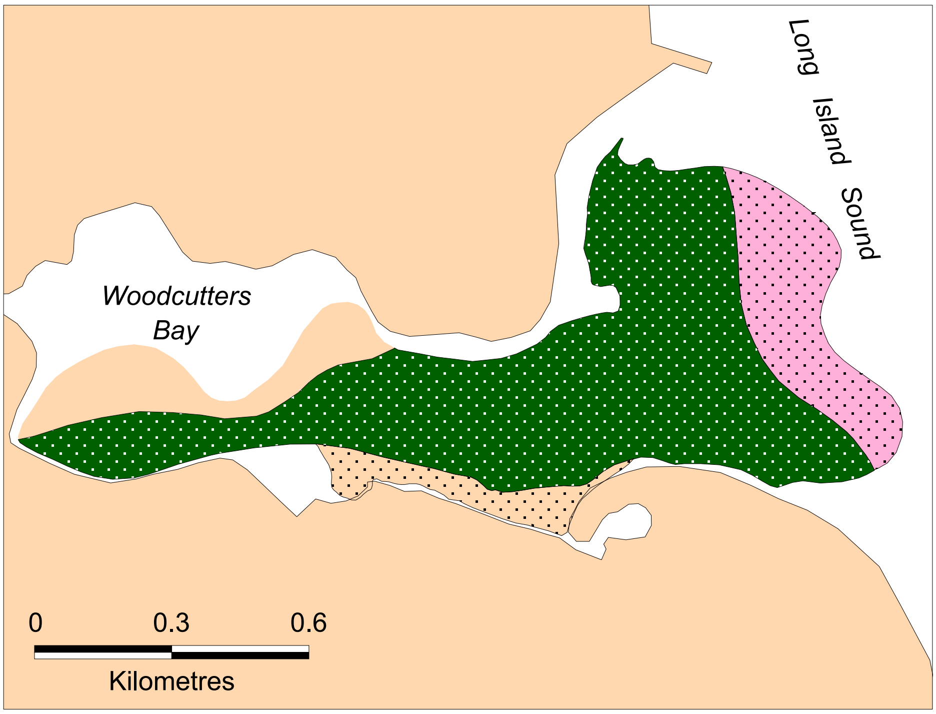
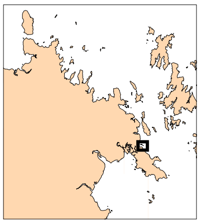
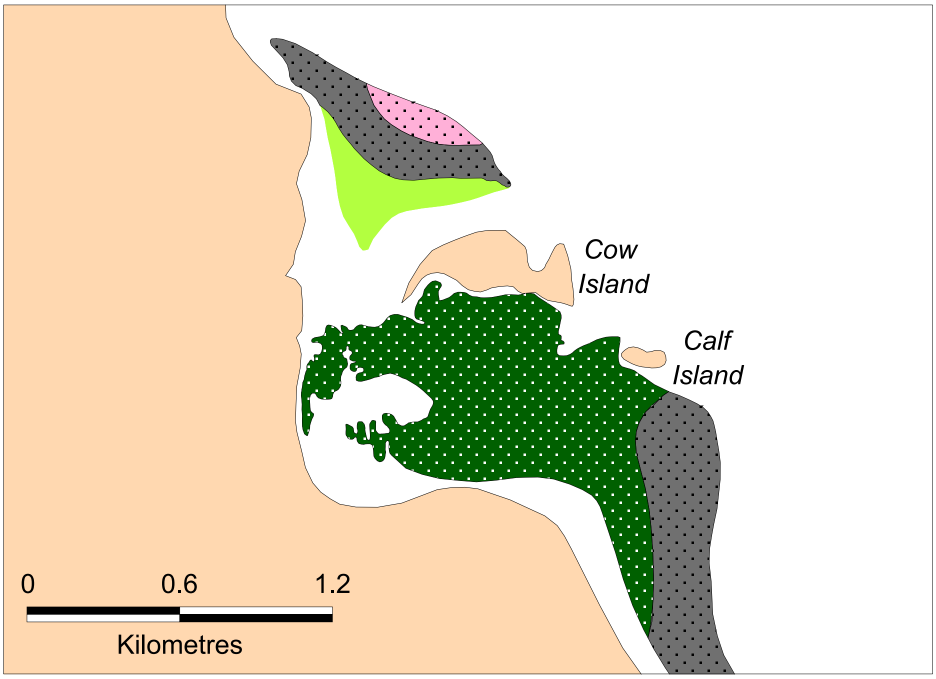
Map 9

Seagrass meadows of Woodcutters Bay, Cow Island and Calf Island, January 1999









SEAGRASS COMMUNITIES

- *Halophila tricostata*
- *Halophila ovalis with Halodule uninervis*
- *Halophila spinulosa with Halophila spp./Halodule uninervis*
- *Halodule uninervis (wide leaf) with Halophila spp.*
- *Halodule uninervis (wide leaf) with mixed spp.*

SEAGRASS ABUNDANCE

Light   Moderate   Dense

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002) Seagrass Resources of the Whitsunday Region, 1999-2000. DPI Information Series QI02034 (DPI, Cairns), 50 pp.

Sampling dates: Dive survey 8-15 January 1999 and 24-30 January 2000

N

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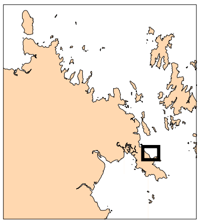
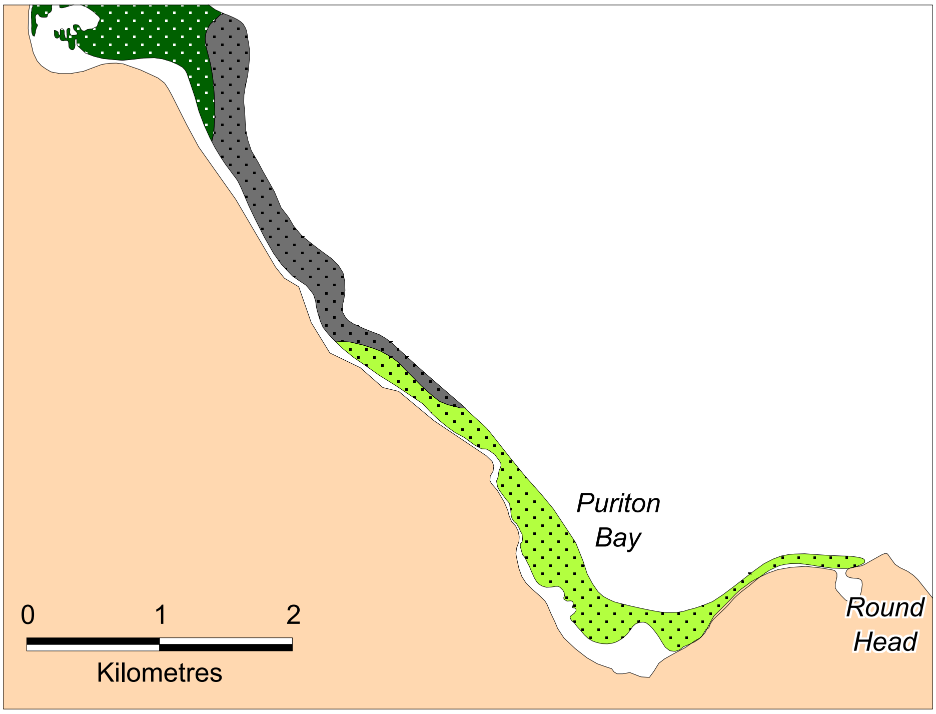
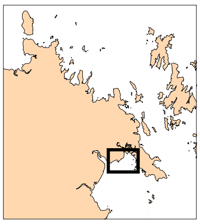
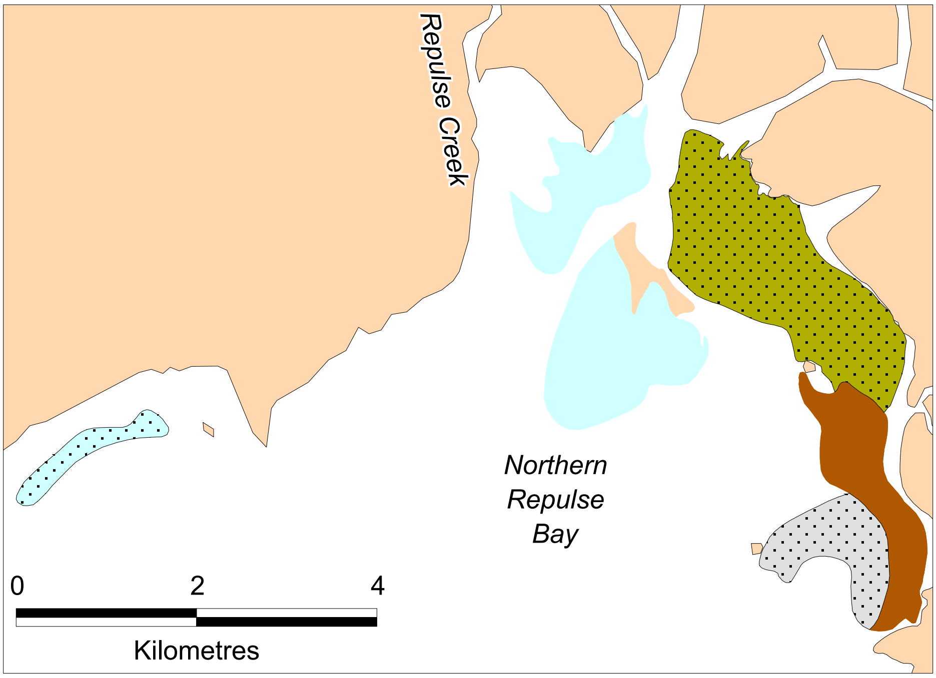
Map 10

Seagrass meadows between Calf Island and Puriton Bay and Northern Repulse Bay, January 1999 and January 2000









SEAGRASS COMMUNITIES

- *Halodule uninervis (narrow leaf)*
- *Halodule uninervis (wide leaf) with Halophila spp.*
- *Halodule uninervis (wide leaf) with mixed spp.*
- *Halophila ovalis*
- *Halophila ovalis with Halodule uninervis*
- *Halophila spinulosa*
- *Halophila spinulosa with Halophila spp./Halodule uninervis*
- *Zostera capricorni*

SEAGRASS ABUNDANCE

Light Moderate Dense

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002) Seagrass Resources of the Whitsunday Region, 1999-2000. DPI Infomation Series QI02043 (DPI, Cairns), 50pp.

Sampling dates: Dive survey 8-15 January 1999 and 24-30 January 2000

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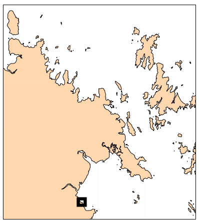
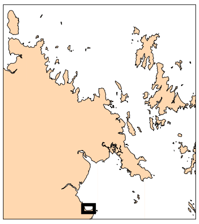
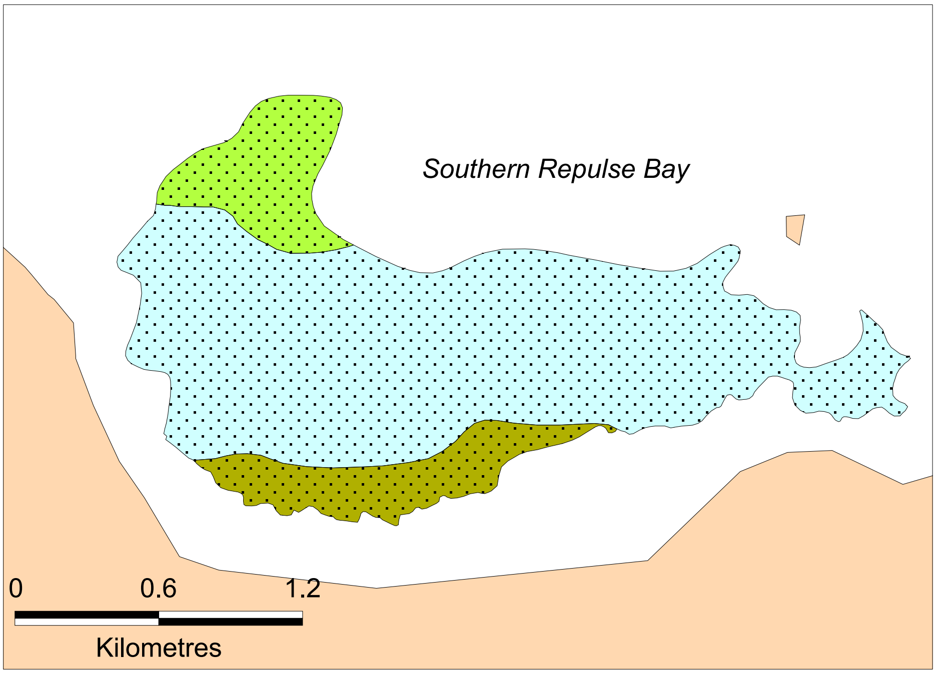
Map 11

Seagrass meadows of Laguna Quays and Southern Repulse Bay, January 2000







SEAGRASS COMMUNITIES

- *Halodule uninervis (narrow leaf)*
- *Halodule uninervis (wide leaf) with Halophila spp.*
- *Zostera capricorni*

SEAGRASS ABUNDANCE

Light Moderate Dense

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002)
Seagrass Resources of the Whitsunday Region, 1999-2000.
DPI Information Series QI02043 (DPI, Cairns), 50pp.

Sampling dates: Dive survey 8-15 January 1999 and 24-30 January 2000

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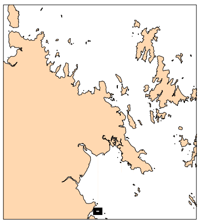
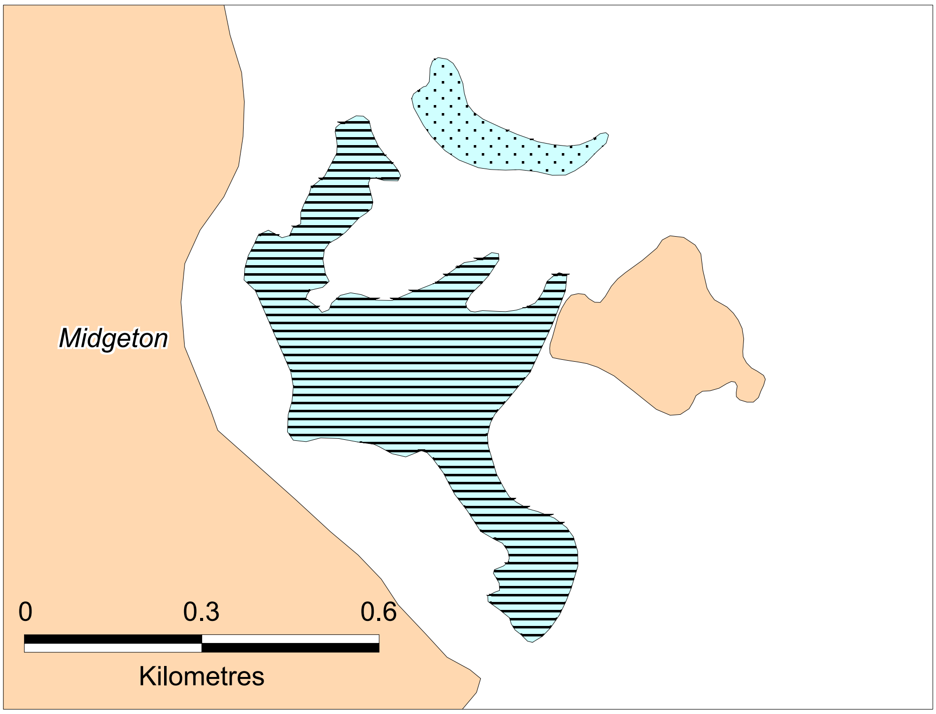
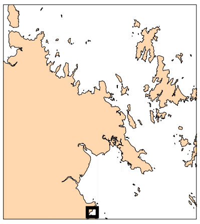
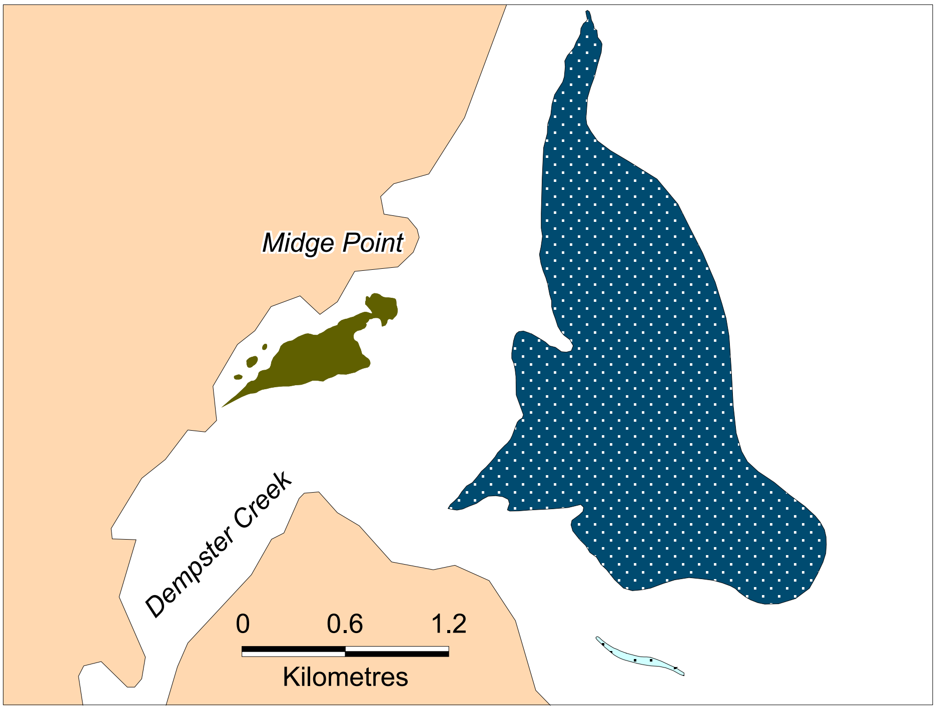
Map 12

Seagrass meadows of Midgeton and Midge Point, January 2000









SEAGRASS COMMUNITIES

- *Halodule uninervis (narrow leaf)*
- *Halodule uninervis (narrow leaf) with Halodule uninervis (wide leaf)/ Halophila ovalis*
- *Zostera capricorni with Halodule uninervis/ Halophila ovalis*

SEAGRASS ABUNDANCE

Light | Moderate | Dense

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002) Seagrass Resources of the Whitsunday Region, 1999-2000. DPI Information Series QI02043 (DPI, Cairns), 50pp.

Sampling dates: Dive survey 8-15 January 1999 and 24-30 January 2000

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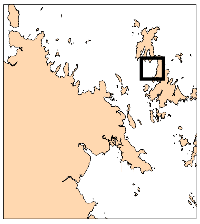
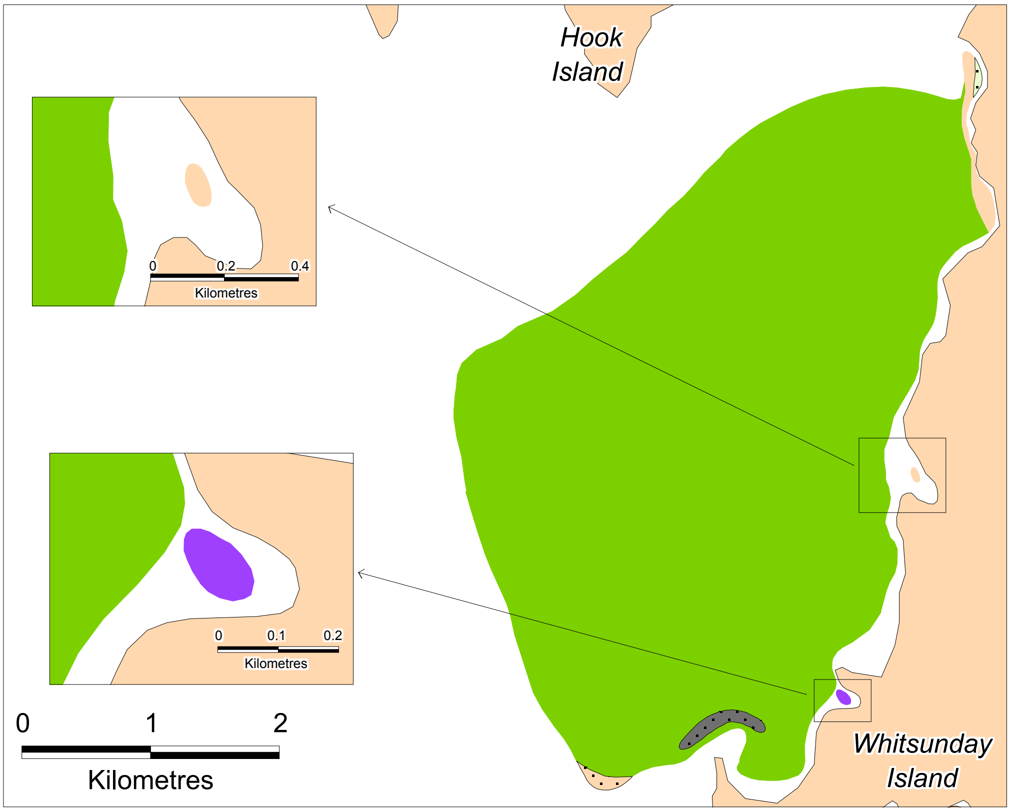
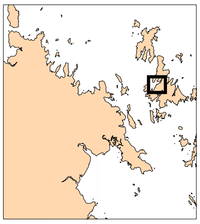
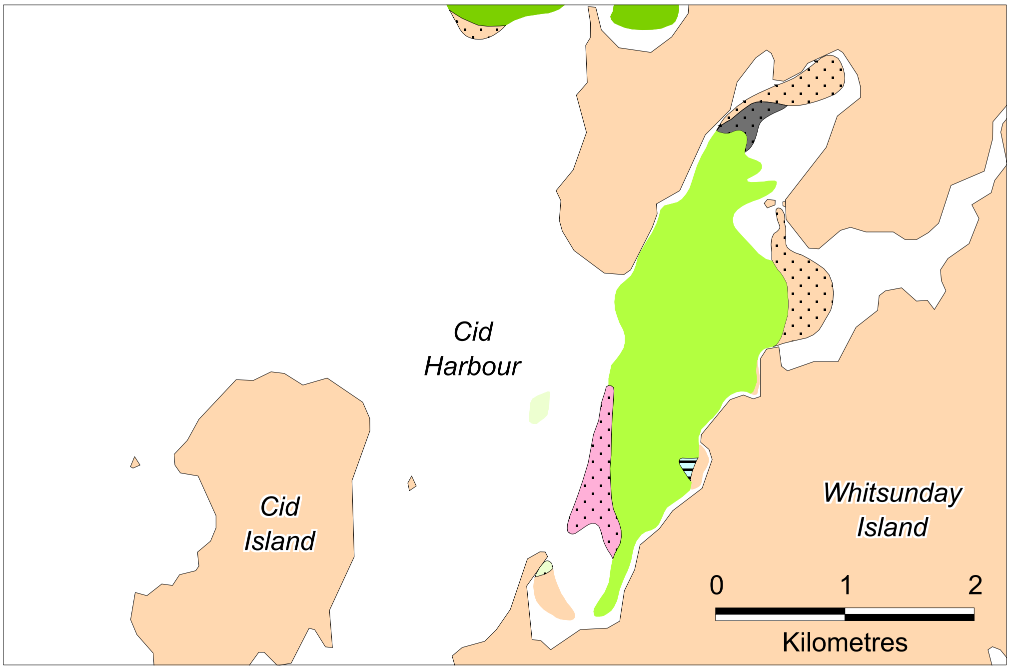
Map 13 Seagrass meadows of north-west Whitsunday Island, and Cid Harbour, January 1999









SEAGRASS COMMUNITIES

- *Halodule uninervis (narrow leaf)*
- *Halodule uninervis (wide leaf)*
- *Halodule uninervis (wide leaf) with Halophila spp.*
- *Halodule uninervis (wide leaf) with Cymodocea serrulata/ Halophila spp.*
- *Halodule uninervis (wide leaf) with mixed species*
- *Halophila ovalis*
- *Halophila tricostata*
- *Halophila spinulosa with Halophila spp./ Halodule uninervis*
- *Cymodocea serrulata with Syringodium isoetifolium/ Halodule uninervis (wide leaf)*

SEAGRASS ABUNDANCE

Light Moderate Dense

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002) Seagrass Resources of the Whitsunday Region, 1999-2000. DPI Information Series (DPI, Cairns), 50pp.

Sampling dates: Dive survey 8-15 January 1999 and 24-30 January 2000

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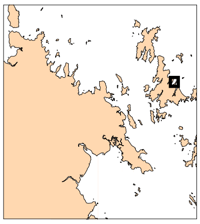
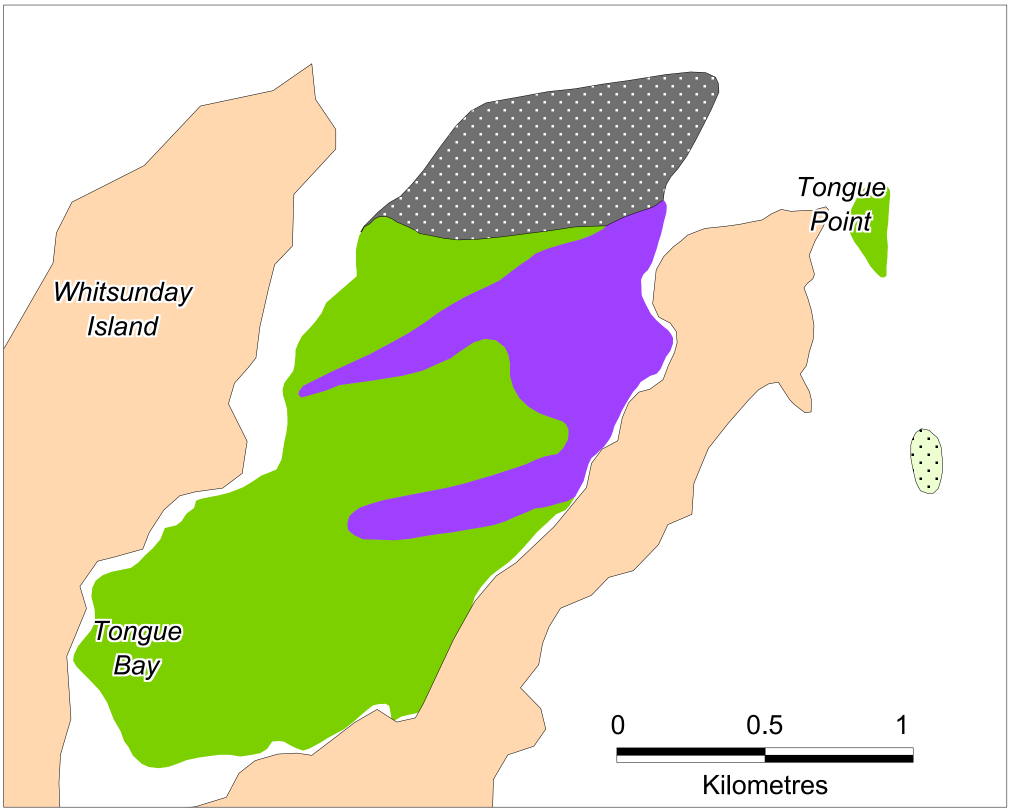
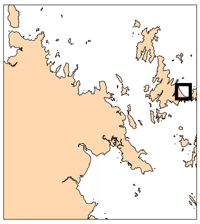
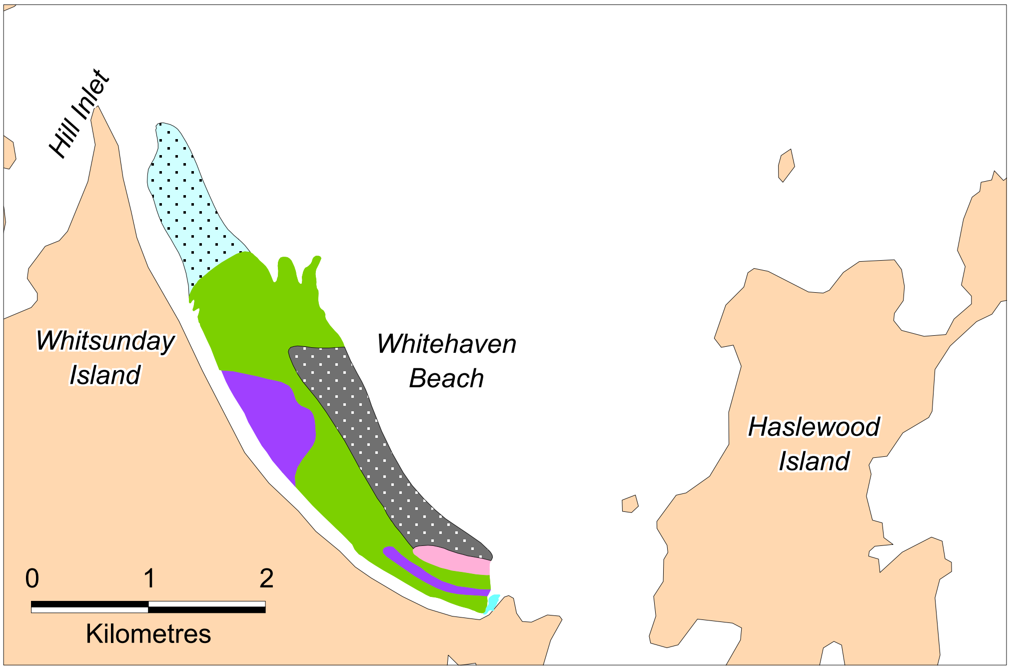
Map 14 Seagrass meadows of Tongue Bay and Whitehaven Beach, January 1999









SEAGRASS COMMUNITIES

- *Halodule uninervis (narrow leaf)*
- *Halodule uninervis (wide leaf)*
- *Halodule uninervis (wide leaf) with Halophila spp.*
- *Halodule uninervis (wide leaf) with Cymodocea serrulata/ Halophila spp.*
- *Halodule uninervis (wide leaf) with mixed species*
- *Halophila ovalis*
- *Halophila tricostata*
- *Halophila spinulosa with Halophila spp./ Halodule uninervis*
- *Cymodocea serrulata with Syringodium isoetifolium/ Halodule uninervis (wide leaf)*

SEAGRASS ABUNDANCE

Light Moderate Dense

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002)
Seagrass Resources of the Whitsunday Region, 1999-2000.
DPI Information Series QI02043 (DPI, Cairns), 50pp.
Sampling dates: Dive survey 8-15 January 1999 and 24-30 January 2000

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Map 15 Seagrass-Watch monitoring sites in the Whitsunday Region

LEGEND

★ *Seagrass-Watch Monitoring Locality*

Source: Campbell, S.J., Roder, C.A., McKenzie, L.J. and Lee Long, W.J. (2002) Seagrass Resources of the Whitsunday Region, 1999-2000. DPI Information Series QI02043 (DPI, Cairns), 50pp.

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DISCUSSION

➥ Seagrass resources

Abundance and distribution

Seagrass meadows were mostly found in the sheltered bays along the mainland coast from the southern tip of Gloucester Island situated on the north coast to Midgeton in the south. The most abundant seagrass areas along the mainland coast inhabited the northern mainland coast (863 ha), northern Repulse Bay (822 ha) and southern Repulse Bay (678 ha). Coastal mainland areas were characterised by meadows of *Halodule uninervis* (wide and narrow leaf form) growing in sheltered intertidal habitats. Intertidal *Zostera capricorni* meadows existed in a few locations along the mainland coast south of Pioneer Bay. This species was mostly present on muddy sediments, where mangroves formed a fringing habitat. The most extensive meadows mapped in this survey were dominated by *Halodule uninervis* (wide leaf form) and these were found growing in the less turbid waters of Whitsunday Island along the north-west coast (1431 ha) and Whitehaven Beach (mostly sand/ shell and mud sediments). Major differences in seagrass community type between localities are likely to influence the abundance and diversity of fish and other species that contribute production to local fisheries, but this remains little understood.

The seagrass species found in this survey represent 80% of the known species found in Queensland waters. The wide range of physical habitats where seagrasses were found undoubtedly contribute to the high species diversity. Habitats included coastal intertidal and subtidal, fringing reef and deepwater habitats. Seagrass distribution throughout the region is most likely influenced by shelter, sediment characteristics, water turbidity and tidal exposure. The highest diversity of seagrasses occurred between Dingo Beach and Bluff Point, in north facing bays protected from south-easterly winds. Fringing reefs protect many of these bays from northerly winds, providing an ideal sheltered habitat for seagrass to grow. There are no major rivers flowing into this coastal section and a high proportion of the catchment in this region is covered with native terrestrial vegetation. Negative impacts from catchment inputs and urban and agricultural development are likely to be low. A high diversity of seagrasses was also found in central coastal and island habitats. Both geographic regions have large areas of intact native vegetation and islands (Hook, South Molle, Whitsunday *etc*) shelter much of the coast from predominant south-easterly winds. In contrast the highly agriculturally modified southern region of Repulse Bay is exposed to south-easterly winds and to catchment based sediment and nutrient inputs from riverine inputs (Proserpine and O'Connell rivers). The lowest diversity of seagrass species and low abundance of seagrass was recorded from this region. To determine whether agricultural inputs are influencing seagrass abundance in this region, the existing seagrass monitoring program in Repulse Bay could be modified and coupled with a detailed water quality monitoring program.

Change in Seagrass Area since 1987

From 1987 to 1999-2000 a 40% increase in meadow area compared with surveys in 1987 (3355 ha) was measured. The 3- fold increase in the area of seagrass meadows in the northern and southern coasts of the Whitsundays (Table 5) may be an artefact of different sampling methods employed during respective surveys. In 1987 fewer sites were sampled than in 1999-2000, as intertidal regions were often inaccessible by boat due to low tidal conditions (Coles *et al.* 1987a). The objective of the 1987 survey was to map seagrass meadows along the Queensland coast at broad spatial scales, and the following differences should be considered:

- Aerial photography was not used to map meadow boundaries, therefore meadow boundaries were interpolated between sites where seagrass was present.
- One tenth of the sites were sampled in 1987, compared to 1999-2000, which targeted localities at fine to medium spatial scales.
- Position of sites was predominant by radar and errors for mapping quality were estimated at ± 100m. Error estimates in 1999-2000 were calculated for each meadow and aerial photography was used to map meadow boundaries where suitable.

Despite these differences in survey approach the magnitude of the increase in seagrass meadows at northern and southern coastal regions of the Whitsundays suggests that seagrass meadows have expanded over the past 13 years (Table 5). The 1987 estimates fall outside the error estimates in 1999-2000. The increase is also unlikely to be associated with seasonal differences because surveys were conducted in March (1987) and January (1999-2000). The reason for the increase is unknown but may be associated with an absence of flooding events in the region over the past 13 years. The expansion of seagrass meadows is also consistent with reports of increased dugong numbers in the region over the past 13 years (Marsh and Lawler 2001).

Seagrass meadows in Pioneer Bay however, appear to have declined since the 1987 survey with a 74% decline in seagrass meadow area from 519 ha (1987) to 134 ha (1999-2000) (Table 5). Comparing both sets of data, there appears to have been a contraction of up to 1.3km in the seaward extent of the meadow mapped in 1987. The inshore meadow edge seems relatively unchanged. The maximum depth recorded in this study ranged was 0.9m which compares favourably with depth ranges recorded from 1995 to 1999 (0.6-1.53m) (FRC 1999). Mapping records show that the maximum depth of seagrass in 1987 was greater than 2m. Seagrass meadows along the north-west coast of Whitsunday Island have also declined from 1752 ha to 1432±113 ha, however this decline in area is within the expected range of mapping error.

Seagrass meadows in Repulse Bay and the northern mainland coast appear to have increased in area since the 1987 survey. 583 ha was mapped in Repulse Bay in 1987, while 1515±291 ha was mapped from the 1999/2000 data (Table 5). This increase in seagrass area has occurred mostly at the mouth of Repulse Creek. Most of the seagrass of northern repulse Bay mapped in the 2000 survey is contained within the Northern Repulse Bay DPA boundary. Seagrass meadows at Whitehaven Beach have also increased in area, with the seaward edge extending up to 300m beyond the edge mapped in 1987. The seagrass meadows of the northern mainland coast have also increased in area more than 300%, from 235.0 to 863.1ha. The increase in seagrass area is unlikely to be an artefact of increased number of sampling sites, as the 1987 sites are well distributed amongst the area surveyed in 1999/2000.

Table 5 Comparison of areal extent of seagrass in selected regions in the Whitsundays between March 1987 and January 1999-2000.

Locality	Seagrass Area in 1987* (ha)	Seagrass Area in 1999/2000 (ha)
Northern Mainland coast (Cape Gloucester to Bluff Point)	235.0	865.1±242.8
Pioneer Bay	519.3	122.2±28.5
Whitehaven Beach	266.3	358.6±108.3
North-west coast Whitsunday Island	1752.0	1432.8±112.6
Central Mainland Coast (Airlie Beach to Cape Conway)	653.5	690.2±228.7
Northern Repulse Bay	379.3	822.4±156.8
Southern Repulse Bay	203.4	677.7±131.7

*Note that the 1987 survey was broadscale and large error in the precision of the mapping exists

Key conservation issues

There are several diverse and dense seagrass meadows in the intertidal and shallow sub-tidal nearshore zone from Gloucester Island to Earlando's (Map 3 & 4). From Hydeaway Bay to George Point seagrass meadows are dominated by meadows consisting of *Thalassia hemprichii*, *Halodule uninervis* (wide leaf form), *Halophila spinulosa* and *Halophila ovalis* (2.95-3.11 g DW m^{-2}). The abundance of seagrass in the region represents a significant food source and valuable habitat for green sea turtle and dugong moving between Edgecombe Bay and the Whitsundays. Land based development contributing to high sediment runoff poses a threat to seagrass meadows in the region. Community concern about the effects of benthic prawn trawling on seagrass stability is high but no studies have examined the relationship between seagrass loss and trawling in the region.

To the south, from Earlando to Pioneer Bay, dominant seagrass species are relatively low in biomass (0.53-0.59 g DW m^{-2}) and include *Halodule uninervis* (narrow form), *Zostera capricorni, Halophila spinulosa* and *Halophila ovalis*. Extensive seagrass meadows north of Shingley Point in Pioneer Bay are important dugong feeding grounds in the region. Dugong sightings are common, and abundant feeding trails were observed during the 1999-2000 surveys. Additional reclamation and marina development planned for the area adjacent to these meadows presents a threat to seagrass ecosystems due to the potential for increased marine pollution and vessel strikes on dugongs and turtles.

The decline in the spatial distribution and maximum depth of seagrass in Pioneer Bay in 2001, compared with data from 1987, may be due to poor water quality and the abundant growth of algae. During periods of effluent discharge increases in concentrations of nutrients have resulted in concentrations exceeding ANZECC guidelines[2] (Dennison *et al.* 1995). Pioneer Bay receives high nutrient discharges from the Cannonvale Sewage Treatment Plant (STP). To minimise impacts associated with nutrient inputs in Pioneer Bay the Whitsundays Shire council discharge sewage effluent on the ebbtide in an attempt to increase the rate of nutrient dispersal and dilution (FRC 1999). Subsequent monitoring of water quality has

[2] Australian and New Zealand Environmental Conservation Council's guidelines (1992) for maintenance of health of marine, estuarine and freshwaters.

recorded a reduction in nutrient concentrations (FRC 1999). Nevertheless monitoring of seagrass meadows in Pioneer Bay from 1999 to 2002 has detected a high abundance of algae at intertidal sites, relative to intertidal sites in northern and southern Whitsunday regions (Campbell and McKenzie 2001) and a high abundance of algae at subtidal sites (FRC 1999, 2001). One of the algal species identified was the blue-green alga *Lyngbya majuscula*. In March 2001, excessive amounts of *Lyngbya majuscula* were also found growing over the seagrass meadows at Whitehaven Beach. Factors such as nutrient (iron, nitrogen and phosphorus) enrichment, organic enrichment and favourable light and temperature conditions have been implicated in recent *Lyngbya* blooms in Moreton Bay (Dennison and Abal, 1999). The persistence and frequent abundance of filamentous algae in the Whitsundays region is cause for concern as it can smother seagrass meadows that provide food for dugong and turtle populations.

Monitoring of concentrations of nitrogen isotopes in epiphytes and algae growing on seagrass has shown that algae utilise nitrogen released from the Cannonvale Sewage Treatment Plant (FRC 1999, 2001). The finding suggests that nitrogen loads from the sewage outfall contribute to excessive algal growth in Pioneer Bay (FRC 1999). Shading by algae may displace seagrass meadows and in part explain the reduction in depth to which seagrasses grow in Pioneer Bay, compared with 1987 data and over the past 2 years (FRC 2001). Boats from Abal Point marina may also contribute nutrients to the meadows but these have yet to be quantified and are likely to be relatively low compared with the Sewage Treatment Plant. No major rivers flow into the region surrounding Pioneer Bay so nutrient inputs from catchment runoff are unlikely to have an impact on seagrass meadows. Current regulations necessitate the upgrading of the Cannonvale Sewage Treatment Plant to tertiary level in 2006. The reduction in nutrient loads associated with this upgrade is likely to benefit seagrass meadows, but if loss of seagrass habitat continues a shift in some areas to algal dominance may occur (Valiela *et al.* 1997).

A sewage outfall also discharges into Muddy Bay (or Boat Haven Bay) situated near the township of Airlie Beach. A small seagrass meadow consisting of *Halodule uninervis* is threatened and has declined in distribution over the past 5 years (FRC 1999). Adjacent mangroves are likely to support species of juvenile fish of value to fisheries in the region. The meadow is also threatened by plans to reclaim mudflats and expand the existing marina development. Further south, Shoalhaven Bay and Shute Harbour are high-use anchorages with large numbers of mooring bouys. Seagrass meadows at this locality consist mostly of *Halodule uninervis* (narrow morphology), *Halophila ovalis* and *Zostera capricorni* (narrow morphology). Seagrass meadows of fisheries and habitat value are located in proximity to the mooring area and near the existing channel used by the ferries and barges. Ongoing dredging and development could threaten the integrity of seagrass ecosystems in the area.

Trammel Bay has a small but dense intertidal meadow of *Zostera capricorni* that is similar to other productive prawn nursery habitats in Queensland. Adjacent mangroves are likely to add to the fisheries value of this meadow. National Park surrounds Trammel Bay, and development impacts are likely to remain minimal. Dense seagrass meadows around Cow and Calf Islands support a healthy turtle population and do not appear to be heavily threatened by human impacts apart from some small vessel activity.

The north-eastern corner of Repulse Bay has extensive intertidal seagrass meadows (primarily *Zostera capricorni*) suitable for feeding by dugong and turtles. Large numbers of turtles were observed feeding in this region during surveys. At Laguna Quays in the southern region of Repulse Bay, a small meadow consisting of a mix of *Halodule uninervis* (narrow leaf form), *Zostera capricorni* and *Halophila ovalis* is commonly used as a dugong feeding ground. This small meadow is significant as it provides a central feeding area for dugong and turtle roving between southern and northern sections of Repulse Bay. At Midge Point, and Dempster Creek near Midgeton, there are large intertidal meadows (mostly *Zostera capricorni* with some *Halodule uninervis* and *Halophila ovalis*) that appear to be valuable for dugong feeding, turtle feeding and fisheries productivity. Catchment inputs from agricultural lands potentially threaten the viability of seagrass meadows in this area.

Extensive seagrass habitats occur off Whitsunday Island. The 34 km^2 mixed-species, subtidal meadow north of Cid Harbour is important foraging habitat for green sea turtles and dugongs. Dugong are commonly observed at this location and some tour vessel operators report that dugong can be seen regularly at the southern section of this large meadow. High-speed vessels transiting through the Hook Island passage, at the northern end of this meadow, are potential causes of vessel impact or propeller strike on turtles or dugong that feed in the area. A turtle killed by a high-speed propeller strike was found here during the survey (12th January 1999). A dugong was also killed by vessel strike just to the north of this location, near Nara Inlet, in May 1997. Large cruise ships anchor in deep waters of Cid Harbour, and it is unsure what impact that has had on seagrass in the past. Small vessels using the popular Cid Harbour anchorages appear to be impacting areas of low-density seagrass, where low light limits their distribution (pers observation). Boating can also disturb feeding patterns in dugongs resulting in loss of body condition, movement away from feeding areas, reduced fecundity as well as direct mortality (Marsh *et al.* 2002).

The extensive seagrass meadow at Whitehaven Bay consists of a mix of up to six seagrass species that constitute high biomass communities. Numerous turtles were observed during the survey and are commonly seen feeding over this meadow. Implementing vessel traffic management such as speed limits or transit lanes for Whitehaven Bay and Cid Harbour to reduce potential of vessel and propeller strikes on turtles and dugong is recommended. Impacts on seagrass from anchor damage have also been linked to high daily anchor pressure and from the annual Whitehaven Beach party associated with the Hamilton Island Yacht race (Hamish Malcolm pers comm.). A study was conducted to identify the type of damage to seagrass caused by anchor chains and anchors from boats of different size classes (Campbell and McKenzie 2001). The findings suggest that the damage to seagrass meadows from anchored boats is primarily from the chains attached to anchors. The size of chain scars in seagrass meadows caused by medium and large size boats was greater than that of small boats. The findings suggest that larger boats cause greater damage to seagrass than small boats because of longer anchor chains and the thickness of chain used. The use of plough anchors in preference to sand anchors may also contribute to increased seagrass damage, because of the high probability of anchor and chain movement causing deep anchor scars and long chain scars. The time that boats spend anchored on site and the prevailing weather conditions may also be factors that contribute to damage of seagrass meadows. Damage to seagrass meadows from the deployment of anchors was also identified. Although the study found that the length of anchor scars from small boats (9-11 m) did not differ from those of medium sized (11-15m) and large boats (15-19 m), the depth of anchor scar was highest for medium and large sized boats. Seagrass-Watch monitoring of seagrass meadows supports these findings as 20-50% less cover of seagrass has been consistently found in areas of high anchor use compared to areas of low anchor use (Campbell and McKenzie 2001). Management options to reduce the extent of anchor and chain damage include increasing the amount of fixed moorings in areas with extensive seagrass meadows.

↳ *Monitoring*

Many catchment activities are a source of nutrients, suspended particulate matter and other pollutants that threaten the viability of seagrass habitats in the Whitsundays. Seagrass meadows vary in time and space, and an ongoing monitoring program of seagrass status within the region has been established to detect natural and anthropogenic causes of seagrass change. By increasing our understanding of the relationships between anthropogenic impacts and seagrass productivity it is possible to develop management strategies to ensure the continued survival of seagrass habitats and a range of dependent faunal species. In addition to mapping seagrass meadows every 4-5 years, the long-term community-based monitoring program - *Seagrass-Watch* - has been established to provide an early warning of human impacts on seagrasses and more reliable information for managing human activities in key coastal areas. This program has been established to improve the protection of seagrass. It is an intensive scientific seagrass monitoring program where community volunteers monitor seagrass abundance and composition at selected sites throughout the Whitsunday region (Map 13). The program monitors a range of habitats throughout the region so that information collected will enable rapid management responses to damage or threat to seagrass habitat in the region. For example, if monitoring indicated large areas of seagrass within a particular region were threatened, degraded or lost, extra protective measures may need to be implemented in nearby seagrass areas to ensure that habitat is available for dependent species of marine fauna.

There is also little information on the sub-lethal and chronic impacts of land run-off (eg., sediments, nutrients, agro-chemicals) on Whitsunday region seagrasses and dependant fauna. Research is urgently required to describe the response of these seagrasses to natural and human factors and to examine (*1*) the water-quality conditions that lead to these changes and (*2*) acceptable levels of change in response to such factors. The next phase of the *Seagrass-Watch* program will aim to integrate the existing *Seagrass-Watch* monitoring program with other programs (eg. turtle and dugong monitoring, water/sediment quality monitoring, climate monitoring) designed to monitor the condition and health of estuarine and marine ecosystems.

At workshops with QDPI, QPWS and community groups, key seagrass locations and conservation issues were identified and helped in the selection of long-term monitoring sites in the Seagrass-Watch Program (Table 6).

Table 6. Key seagrass locations and conservation issues in the Whitsunday region identified by QPWS staff and community volunteer groups.

Key Site	Issue	Relevant Community Groups for Seagrass-Watch monitoring
Dingo Beach / Hydeaway Bay	Urban expansion, sewage and groundwater, siltation due to clearing and erosion	Dingo Beach residents
Pioneer Bay	Urban expansion, coastal development, sewage, vessel use, dredging, marina expansion, reclamation	Whitsunday Volunteers
Shute Harbour	Increasing vessel use, marina expansion, dredging and spoil dumping	QPWS & Whitsunday Volunteers
Cid Harbour	Increasing vessel use, anchor impacts	Whitsunday OUCH Volunteers
Whitehaven Bay	Increasing vessel use, anchor impacts, nutrient inputs from boats	Whitsunday OUCH Volunteers
Laguna Quays, Midge Point & Midgeton	Resort and marina development, vessel traffic near dugong and turtle habitat, catchment inputs from agriculture	Laguna Quays, Proserpine and Midge Point residents
Cow and Calf Island or Trammel Bay	Possible reference sites – protected natural setting under Whitsunday Plan	QPWS staff

Fisheries

Seagrass meadows in the Whitsundays typically support diverse fisheries including commercial prawns, fish and several species targeted by recreational fishers. Seagrass meadows are likely to contribute a large proportion of the total primary production and fisheries productivity in the Whitsunday coastal and island waters. We recommend that the relationship between fisheries and habitat productivity, within the key meadows identified in this study, be examined to determine the value of these seagrasses to regional fisheries.

Dugongs and sea turtles

The Whitsundays region supports large meadows of seagrass species consumed by dugong such as *Halodule uninervis* (narrow leaf form), *Halophila* species and *Zostera capricorni* (Preen 1995). Dugong were observed in the seagrass meadows during the survey and dugong feeding trails were commonly found indicating that dugong actively use the seagrass meadows for feeding. These meadows occurred in both shallow subtidal and intertidal areas of the area, providing a potential food source for dugong throughout the tidal cycle. Intensive dugong grazing at intertidal sites at Dingo Beach, Pioneer Bay, Laguna Quays and Midge Point sites contributes to the high productivity of seagrasses by allowing fast growing *Halophila*, *Halodule* and *Zostera* species to rapidly colonise available "grazed" space. Grazing is an important process that contributes to the fast turnover of seagrasses and improved nutritional quality as "new growth" is often rich in carbohydrates and high in digestability (Preen 1995a, Aragones and Marsh 2000).

Seagrass meadows are known to be highly seasonal and susceptible to natural climatic events (eg., storms). Dugong and turtle survival is strongly influenced by dynamic changes to seagrass meadows and large-scale loss of seagrass due to storm-related damage has been associated with high dugong mortality in Hervey Bay (Preen and Marsh 1995). Anecdotal evidence of storm damage to shallow water seagrass meadows in the Shoal Bay and Dingo Beach areas of the Whitsundays may also have implications for dugong and turtle survival. The loss of shallow water seagrasses may result in increased grazing pressure in deepwater (>6 m) seagrass meadows in coastal and island regions of the Whitsundays, as an alternative to shallow meadows. The implications of seagrass loss to dugong survival depends, in part, on the ability of the meadow to recover. The capacity of Whitsundays meadows for recovery is unknown, as seed-bank status and reproductive strategies of these meadows have not been measured. Preliminary data on *Halodule uninervis* seed abundance in the region suggests that meadows have a high propensity for recovery because of an abundant seed reserve in the sediments (Campbell and McKenzie 2001). Recent data also suggests that the recovery of intertidal meadows following loss due to flood damage may take up to 3 years, depending on the location of the meadow (Campbell and McKenzie 2001).

Long-term monitoring of dugong populations by aerial surveys has found that the population in the Whitsunday region is increasing (Marsh and Lawler, 2001) (Table 7). The dugong populations have increased between Gloucester Island to Cape Conway, Northern Repulse Bay and Southern Repulse Bay since the 1994 aerial survey (Table 7). These population values are possibly correlated with the increase in suitable seagrass area for dugong feeding recorded between 1987 and 1999/2000 (Table 5) influencing fecundity and immigration from northern sections.

Nutrition is important for dugong fecundity, and Marsh and Lawler (2001) suggest that the high proportion of calves recorded in the Central Section the 1999 survey (19.7% of total population were calves) was attributed to improved food availability in the central section since the early 1990s. However, Marsh and Lawler (2001) suggest that it is unlikely that the increase in dugong population estimates the southern GBR area (including the central section) is the result of natural population increase in the absence of immigration. Marsh and Lawler (2001) suggest that the increase in dugong abundance in the central section of the GBR may be the result of dugongs immigrating to this region from outside in search of higher quality habitat, with the source population being from the northern GBR. Currently this hypothesis is unsubstantiated.

Table 7 Estimates of dugong numbers for each survey block in the Whitsunday study area, for 1986/1987, 1992, 1994 and 1999 (sourced from Marsh and Lawler (2001))

Location	1986-1987 Population (S.E.)	1992 Population (S.E.)	1994 Population (S.E.)	1999 Population (S.E.)
Gloucester Island to Cape Conway	0	35 (27)	27 (21)	353 (211)
Northern Repulse Bay	31(35)	71(59)	0	90 (57)
Southern Repulse Bay (including the Newry Island Group)	360 (92)	106 (56)	183 (29)	361 (157)

At present large areas of sub-tidal seagrasses in the Whitsundays, consist mostly of wider-bladed and slower growing species compared with seagrasses from intertidal meadows. Species of seagrass preferred by dugong (ie *Halophila ovalis*, *Zostera capriconi*, *Halodule uninervis*) are relatively patchy in distribution throughout the Whitsunday region so that dugong may need to travel regularly between locations to obtain suitable quantities of food. These limited and patchy food resources make local dugong populations more vulnerable to human and natural impacts (eg., boating, sewage and agricultural run-off, cyclones, floods and climatic changes). Loss of seagrass, decline in the nutrient quality of available seagrass, or a reduction in the time available for feeding due to boat traffic, represent increased stresses that may reduce dugong fecundity, lengthen pre-reproductive period and/or intervals between calving (Marsh *et al.* 1999, 2002).

The abundance of filamentous algae commonly found throughout the year at Pioneer Bay is of potential concern to the nutritional requirements of dugong and turtles. Algae may comprise a small percentage (2% volume) of dugong diets (Marsh *et al.* 1982), but dugong have been shown to avoid feeding on *Halophila spinulosa* and *Syringodium isoetifolium* carrying large quantities of epiphytic algae (Preen 1995a). If dugong and sea turtles are forced to seek food resources in other areas, this may increase grazing pressure on already limited seagrass resources. We recommend improvements in sewage management to minimise human-related nutrient loads in Pioneer Bay that are causing algal blooms.

Dugong Protection Areas have been established to protect dugongs from netting and other pressures that are related to fishing practices. To manage DPA's effectively, other factors such as water-quality that may affect dugong health, the sources of which lie outside the DPA borders, require investigation. Pollutants such as dioxins have already been detected in high concentrations in dugongs in northern Queensland waters (Haynes *et al* 2000b). Significant reductions in nutrient, sediments and pollutant inputs could be achieved by the adoption of industry codes of best practice and through implementation of Integrated Catchment Management programs (ICM). ICM programs incorporate better land management methods, retention and rehabilitation of riparian zones and wetlands, vegetation management on agricultural lands, improved fertiliser application technology, and urban stormwater management.

Green turtle populations are known to vary from year to year, and recent evidence suggests this may be linked to their food resources. Limpus and Nicholls (1990, 2000) suggested that changes in climate (indicated by the Southern Oscillation Index - SOI) probably affects turtle food sources (eg. seagrasses), and that there is a nutritional basis to annual fluctuations in fat deposition, vitellogenesis, spermatogenesis and growth within a total population of green turtles. Limpus and Nicholls (2000) reported significant correlations between the Southern Oscillation Index (SOI) two years before a breeding season and the number of females recorded on the nesting beach. They found that in the extremes, massed nesting occurs two years following major El Niño events and crashes in nesting numbers occur two years after major anti-El Niño (La Nina) events (Limpus and Nicholls 2000). Although the mechanisms of the ENSO (El Niño Southern Oscillation) linkage to green turtle fluctuations have not been established, potential links could range from damage to seagrass pastures during cyclones and floods, or changes in growth of pastures in response to prevailing ENSO-related weather conditions.

There is presently no database to verify whether fluctuations in green turtle populations are driven by the changes in quantity and quality of the food resource, and we strongly recommend multi-disciplinary studies that examine the role of climatic cycles and seagrass productivity on dugong and green turtle populations.

Recommendations

- Additional funding to ensure the continuation of the Seagrass-Watch program to community-based monitoring of intertidal and sub-tidal seagrass habitats in the Whitsundays region.
- Establish links between the community Seagrass-Watch program and other community based programs (eg. Water Watch).
- Multidisciplinary studies be supported to examine the linkages between seagrass productivity and associated fisheries, green turtle and dugong populations.
- A collaborative water quality program be undertaken to examine the effects, if any, that sewage loading, catchment run-off and other developments have on water quality and coastal seagrasses. Areas of interest include Repulse Bay and Pioneer Bay as these systems receive high loads of nutrients and have low seagrass abundance.

- Additional research to address issues influencing habitat quality, such as the effects of land runoff constituents (nutrients, metals, herbicides) on the performance and health of seagrasses, be supported.
- Establish strong links between the Seagrass-Watch Program and academic institutions on the potential for seagrass recovery (eg., seagrass seed availability within sediments at key seagrass sites).
- Studies of seagrass restoration be considered to develop contingency measures in case of widespread and catastrophic seagrass loss in key and threatened areas such as Pioneer Bay.
- A broad-scale survey of the Whitsunday region be repeated in Summer 2004, at similar intensity to this survey to assess long-term changes in seagrass and possible impacts on green sea turtles, dugongs and fisheries.

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Appendix 1. Examples of seagrass above-ground biomass, from reference photos of a 0.25 m^2 quadrat.

Halophila ovalis **3.12 g DW m^{-2}**

Halodule uninervis **(wide) 6.44 g DW m^{-2}**

Halodule uninervis **(wide) 12.92 g DW m^{-2}**

Halodule uninervis **(wide) 36.24 g DW m^{-2}**

Syringodium isoetifolium/
Halodule uninervis **(wide) 51.04 g DW m^{-2}**

Halophila spinulosa **58.16 g DW m^{-2}**

Appendix 2. Nomenclature developed for determining seagrass community meadow types of Queensland

Quantitative nomenclature of abundance of seagrass species dominated communities

Abundance category	Above-ground g DW m^{-2}			
	Halophila ovalis, H. decipiens, H. tricostata, Halodule uninervis **(narrow leaf morph)**	***Cymodocea serrulata, C. rotundata ,Halodule uninervis*** **(wide leaf morph)** ***Thalassia hemprichii, Syringodium isoetifolium***	***Halophila spinulosa***	***Zostera capricorni***
Light	<0.5 g	<5	<15	<20 g
Moderate	0.6 – 3.9 g	5.1 – 24.9 g	15.1-34.9 g	20.1- 59.9 g
Dense	>4g	>25	>35 g	>60 g

Composition nomenclature - composition defined by seagrass species dominance

Community/ Meadow type	Seagrass species composition
Species A	Species A is 90-100% of composition
Species A with species B	Species A is 61-89% of composition
Species A with Species B/ Species C *Alternatives:* *Species A with Genus spp.* *Species A with mixed spp.*	Species A is at least 50% of composition. Species B/ C make up other 50% composition
Species A/ Species B	Species A is 50-60% of composition, while Species B comprises 40-50% of composition

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